TPC Benchmark™ H
Full Disclosure Report

Ingres VectorWise 1.5
using
HP Proliant DL380 G7

Submitted for Review
Report Date March 1, 2011
TPC Benchmark H™ Full Disclosure Report
Second Printing
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All performance data contained in this report was obtained in a rigorously controlled environment. Results obtained in other operating environments may vary significantly. No warranty of system performance or price/performance is expressed or implied in this report.

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Overview

This report documents the methodology and results of the TPC Benchmark™ H test conducted on the HP DL380 G7, in conformance with the requirements of the TPC Benchmark™ H Standard Specification, Revision 2.13.0. The operating system used for the benchmark was Red Hat Enterprise Linux Server; the DBMS was Ingres.

Standard and Executive Summary Statements

The pages following this preface contain the Executive Summary and Numerical Quantities Summary of the benchmark results.

Auditor

The benchmark configuration, environment and methodology used to produce and validate the test results and the pricing model used to calculate the cost per QphH was audited by Lorna Livingtree and Steve Barrish, Performance Metrics, to verify compliance with the relevant TPC specifications.

TPC Benchmark H Overview

The TPC Benchmark™ H (TPC-H) is a decision support benchmark. It consists of a suite of business oriented ad-hoc queries and concurrent data modifications. The queries and the data populating the database have been chosen to have broad industry-wide relevance while maintaining a sufficient degree of ease of implementation. This benchmark illustrates decision support systems that

- Examine large volumes of data;
- Execute queries with a high degree of complexity;
- Give answers to critical business questions.

TPC-H evaluates the performance of various decision support systems by the execution of sets of queries against a standard database under controlled conditions. The TPC-H queries:

- Give answers to real-world business questions;
- Simulate generated ad-hoc queries (e.g., via a point and click GUI interface);
- Are far more complex than most OLTP transactions;
- Include a rich breadth of operators and selectivity constraints;
- Generate intensive activity on the part of the database server component of the system under test;
- Are executed against a database complying to specific population and scaling requirements;
- Are implemented with constraints derived from staying closely synchronized with an on-line production database.

The TPC-H operations are modeled as follows:
The database is continuously available 24 hours a day, 7 days a week, for ad-hoc queries from multiple end users and updates against all tables, except possibly during infrequent (e.g., once a month) maintenance sessions;
The TPC-H database tracks, possibly with some delay, the state of the OLTP database through on-going updates which batch together a number of modifications impacting some part of the decision support database;

Due to the world-wide nature of the business data stored in the TPC-H database, the queries and the updates may be executed against the database at any time, especially in relation to each other. In addition, this mix of queries and updates is subject to specific ACIDity requirements, since queries and updates may execute concurrently;

To achieve the optimal compromise between performance and operational requirements the database administrator can set, once and for all, the locking levels and the concurrent scheduling rules for queries and updates.
The minimum database required to run the benchmark holds business data from 10,000 suppliers. It contains almost ten million rows representing a raw storage capacity of about 1 GB. Compliant benchmark implementations may also use one of the larger permissible database populations (e.g. 1000 GB), as defined in Clause 4.1.3.

The performance metrics reported by TPC-H measure multiple aspects of the capability of the system to process queries. The TPC-H metric at the selected size (QphH@Size) is the performance metric. To be compliant with the TPC-H standard, all references to TPC-H results for a given configuration must include all required reporting components (see Clause 5.4.7). The TPC believes that comparisons of TPC-H results measured against different database sizes are misleading and discourages such comparisons.

The TPC-H database must be implemented using a commercially available database management system (DBMS), and the queries executed via an interface using dynamic SQL. The specification provides for variants of SQL, as implementers are not required to have implemented a specific SQL standard in full. TPC-H uses terminology and metrics that are similar to other benchmarks, originated by the TPC and others. Such similarity in terminology does not in any way imply that TPC-H results are comparable to other benchmarks. The only benchmark results comparable to TPC-H are other TPC-H results compliant with the same revision.

Despite the fact that this benchmark offers a rich environment representative of many decision support systems, this benchmark does not reflect the entire range of decision support requirements. In addition, the extent to which a customer can achieve the results reported by a vendor is highly dependent on how closely TPC-H approximates the customer application. The relative performance of systems derived from this benchmark does not necessarily hold for other workloads or environments. Extrapolations to any other environment are not recommended.

Benchmark results are highly dependent upon workload, specific application requirements, and systems design and implementation. Relative system performance will vary as a result of these and other factors. Therefore, TPC-H should not be used as a substitute for a specific customer application benchmarking when critical capacity planning and/or product evaluation decisions are contemplated.

Benchmark sponsors are permitted several possible system designs, provided that they adhere to the model described in Clause 6. A full disclosure report (FDR) of the implementation details, as specified in Clause 8, must be made available along with the reported results.

**General Implementation Guidelines**

The purpose of TPC benchmarks is to provide relevant, objective performance data to industry users. To achieve that purpose, TPC benchmark specifications require that benchmark tests be implemented with systems, products, technologies and pricing that:

- Are generally available to users;
- Are relevant to the market segment that the individual TPC benchmark models or represents (e.g. TPC-H models and represents complex, high data volume, decision support environments);
- Would plausibly be implemented by a significant number of users in the market segment the benchmark models or represents.

**Ingres Corporation does not warrant or represent that a user can or will achieve performance similar to the benchmark results contained in this report. No warranty of system performance or price/performance is expressed or implied by this report.**
## TPC Benchmark H™ Full Disclosure Report for HP DL380 G7 – March 1, 2011

- **TPC-H Rev 2.13.0**
- **TPC Pricing Rev 1.5.0**
- **Report Date:** Feb. 9, 2011
- **Revision Date:** Mar. 1, 2011

### System Configuration

- **Number of Nodes:** 1
- **Processors/Cores/Threads/Type:** 2/12/12/ Intel Xeon X5680 3.3 Ghz (hyperthreading disabled)
- **Memory:** 144 GB
- **Disk Drives:** 16 X 146 GB SAS Disk Drives at 15K RPM
- **Total Disk Storage:** 2336 GB
- **Lan Controllers:** 4 X 1GB Ethernet Connections

### Database Size

- **Database Size:** 100 GB
- **Database Load Time:** 03:16:48
- **Memory/Database Size Percentage:** 144.0%

### Database Manager

- **VectorWise 1.5**

### Operating System

- **Red Hat Enterprise Linux 6.0**

### Other Software

- **None**

### Availability Date

- **3/31/2011**

### Composite Query per Hour Metric

- **QphH@100GB:** 251,561.7

### Price/Performance

- **Price/QphH@100GB:** $0.38 USD

### Total System Cost

- **$94,667 USD**

### Power Test Throughput Test

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<tr>
<th>Query</th>
<th>Time (s)</th>
</tr>
</thead>
<tbody>
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</tr>
<tr>
<td>Q2</td>
<td>5.1</td>
</tr>
<tr>
<td>Q3</td>
<td>6.7</td>
</tr>
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<td>11.3</td>
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<tr>
<td>RF1</td>
<td>21.1</td>
</tr>
<tr>
<td>RF2</td>
<td>21.5</td>
</tr>
</tbody>
</table>

### Query times in seconds

- **Database Load Time:** 03:16:48
- **Load Includes Backup:** N

### Storage Redundancy Level

- 5+0 for Base Tables, Auxiliary Data Structures, DBMS temporary space, and OS and DBMS Software
## Server Hardware

<table>
<thead>
<tr>
<th>Description</th>
<th>Part Number</th>
<th>Source</th>
<th>Reference Price</th>
<th>Qty</th>
<th>Extended Price</th>
<th>3 yr Maint Price</th>
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</thead>
<tbody>
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<td>HPDL380C6147-CM-S</td>
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<td>0</td>
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<tr>
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Subtotal: 24,467

## Storage

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<th>Description</th>
<th>Part Number</th>
<th>Source</th>
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<th>Qty</th>
<th>Extended Price</th>
<th>3 yr Maint Price</th>
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<tbody>
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Subtotal: 0

### Hardware and Maintenance Discount

- Large Purchase and Net 30 Discount*: 0%
- Hardware Subtotal: 24,467

#### Server Software

<table>
<thead>
<tr>
<th>Description</th>
<th>Part Number</th>
<th>Source</th>
<th>Reference Price</th>
<th>Qty</th>
<th>Extended Price</th>
<th>3 yr Maint Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ingres VectorWise release 1.5 3-year 1 core license**</td>
<td>ING-VW-3Y</td>
<td>1</td>
<td>5,000</td>
<td>12</td>
<td>60,000</td>
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<tr>
<td>Ingres VectorWise 1-year maintenance for 1 core**</td>
<td>ING-VW-3Y-MNT</td>
<td>1</td>
<td>500</td>
<td>36</td>
<td>18,000</td>
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<tr>
<td>Ingres discount for 10 or more cores*</td>
<td>10%</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>(6,000)</td>
<td>(1,800)</td>
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<tr>
<td>RHEL 1-2 SKT 24x7 3 Year RHN SW</td>
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<td>included in pkg</td>
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Subtotal: 54,000

Total: 78,467

*All discounts are based on US list prices and for similar quantities and configurations

**These components are not immediately orderable. See FDR for more information

Source 1=Ingres sales@ingres.com; 2=Trivad 650-286-1086

Audited By: Lorna Livingtree and Steve Barrish for Performance Metrics, Inc. (www.perfmetrics.com)

Prices used in TPC benchmarks reflect actual prices a customer would pay for a one-time purchase of the stated components. Individually negotiated discounts are not permitted. Special prices based on assumptions about past or future purchases are not permitted. All discounts reflect standard pricing policies for the listed components. For complete details, see the pricing sections of the TPC benchmark specifications. If you find the stated prices are not available according to these terms, please inform the TPC at pricing@tpc.org. Thank you.
Measurement Results

Database Scaling (SF/size) 100
Total Data Storage/Database Size 23.36
Memory/Database Size Percentage 144.00%
Start of Database Load Time 02/04/11 00:51:31
End of Database Load Time 02/04/11 04:08:19
Database Load Time 3:16:48
Query Streams for Throughput Test (S) 11
TPC-H Power 257,142.9
TPC-H Throughput 246,101.7
TPC-H Composite Query-per-Hour Metric (QphH@100GB) 251,561.7
Total System Price Over 3 Years 94,667
TPC-H Price/Performance Metric ($/QphH@100GB) 0.38

Measurement Intervals

Measurement Interval in Throughput Test (Ts) 354

Duration of Stream Execution:

<table>
<thead>
<tr>
<th>Power Run</th>
<th>Seed</th>
<th>Query Start Time</th>
<th>Query End Time</th>
<th>Duration (sec)</th>
<th>RF1 Start Time</th>
<th>RF1 End Time</th>
<th>RF2 Start Time</th>
<th>RF2 End Time</th>
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</thead>
<tbody>
<tr>
<td>204040819</td>
<td>02/04/11 10:48:02</td>
<td>02/04/11 10:48:45</td>
<td>44</td>
<td>02/04/11 10:47:50</td>
<td>02/04/11 10:48:02</td>
<td>02/04/11 10:48:46</td>
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</table>

Throughput Stream

<table>
<thead>
<tr>
<th>Throught Stream</th>
<th>Seed</th>
<th>Query Start and End Times</th>
<th>Duration (sec)</th>
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</thead>
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<tr>
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<td>02/04/11 10:48:50 02/04/11 10:54:44</td>
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### Duration of Stream Execution (Continued):

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<th>Throughput Stream</th>
<th>Seed</th>
<th>Query Start and End Times</th>
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<td>204040830</td>
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<tr>
<td>RFs</td>
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### TPC-H Timing Intervals (in seconds)

#### Duration of stream execution:

<table>
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<tr>
<th>Stream ID</th>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
<th>Q5</th>
<th>Q6</th>
<th>Q7</th>
<th>Q8</th>
<th>Q9</th>
<th>Q10</th>
<th>Q11</th>
<th>Q12</th>
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<tbody>
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<td>0.6</td>
<td>0.4</td>
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<tr>
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<td>6.6</td>
<td>24.4</td>
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<td>22.6</td>
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<td>10.0</td>
<td>30.2</td>
<td>7.4</td>
<td>20.8</td>
<td>7.1</td>
</tr>
</tbody>
</table>
5.4 Number of Streams for the Throughput Test

5.5 Start and End Date/Time of Each Query Stream

5.6 Total Elapsed Time of the Measurement Interval

5.7 Refresh Function Start Date/Time and Finish Date/Time

5.8 Timing Intervals for Each Query and Each Refresh Function for Each Stream

5.9 Performance Metrics

5.10 The Performance Metric and Numerical Quantities from Both Runs

5.11 System Activity Between Performance Tests

5.12 Dataset Verification

5.13 Referential Integrity

6 Clause 6 SUT and Driver Implementation Related Items

6.1 Driver

6.2 Implementation-Specific Layer (ISL)

6.3 Profile-Directed Optimization

7 Clause 7 Pricing

7.1 Hardware and Software Used in the Priced System

7.2 Total Three Year Price

7.3 Availability Date

8 Clause 8 Full Disclosure

8.1 Supporting Files Index Table

9 Clause 9 Audit Related Items

9.1 Auditor's Report

Appendix A Price Quotes
0 General Items

0.1 Benchmark Sponsor
A statement identifying the benchmark sponsor(s) and other participating companies must be provided.
Ingres Corporation is the test sponsor of this TPC Benchmark H benchmark.

0.2 Parameter Settings
Settings must be provided for all customer-tunable parameters and options which have been changed from the defaults found in actual products, including but not limited to:
- Database Tuning Options
- Optimizer/Query execution options
- Query processing tool/language configuration parameters
- Recovery/commit options
- Consistency/locking options
- Operating system and configuration parameters
- Configuration parameters and options for any other software component incorporated into the pricing structure;
- Compiler optimization options.

The Supporting Files Archive contains the Operating System and DBMS parameters used in this benchmark.
0.3 Configuration Diagrams

Diagrams of both measured and priced configurations must be provided, accompanied by a description of the differences.

Both the priced and measured configurations are the same (HP DL380 G7)

2 x Intel Xeon X5680 CPU’s @3.3 GHz
144 GB Memory
16 x 146 GB 15K RPM SAS Drives
4 x 1GB Ethernet Connections
1 Clause 1 Logical Database Design Related Items

1.1 Database Definition Statements

Listings must be provided for all table definition statements and all other statements used to set up the test and qualification databases.

The Supporting Files Archive contains the scripts that define, create, and analyze the tables and indices for the TPC-H database.

1.2 Physical Organization

The physical organization of tables and indices, within the test and qualification databases, must be disclosed. If the column ordering of any table is different from that specified in Clause 1.4, it must be noted.

No record clustering or index clustering was used. Columns were not reordered in the tables.

1.3 Horizontal Partitioning

Horizontal partitioning of tables and rows in the test and qualification databases (see Clause 1.5.4) must be disclosed.

No horizontal partitioning was used

1.4 Replication

Any replication of physical objects must be disclosed and must conform to the requirements of Clause 1.5.6.

No replication was used.
2 Clause 2 Queries and Refresh Functions

2.1 Query Language

The query language used to implement the queries must be identified.

SQL was the query language used to implement all queries.

2.2 Verifying Method for Random Number Generation

The method of verification for the random number generation must be described unless the supplied DBGEN and QGEN were used.

TPC supplied versions 2.13.0 of DBGEN and QGEN were used for this TPC-H benchmark.

2.3 Generating Values for Substitution Parameters

The method used to generate values for substitution parameters must be disclosed. If QGEN is not used for this purpose, then the source code of any non-commercial tool used must be disclosed. If QGEN is used, the version number, release number, modification number, and patch level of QGEN must be disclosed.

QGEN version 2.13.0 was used to generate the substitution parameters.

2.4 Query Text and Output Data from Qualification Database

The executable query text used for query validation must be disclosed along with the corresponding output data generated during the execution of the query text against the qualification database. If minor modifications (see Clause 2.2.3) have been applied to any functional query definition or approved variants in order to obtain executable query text, these modifications must be disclosed and justified. The justification for a particular minor query modification can apply collectively to all queries for which it has been used. The output data for the power and throughput tests must be made available electronically upon request.

The Supporting Files Archive contains the actual query text and query output.

2.5 Query Substitution Parameters and Seeds Used

The query substitution parameters used for all performance tests must be disclosed in tabular format, along with the seeds used to generate these parameters.

The Supporting Files Archive contains the seed and query substitution parameters.

2.6 Query Isolation Level

The isolation level used to run the queries must be disclosed. If the isolation level does not map closely to the levels defined in Clause 3.4, additional descriptive detail must be provided.

The queries and transactions were run with “Snapshot Isolation”.

2.7 Source Code of Refresh Functions

The details of how the refresh functions were implemented must be disclosed (including source code of any non-commercial program used).

The source code for the refresh functions is included in the Supporting Files Archive.
3 Clause 3 Database System Properties

3.1 ACID Properties

The ACID (Atomicity, Consistency, Isolation, and Durability) properties of transaction processing systems must be supported by the system under test during the timed portion of this benchmark. Since TPC-H is not a transaction processing benchmark, the ACID properties must be evaluated outside the timed portion of the test.

Source code for ACID test is included in the Supporting Files Archive.

3.2 Atomicity

The system under test must guarantee that transactions are atomic; the system will either perform all individual operations on the data, or will assure that no partially completed operations leave any effects on the data.

Completed Transaction

*Perform the ACID Transaction for a randomly selected set of input data and verify that the appropriate rows have been changed in the ORDERS, LINEITEM, and HISTORY tables.*

1. The total price from the ORDERS table and the extended price from the LINEITEM table were retrieved for a randomly selected order key.
2. The ACID Transaction was performed using the order key from step 1.
3. The ACID Transaction committed.
4. The total price from the ORDERS table and the extended price from the LINEITEM table were retrieved for the same order key. It was verified that the appropriate rows had been changed.

Aborted Transaction

*Perform the ACID Transaction for a randomly selected set of input data, substituting a ROLLBACK of the transaction for the COMMIT of the transaction. Verify that the appropriate rows have not been changed in the ORDERS, LINEITEM, and HISTORY tables.*

1. The total price from the ORDERS table and the extended price from the LINEITEM table were retrieved for a randomly selected order key.
2. The ACID Transaction was performed using the order key from step 1. The transaction was stopped prior to the commit.
3. The ACID Transaction was ROLLED BACK.
4. The total price from the ORDERS table and the extended price from the LINEITEM table were retrieved for the same order key. It was verified that the appropriate rows had not been changed.

3.3 Consistency

Consistency is the property of the application that requires any execution of transactions to take the database from one consistent state to another.

Consistency Test

*Verify that ORDERS and LINEITEM tables are initially consistent, submit the prescribed number of ACID Transactions with randomly selected input parameters, and re-verify the consistency of the ORDERS and LINEITEM.*

1. The consistency of the ORDERS and LINEITEM tables was verified based on a sample of order keys.
2. 100 ACID Transactions were submitted from each of 65 execution streams.
3. The consistency of the ORDERS and LINEITEM tables was re-verified.

3.4 Isolation

Operations of concurrent transactions must yield results, which are indistinguishable from the results, which would be obtained by forcing each transaction to be serially executed to completion in some order.
Read-Write Conflict with Commit

Demonstrate isolation for the read-write conflict of a read-write transaction and a read-only transaction when the read-write transaction is committed.

1. An ACID query was run with randomly selected values for O_KEY, L_KEY and DELTA to get the initial value for O_TOTALPRICE.
2. An ACID Transaction was started using the randomly selected values from step 1. The ACID Transaction was suspended prior to COMMIT.
3. An ACID Query was started for the same O_KEY used in step 1. The ACID Query ran to completion but did not see any uncommitted changes made by the ACID Transaction.
4. The ACID Transaction was resumed, and COMMITTED.
5. The ACID Query was run again to verify that the transaction updated O_TOTALPRICE.

Read-Write Conflict with Rollback

Demonstrate isolation for the read-write conflict of a read-write transaction and a read-only transaction when the read-write transaction is rolled back.

1. An ACID Query was run for a randomly selected O_KEY, L_KEY and DELTA to get the initial value for O_TOTALPRICE.
2. An ACID Transaction was started using the values selected in step 1. The ACID Transaction was suspended prior to ROLLBACK.
3. An ACID Query was started for the same O_KEY used in step 1. The ACID Query ran to completion but did not see the uncommitted changes made by the ACID Transaction.
4. The ACID Transaction was ROLLED BACK.
5. The ACID Query completed was run again to verify that O_TOTALPRICE was unchanged from step 1.

Write-Write Conflict with Commit

Demonstrate isolation for the write-write conflict of two update transactions when the first transaction is committed.

Two tests were run, the first with a transaction that COMMITS and the second with a transaction that ROLLS BACK.

Results from the first test were as follows:
1. An ACID Query was run for a randomly selected O_KEY, L_KEY and DELTA to get the initial value for O_TOTALPRICE.
2. An ACID Transaction, T1, was started with the values used in step 1. The ACID transaction T1 was suspended prior to COMMIT.
3. Another ACID Transaction, T2, was started using the same O_KEY and L_KEY used in step 1 and a randomly selected DELTA.
4. T2 COMMITTED and completed normally.
5. T1 was allowed to commit and received an error, this was expected due to the “Snapshot Isolation” in use by the DBMS. This is also known as “First Committer Wins”.
6. The ACID Query was run to verify that O_TOTALPRICE was the value from T2.

Results from the second test were as follows:
1. An ACID Query was run for a randomly selected O_KEY, L_KEY and DELTA to get the initial value for O_TOTALPRICE.
2. An ACID Transaction, T1, was started with the values used in step 1. The ACID transaction T1 was suspended prior to COMMIT.

3. A Second ACID transaction, T2, was started with the same O_KEY and L_KEY as step 1 and a different value for DELTA.

4. T2 ROLLED BACK and completed.

5. T1 resumed and completed normally.

6. The ACID Query was run to verify the database was updated with the values from T1 and not T2.

**Write-Write Conflict with Rollback**

*Demonstrate isolation for the write-write conflict of two update transactions when the first transaction is rolled back.*

Two tests were run, the first with a transaction that COMMITS and the second with a transaction that ROLLS BACK.

The results from the first test were as follows:

1. An ACID Query was run for a randomly selected O_KEY, L_KEY and DELTA to get the initial value for O_TOTALPRICE.

2. An ACID Transaction, T1, was started for a randomly using the values from step 1. The ACID transaction T1 was suspended prior to ROLLBACK.

3. Another ACID Transaction, T2, was started using the same O_KEY and L_KEY and a randomly selected DELTA.

4. T2 completed normally.

5. T1 was allowed to ROLLBACK.

6. It was verified that O_TOTALPRICE was from T2.

The results from the second test were as follows:

1. An ACID Query was run for a randomly selected O_KEY, L_KEY and DELTA to get the initial value for O_TOTALPRICE.

2. An ACID Transaction, T1, was started with the same values as from step 1. T1 suspended prior to COMMIT.

3. Another ACID Transaction, T2, was started and it ROLLED BACK its updates and completed normally.

4. T1 resumed and COMMITED its updates.

5. An ACID Query was run to verify that O_TOTALPRICE was the value from T1 and not T2.

**Concurrent Progress of Read and Write on Different Tables**

*Demonstrate the ability of read and write transactions affecting different database tables to make progress concurrently.*

1. An ACID Query was run for a randomly selected O_KEY, L_KEY and DELTA to get the initial value for O_TOTALPRICE.

2. An ACID Transaction, T1, was started with the values from step 1. T1 was suspended prior to COMMIT.

3. A query was started using random values for PS_PARTKEY and PS_SUPPKEY, all columns of the PARTSUPP table for which PS_PARTKEY and PS_SUPPKEY are equal are returned. The query completed normally.

4. T1 was allowed to COMMIT.

5. It was verified that O_TOTALPRICE had been changed by T1.

**Read-Only Query Conflict with Update Transactions**

TPC Benchmark H™ Full Disclosure Report for HP DL380 G7 – March 1, 2011
Demonstrates that the continuous submission of arbitrary (read-only) queries against one or more tables of the database does not indefinitely delay update transactions affecting those tables from making progress.

1. A Stream was submitted that executed Q1 20 times in a row with a delta of 0 to ensure that each query ran as long as possible.
2. An ACID Transaction, T1, was started for a randomly selected O_KEY, L_KEY and DELTA.
3. T1 completed and it was verified that O_TOTALPRICE was updated correctly.
4. The stream submitting Q1 finished.

3.5 Durability
The tested system must guarantee durability: the ability to preserve the effects of committed transactions and insure database consistency after recovery from any one of the failures listed in Clause 3.5.3.

Failure of a Durable Medium
Guarantee the database and committed updates are preserved across a permanent irrecoverable failure of any single durable medium containing TPC-H database tables or recovery log tables.

1. The consistency of the ORDERS and LINEITEM tables was verified using 120 randomly chosen values for O_ORDERKEY.
2. At least 100 ACID transactions were submitted from 12 streams.
3. A randomly selected disk drive was removed from the SUT and the SUT continued to process work until each stream had submitted 300 transactions.
4. An analysis of the transaction start and end times from each stream showed that there was at least 1 transaction in-flight at all times.
5. An analysis of the HISTORY table showed that all of the values used for O_ORDERKEY in step 1 were used by some transaction in step 2.
6. An analysis of the success file and the HISTORY table showed that all entries in the HISTORY table had a corresponding entry in the success file and that every entry in the success file had a corresponding entry in the HISTORY table.

System Crash
Guarantee the database and committed updates are preserved across an instantaneous interruption (system crash/system hang) in processing which requires the system to reboot to recover.

The system crash and memory failure tests were combined. First the consistency of the ORDER and LINEITEM tables was verified. Then transactions were submitted from 12 streams, once the driver script indicated that 100 transactions had been submitted from each stream power to the SUT was removed by turning off the switch to the power strip. When power was restored to the SUT, the system rebooted and the database was restarted. The HISTORY table and success files were compared to verify that every record in the HISTORY table had a corresponding record in the success file and that each record in the success file had a corresponding entry in the HISTORY table. The consistency of the ORDERS and LINEITEM tables was then verified again.

Memory Failure
Guarantee the database and committed updates are preserved across failure of all or part of memory (loss of contents).

See “System Crash”

Disk Durability
First the consistency of the ORDER and LINEITEM tables was verified. Then 12 streams were used to submit 300 transactions to the SUT. Once the driver script indicated that at least 100 transactions had been submitted from each stream
a randomly selected disk drive was removed. The SUT continued to process work until all 300 transactions had completed from all 12 streams. The the start and end time stamps for every transaction in each stream were analyzed to verify that there was always at least 1 in-flight transaction. Then the HISTORY table and success files were compared to verify that every record in the HISTORY table had a corresponding record in the success file and that each record in the success file had a corresponding entry in the HISTORY table. The consistency of the ORDERS and LINEITEM tables was then verified again.
4 Clause 4 Scaling and Database Population

4.1 Ending Cardinality of Tables

The cardinality (e.g., the number of rows) of each table of the test database, as it existed at the completion of the database load (see clause 4.2.5) must be disclosed.

<table>
<thead>
<tr>
<th>Table</th>
<th>Cardinality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Region</td>
<td>5</td>
</tr>
<tr>
<td>Nation</td>
<td>25</td>
</tr>
<tr>
<td>Supplier</td>
<td>1,000,000</td>
</tr>
<tr>
<td>Partsupp</td>
<td>80,000,000</td>
</tr>
<tr>
<td>Customer</td>
<td>15,000,000</td>
</tr>
<tr>
<td>Orders</td>
<td>150,000,000</td>
</tr>
<tr>
<td>LineItem</td>
<td>600,037,902</td>
</tr>
<tr>
<td>Part</td>
<td>20,000,000</td>
</tr>
</tbody>
</table>

4.2 Distribution of Tables and Logs Across Media

Distribution of tables and logs across media:

The SUT has 16 physical disk drives which appear to the OS as 2 logical drives. Each logical drive is RAID 5 array across 8 physical drives. There are 4 partitions, 3 of which are pair-wise combined into RAID-0 logical volumes.

Database (/ivw): executable files, database files, and database transaction logs.
Home (/home): all user files including benchmark scripts.
Scratch (/scratch): not used in this benchmark.
OS: RHEL 6 Installation

Each partition, except the OS is spread across both RAID arrays. The OS partition is on a single RAID array.
4.3 Database Partition/Replication Mapping

The mapping of database partitions/replications must be explicitly described.

No database partitioning or replication was used.

4.4 RAID Feature

Implementation may use some form of RAID to ensure high availability. If used for data, auxiliary storage (e.g. indexes) or temporary space, the level of RAID must be disclosed for each device.

RAID 5+0 storage was used, the RAID configuration is described in 4.2.

4.5 DBGEN Modification

Any modifications to the DBGEN (see clause 4.2.1) source code must be disclosed. In the event that a program other than DBGEN was used to populate the database, it must be disclosed in its entirety.

The supplied DBGEN version 2.13.0 was modified (changes made to a header file) to generate the database population for this benchmark. This header file is included in the supporting files archive.

4.6 Database Load Time

The database load time for the test database (see clause 4.3) must be disclosed.

The database load time is disclosed in the Executive Summary at the beginning of this Full Disclosure Report.

4.7 Data Storage Ratio

The data storage ratio must be disclosed. It is computed as the ratio between the total amount of priced disk space, and the chosen test database size as defined in Clause 4.1.3.

The data storage ratio is computed from the following information:

<table>
<thead>
<tr>
<th>Type</th>
<th>Number</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>6Gb SAS 15k RPM</td>
<td>16</td>
<td>146G</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td>2336GB</td>
</tr>
<tr>
<td>Scale Factor</td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>Size ratio</td>
<td></td>
<td>23.36</td>
</tr>
</tbody>
</table>

4.8 Database Load Mechanism Details and Illustration

The details of the database load must be described, including a block diagram illustrating the overall process.

The database was loaded using flat files stored on an NFS server not included in the priced configuration.

4.9 Qualification Database Configuration

Any differences between the configuration of the qualification database and the test database must be disclosed.

The qualification database used identical scripts to create and load the data with changes to adjust for the database scale factor.
4.10 Memory to Database Size Percentage

The memory to database size percentage, as defined in clause 8.3.5.10, must be disclosed.

The memory to database size percentage is disclosed in the Executive Summary at the beginning of this Full Disclosure Report.
 Clause 5 Performance Metrics and Execution-Rules

5.1 System Activity Between Load and Performance Tests
Any system activity on the SUT that takes place between the conclusion of the load test and the beginning of the performance test must be fully disclosed.

Auditor requested script was run to display the indices that had been created on the database.

All scripts and queries used are included in the Supporting Files Archive.

5.2 Steps in the Power Test
The details of the steps followed to implement the power test (e.g., system boot, database restart, etc.) must be disclosed.

The following steps were used to implement the power test:

1. RF1 Refresh Transaction
2. Stream 0 Execution
3. RF2 Refresh Transaction

5.3 Timing Intervals for Each Query and Refresh Functions
The timing intervals for each query for both refresh functions must be reported for the power test.

The timing intervals for each query and both update functions are given in the Executive Summary earlier in this document.

5.4 Number of Streams for the Throughput Test
The number of execution streams used for the throughput test must be disclosed.

11 streams were used for the throughput test.

5.5 Start and End Date/Time of Each Query Stream
The start time and finish time for each query stream must be reported for the throughput test.

The throughput test start time and finish time for each stream are given in the Executive Summary earlier in this document.

5.6 Total Elapsed Time of the Measurement Interval
The total elapsed time of the measurement interval must be reported for the throughput test.

The total elapsed time of the throughput test is given in the Executive Summary earlier in this document.

5.7 Refresh Function Start Date/Time and Finish Date/Time
Start and finish time for each update function in the update stream must be reported for the throughput test.

Start and finish time for each update function in the update stream are given in the Executive Summary earlier in this document.

5.8 Timing Intervals for Each Query and Each Refresh Function for Each Stream
The timing intervals for each query of each stream and for each refresh function must be reported for the throughput test.

The timing intervals for each query and each update function are given in the Executive Summary earlier in this document.

5.9 Performance Metrics
The computed performance metric, related numerical quantities and price performance metric must be reported.

The performance metrics, and the numbers, on which they are based, is given in the Executive Summary earlier in this document.
5.10 The Performance Metric and Numerical Quantities from Both Runs

The performance metric and numerical quantities from both runs must be disclosed.

Performance results from the first two executions of the TPC-H benchmark indicated the following percent difference for the metric points:

<table>
<thead>
<tr>
<th></th>
<th>Qph@100GB</th>
<th>Qth@100GB</th>
<th>QphH@100GB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reported Run</td>
<td>257142.9</td>
<td>246101.7</td>
<td>251561.7</td>
</tr>
<tr>
<td>Reproducibility Run</td>
<td>257142.9</td>
<td>252521.7</td>
<td>254821.8</td>
</tr>
<tr>
<td>% Difference</td>
<td>0%</td>
<td>2.61%</td>
<td>1.3%</td>
</tr>
</tbody>
</table>

5.11 System Activity Between Performance Tests

Any activity on the SUT that takes place between the conclusion of the Reported Run and the beginning of Reproducibility Run must be disclosed.

There was no activity on the SUT between the reported run and reproducibility run.

5.12 Dataset Verification

Verify that the rows in the loaded database after the performance test are correct by comparing some small number of rows extracted at random from any two files of the corresponding Base, Insert and Delete reference data set files for each table and the corresponding rows of the database.

Verified according to the specification.

5.13 Referential Integrity

Verify referential integrity in the database after the initial load.

An auditor supplied script was to verify referential integrity.
6 Clause 6 SUT and Driver Implementation Related Items

6.1 Driver

A detailed description of how the driver performs its functions must be supplied, including any related source code or scripts. This description should allow an independent reconstruction of the driver.

The supporting files archive contains the scripts that were used to implement the driver.

The power test is invoked through the script power_test.sh. It starts the stream 0 SQL script along with the refresh functions such that:
• The SQL for RF1 is submitted and executed by the database
• Then the queries as generated by QGEN are submitted in the order defined by Clause 5.3.5.4
• The SQL for RF2 is then submitted from the same connection used for RF1 and executed by database

The Throughput test is invoked through the script throughput_test.sh. This script then initiates all of the SQL streams and the refresh stream.

6.2 Implementation-Specific Layer (ISL)

If an implementation specific layer is used, then a detailed description of how it performs its functions must be provided. All related source code, scripts and configuration files must be disclosed. The information provided should be sufficient for an independent reconstruction of the implementation specific layer.

There was no Implementation Specific Layer.

6.3 Profile-Directed Optimization

If profile-directed optimization as described in Clause 5.2. is used, such use must be disclosed.

Profile-directed optimization was not used.
7 Clause 7 Pricing

7.1 Hardware and Software Used in the Priced System

A detailed list of hardware and software used in the priced system must be reported. Each item must have vendor part number, description, and release/revision level, and either general availability status or committed delivery date. If package pricing is used, contents of the package must be disclosed. Pricing source(s) and effective date(s) of price(s) must also be reported.

A detailed list of hardware and software used in the priced system is included in the pricing sheet in the executive summary. All prices are currently effective.

7.2 Total Three Year Price

The total 3-year price of the entire configuration must be reported including: hardware, software, and maintenance charges. Separate component pricing is recommended. The basis of all discounts used must be disclosed.

A detailed pricing sheet of all the hardware and software used in this configuration and the 3-year maintenance costs, demonstrating the computation of the total 3-year price of the configuration, is included in the executive summary at the beginning of this document.

7.3 Availability Date

The committed delivery date for general availability of products used in the priced calculations must be reported. When the priced system includes products with different availability dates, the reported availability date for the priced system must be the date at which all components are committed to be available.

<table>
<thead>
<tr>
<th>Component</th>
<th>Availability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Server Hardware</td>
<td>Currently Available</td>
</tr>
<tr>
<td>Server Software</td>
<td>Currently Available</td>
</tr>
<tr>
<td>Storage</td>
<td>Currently Available</td>
</tr>
<tr>
<td>Ingres VectorWise 1.5</td>
<td>Available 3/31/2011</td>
</tr>
</tbody>
</table>
## 8 Clause 8 Full Disclosure

### 8.1 Supporting Files Index Table

An index for all files included in the supporting files archive as required by Clauses 8.3.2 must be provided in the report.

<table>
<thead>
<tr>
<th>Clause</th>
<th>Description</th>
<th>Archive File</th>
<th>Pathname</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clause 1</td>
<td>Device setup</td>
<td>benchmark_scripts.zip</td>
<td>scripts/ingres_vectorwise/sysinfo/disk</td>
</tr>
<tr>
<td></td>
<td>Installation and configuration</td>
<td>benchmark_scripts.zip</td>
<td>scripts/ingres_vectorwise/sysinfo/install_*.txt</td>
</tr>
<tr>
<td></td>
<td>OS Tunable Parameters</td>
<td>benchmark_scripts.zip</td>
<td>scripts/ingres_vectorwise/sysctl.conf</td>
</tr>
<tr>
<td></td>
<td>DB creation scripts</td>
<td>benchmark_scripts.zip</td>
<td>scripts/ingres_vectorwise/ddl/create_*.sql</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>scripts/ingres_vectorwise/create_db.sh</td>
</tr>
<tr>
<td>Clause 2</td>
<td>QGen Modifications</td>
<td>benchmark_scripts.zip</td>
<td>tpch_tools/tpcd.h</td>
</tr>
<tr>
<td>Clause 3</td>
<td>ACID Test scripts</td>
<td>benchmark_scripts.zip</td>
<td>scripts/ingres_vectorwise/acid/*_sh</td>
</tr>
<tr>
<td></td>
<td>ACID Test Results</td>
<td></td>
<td>scripts/ingres_vectorwise/acid/[atom cons iso dur]/*sh</td>
</tr>
<tr>
<td>Clause 4</td>
<td>Qualification db load results</td>
<td>benchmark_scripts.zip</td>
<td>scripts/ingres_vectorwise/output/7</td>
</tr>
<tr>
<td></td>
<td>Qualification db validation results</td>
<td>benchmark_scripts.zip</td>
<td>scripts/ingres_vectorwise/output/8</td>
</tr>
<tr>
<td></td>
<td>DBGEN Modifications</td>
<td>benchmark_scripts.zip</td>
<td>tpch_tools/tpcd.h</td>
</tr>
<tr>
<td></td>
<td>Database Load Scripts</td>
<td>benchmark_scripts.zip</td>
<td>scripts/ingres_vectorwise/load_test.sh</td>
</tr>
<tr>
<td></td>
<td>Test db Load results</td>
<td>benchmark_scripts.zip</td>
<td>scripts/ingres_vectorwise/output/9</td>
</tr>
<tr>
<td>Clause 5</td>
<td>Run 1 (10 performance run, 11 power, 12 throughput)</td>
<td>run1results.zip</td>
<td>scripts/ingres_vectorwise/output/10</td>
</tr>
<tr>
<td></td>
<td>Run 2 (10 performance run, 13 power, 14 throughput)</td>
<td>run1results.zip</td>
<td>scripts/ingres_vectorwise/output/11</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>scripts/ingres_vectorwise/output/12</td>
</tr>
<tr>
<td>Clause 6</td>
<td>implementation scripts</td>
<td>benchmark_scripts.zip</td>
<td>scripts/ingres_vectorwise/run_perf.sh</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>scripts/ingres_vectorwise/performance_test.sh</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>scripts/ingres_vectorwise/power_test.sh</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>scripts/ingres_vectorwise/throughput_test.sh</td>
</tr>
<tr>
<td>Clause 7</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Clause 8</td>
<td>Executable query test</td>
<td>benchmark_scripts.zip</td>
<td>scripts/ingres_vectorwise/<em>/queries/stream/</em>_*.sql</td>
</tr>
<tr>
<td></td>
<td>Query substitution parameters and seeds</td>
<td>benchmark_scripts.zip</td>
<td>scripts/ingres_vectorwise/<em>/queries/stream/</em>_param</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>scripts/ingres_vectorwise/*/test_report.txt</td>
</tr>
<tr>
<td></td>
<td>RF function source code</td>
<td>benchmark_scripts.zip</td>
<td>scripts/ingres_vectorwise/<em>rf</em></td>
</tr>
</tbody>
</table>
9 Clause 9 Audit Related Items

9.1 Auditor's Report

The auditor's agency name, address, phone number, and Attestation letter with a brief audit summary report indicating compliance must be included in the full disclosure report. A statement should be included specifying who to contact in order to obtain further information regarding the audit process.

This implementation of the TPC Benchmark H was audited by Lorna Livingtree and Steve Barrish for Performance Metrics. Further information regarding the audit process may be obtained from:

Performance Metrics

Box 984

Klamath, CA 95548

707-482-0523
February 9, 2011

Mr. Dan Koren  
Ingres Corporation  Suite 200  
500 Arguello Street  
Redwood City, CA 94063

I have verified on-site and remote the TPC Benchmark™ H for the following configuration:

Platform: HP ProLiant DL385 G7  
Database Manager: VectorWise R1.5  
Operating System: Red Hat Enterprise Linux 6.0

<table>
<thead>
<tr>
<th>CPU’s</th>
<th>Memory</th>
<th>Total Disks</th>
<th>QphH@100GB</th>
<th>QthH@100GB</th>
<th>QppH@100GB</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 Intel Xeon @ 3.3 Ghz</td>
<td>144 GB</td>
<td>16@146 GB</td>
<td>257,142.0</td>
<td>246,101.7</td>
<td>251,561.7</td>
</tr>
</tbody>
</table>

In my opinion, these performance results were produced in compliance with the TPC requirements for the benchmark. The following attributes of the benchmark were given special attention:

- The database tables were defined with the proper columns, layout and sizes.
- The tested database was correctly scaled and populated for 100GB using DBGEN. The version of DBGEN was 2.13.0.
- The data generated by DBGEN was successfully compared to reference data.
- The qualification database layout was identical to the tested database except for the size of the files.
- The query text was verified to use only compliant variants and minor modifications.
- The executable query text was generated by QGEN and submitted through a standard interactive interface. The version of QGEN was 2.13.0.
- The validation of the query text against the qualification database produced compliant results.
- The refresh functions were properly implemented and executed the correct number of inserts and deletes.
- The load timing was properly measured and reported.
- The execution times were correctly measured and reported.
- The performance metrics were correctly computed and reported.
- The repeatability of the measurement was verified.
- The ACID properties were successfully demonstrated and verified.
- The system pricing was checked for major components and maintenance.
- The executive summary pages of the FDR were verified for accuracy.
Auditor’s Notes:

1. This benchmark was run with DBGen version 2.13 which is known to generate part.p_name differently for different degrees of parallelism. When verifying the reference data as required by clause 9.2.4.3, the part.p_name differences were ignored in compliance with motion 20110111-3 of the TPC-H committee.

2. This database uses a modified MVCC locking scheme as permitted by clause 3.4.2. Consequently isolation tests #3 and #4 did not complete as described in the spec, but did correctly demonstrated the isolation level required.

3. All isolation tests were executed on the scale factor 100 database as permitted by TAB motion in FogBugz #388.

Sincerely,

Lorna Livingtree
Audit

and

Steve Barrish

Lorna Livingtree
Auditor

TPC Certified Performance Council
### Appendix A  Price Quotes

<table>
<thead>
<tr>
<th>P/N</th>
<th>Description</th>
<th>Qty</th>
<th>Unit Cost</th>
<th>Extended</th>
</tr>
</thead>
<tbody>
<tr>
<td>HP DL380 G7 SFF CTO Chassis</td>
<td>1</td>
<td>$24,467.00</td>
<td>$24,467.00</td>
<td></td>
</tr>
<tr>
<td>HP X5600 DL380 G7 IC Kit</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HP X5600 DL380 G7 Kit</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HP 1GB 2Rx4 PC3-10600R-8 Kit</td>
<td>18</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HP 8SFF Cage 38066/G7 Kit</td>
<td>1</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>HP P4/10 n/10 Flash Back Cache Drtr</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HP 1G Flash Backed Cache Upgrade</td>
<td>1</td>
<td></td>
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<td></td>
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<tr>
<td>HP 750W C5-HE Power Supply Kit</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HP LA1761B 17-inch Monitor</td>
<td>1</td>
<td></td>
<td></td>
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<tr>
<td>HP PS/2 Keyboard And Mouse Bundle</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HP by 4h 24x7 ProLiant DL380c HW Support</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HP 146GB 6G SAS 15K 2.6m DP ENT HDD</td>
<td>16</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>RHIE 1-2 SKT 24x73 Year R/R/R SW</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Total** $24,467.00

Signature
**INGRES Order Confirmation**

**Ingres Corporation**
500 Arguello Street Suite 200
Redwood City, CA 94063
United States

Phone: (650) 587-5500
Fax: (650) 649-2358

**Message:**

**ORDER**

Prepared by:
Mark Van de Weel
(650) 587-5538
mark.vandeweel@ingres.com

<table>
<thead>
<tr>
<th>Product Item</th>
<th>Memo</th>
<th>Contract Start</th>
<th>Contract End</th>
<th>Unit</th>
<th>Quantity</th>
<th>Price</th>
<th>Discount %</th>
<th>Extended Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>ING-VW-3Y</td>
<td>3 year license, minimum 8 cores</td>
<td>30-June-2011</td>
<td>29-June-2014</td>
<td>CORE</td>
<td>12</td>
<td>USD 5,000</td>
<td>10</td>
<td>USD 54,000</td>
</tr>
<tr>
<td>ING-VW-3Y-MNT</td>
<td>1 year professional support, 10% of base, minimum 8 cores</td>
<td>30-June-2011</td>
<td>29-June-2014</td>
<td>CORE</td>
<td>35</td>
<td>USD 500</td>
<td>10</td>
<td>USD 16,200</td>
</tr>
</tbody>
</table>

Grand Total: USD 70,200

*Fees herein are exclusive of taxes, withholding, levies, imposts, and duties (“Taxes”), and Customer, not Ingres, is responsible for any such Taxes.*