TPC Benchmark™ H
Full Disclosure Report

DELL PowerEdge R910
8-core Intel® Xeon™ E7-8837 2.66GHz 24MB L3 Cache
using
VectorWise™ 1.6
and
RedHat™ RHEL 6.0

Submitted for Review
Report Date May 3, 2011
TPC Benchmark H™ Full Disclosure Report
First Printing
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Benchmark results are highly dependent upon workload, specific application requirements, and system design and implementation. Relative system performance will vary as a result of these and other factors. Therefore, TPC Benchmark H should not be used as a substitute for a specific customer application benchmark when critical capacity planning and/or product evaluation decisions are contemplated.

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 a Dell PowerEdge R910 server, in conformance with the requirements of the TPC Benchmark™ H Standard Specification, Revision 2.14.0. The operating system used for the benchmark was Red Hat Enterprise Linux Server release 6.0; the DBMS was VectorWise release 1.6.

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 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.

Dell, Inc. 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.
## Total System Cost

<table>
<thead>
<tr>
<th>Database Size</th>
<th>Database Manager</th>
<th>Operating System</th>
<th>Other Software</th>
<th>Availability Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>300 GB</td>
<td>VectorWise 1.6</td>
<td>RedHat Enterprise</td>
<td>None</td>
<td>6/30/2011</td>
</tr>
</tbody>
</table>

## System Configuration

- Number of Nodes: 1
- Processors/Cores/Threads/Type: 4/32/32/Intel Xeon E7-8837 2.67 Ghz, 24MB L3 cache
- Memory: 512 GB
- Disk Controller: Dell PERC H700 RAID Controller with 1GB NVRAM Cache on-board
- Disk Drives: 16 x 146GB 2.5in SAS 6Gb/s 15k rpm
- Total Disk Storage: 2336 GB
- LAN Controllers: 4 x 1Gb Ethernet on-board

## Database Load Time

- Database Load Time = 04:35:56
- Load Includes Backup: N

## Storage Redundancy Level

- Storage Redundancy Level 1 for Base Tables, Auxiliary Data Structures, DBMS temporary space, and OS and DBMS Software

## TPC-H Performance Results

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<th>Power</th>
<th>Throughput</th>
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<td>RF2</td>
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## TPC-H Energy Results

- Price/QphH@300GB = $0.35 USD
- Watts/KqphH@300GB = 2.38
### Server Hardware

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<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>
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<td>R910 Chassis for 16 2.5&quot; HDD &amp; Intel E7 Processors</td>
<td>225-1158</td>
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### Server Software

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<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>
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<tr>
<td>VectorWise 1.6 3-year license Dell server**</td>
<td>ING-VW-3Y-GB-DELL</td>
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<td>VectorWise 1-year maintenance bug fixes**</td>
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| **Subtotal**                                                               | $41,958.70  |        |                 |     |                |                 |

| **No External Storage Required**                                           |             |        |                 |     |                |                 |

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<tr>
<th><strong>3 Year ProSupport and Mission Critical 4HR 7x24</strong></th>
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<th></th>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PSMC TECH SPT,PER910,3 YR</strong></td>
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<tr>
<td><strong>PSMC 4H7X24 OS,PER910,UNY,INIT</strong></td>
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<td><strong>HW WRTY + SVC,PER910,UNY,INIT</strong></td>
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**3-yr Cost of Ownership:** $139,458.70

**Source 1=Dell: Pricing may be verified by calling 1-800-BUY-DELL, contact:
Gregory Olsen, Greg_Olsen@Dell.com, referencing quote #582792206.
**

**Source 2=Ingres: Pricing may be verified by calling 1-650-587-5538, contact:
Mark Van de Wiel, mark.vandwiel@ingres.com.**

**Audited By: Steve Barrish for Performance Metrics, Inc.**

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.
## TPC-H Timing Intervals (in seconds)

Duration of stream execution:

<table>
<thead>
<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>
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<td>6.4</td>
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Energy Summary

Total System Cost | Composite Query per Hour Metric | Price/Performance | TPC-Energy Metric
--- | --- | --- | ---
$139,459 USD | 400,931.80 QphH@300GB | $0.35 USD QphH@300GB Watts/KQphH@300GB | 2.38

Database Size | Database Manager | Operating System | Other Software | Availability Date
--- | --- | --- | --- | ---
300 GB | VectorWise 1.6 | RedHat Enterprise Linux 6.0 | None | June 30, 2011

Numerical Quantities for Reported Energy Configuration:

- REC Idle Power: 674.9
- Average Power of REC: 954.5

Subsytem Reporting:
Secondary (subsytem) Metrics are not reported. Comparisons to other TPC-Energy Results must not reference subsystem energy information.

Lowest ambient temperature at air inlet: 22.88 Degrees Celsius

Items in Priced Configuration not in the Reported Energy Configuration: None.

Items in Reported Energy Configuration not in the Measured Energy Configuration: Dell E170S Monitor
0 General Items

0.1 Benchmark Sponsor

A statement identifying the benchmark sponsor(s) and other participating companies must be provided.

Dell, Inc. 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 (Dell PowerEdge R910):

4 x Intel Xeon E7-8837 CPU's @2.67 GHz
512 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 2.14.0 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 2.14.0 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.

5. The total price from the ORDERS table and the extended price from the LINEITEM table were retrieved for a randomly selected order key.
6. The ACID Transaction was performed using the order key from step 1. The transaction was stopped prior to the commit.
7. The ACID Transaction was ROLLED BACK.
8. 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.

9. The consistency of the ORDERS and LINEITEM tables was verified based on a sample of order keys.
10. 100 ACID Transactions were submitted from each of 8 execution streams.
11. 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.
12. An ACID query was run with randomly selected values for O_KEY, L_KEY and DELTA to get the initial value for O_TOTALPRICE.

13. An ACID Transaction was started using the randomly selected values from step 1. The ACID Transaction was suspended prior to COMMIT.

14. 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.

15. The ACID Transaction was resumed, and COMMITTED.

16. 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.

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

18. An ACID Transaction was started using the values selected in step 1. The ACID Transaction was suspended prior to ROLLBACK.

19. 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.

20. The ACID Transaction was ROLLED BACK.

21. 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:

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

23. An ACID Transaction, T1, was started with the values used in step 1. The ACID transaction T1 was suspended prior to COMMIT.

24. Another ACID Transaction, T2, was started using the same O_KEY and L_KEY used in step 1 and a randomly selected DELTA.

25. T2 COMMITTED and completed normally.

26. 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”.

27. The ACID Query was run to verify that O_TOTALPRICE was the value from T2.

Results from the second test were as follows:

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

29. An ACID Transaction, T1, was started with the values used in step 1. The ACID transaction T1 was suspended prior to COMMIT.

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

31. T2 ROLLED BACK and completed.

32. T1 resumed and completed normally.

33. 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:

34. An ACID Query was run for a randomly selected O_KEY, L_KEY and DELTA to get the initial value for O_TOTALPRICE.
35. An ACID Transaction, T1, was started for a randomly using the values from step 1. The ACID transaction T1 was suspended prior to ROLLBACK.
36. Another ACID Transaction, T2, was started using the same O_KEY and L_KEY and a randomly selected DELTA.
37. T2 completed normally.
38. T1 was allowed to ROLLBACK.
39. It was verified that O_TOTALPRICE was from T2.

The results from the second test were as follows:

40. An ACID Query was run for a randomly selected O_KEY, L_KEY and DELTA to get the initial value for O_TOTALPRICE.
41. An ACID Transaction, T1, was started with the same values as from step 1. T1 suspended prior to COMMIT.
42. Another ACID Transaction, T2, was started and it ROLLED BACK its updates and completed normally.
43. T1 resumed and COMMITED its updates.
44. 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.

45. An ACID Query was run for a randomly selected O_KEY, L KEY and DELTA to get the initial value for O_TOTALPRICE.
46. An ACID Transaction, T1, was started with the values from step 1. T1 was suspended prior to COMMIT.
47. 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.
48. T1 was allowed to COMMIT.
49. It was verified that O_TOTALPRICE had been changed by T1.

Read-Only Query Conflict with Update Transactions

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.

50. A Stream was submitted that executed Q1 10 times in a row with a delta of 0 to ensure that each query ran as long as possible.
51. An ACID Transaction, T1, was started for a randomly selected O_KEY, L_KEY and DELTA.
52. T1 completed and it was verified that O_TOTALPRICE was updated correctly.
53. 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.

54. The consistency of the ORDERS and LINEITEM tables was verified using 120 randomly chosen values for O_ORDERKEY.

55. At least 100 ACID transactions were submitted from 7 streams.

56. A randomly selected disk drive was removed from the SUT and the SUT continued to process work until each stream had submitted 300 transactions.

57. 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.

58. 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.

59. 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 7 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 8 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 7 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>3,000,000</td>
</tr>
<tr>
<td>Partsupp</td>
<td>240,000,000</td>
</tr>
<tr>
<td>Customer</td>
<td>45,000,000</td>
</tr>
<tr>
<td>Orders</td>
<td>450,000,000</td>
</tr>
<tr>
<td>LineItem</td>
<td>1,799,989,091</td>
</tr>
<tr>
<td>Part</td>
<td>60,000,000</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 a single RAID-5 logical drive. This drive is partitioned into a 1GB and another partition occupying all remaining disk space which is used to store the OS, DBMS and user software and the DBMS data store. There is no swap partition.

Database (/ivw): executable files, database files, and database transaction logs.

Home (/home): all user files including benchmark scripts.

OS: Red Hat Enterprise Linux release 6.0 Installation

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 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 2.14.0 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>300</td>
</tr>
<tr>
<td>Size ratio</td>
<td></td>
<td>7.79</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.

![Diagram of database load mechanism]

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.
5 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@300GB</th>
<th>QthH@300GB</th>
<th>QphH@300GB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reported Run</td>
<td>416,862.3</td>
<td>385,610.0</td>
<td>400,931.8</td>
</tr>
<tr>
<td>Reproducibility Run</td>
<td>407,531.1</td>
<td>437,972.4</td>
<td>422,477.7</td>
</tr>
<tr>
<td>% Difference</td>
<td>2.24%</td>
<td>13.58%</td>
<td>5.37%</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 start the stream 0 SQL script along with the refresh functns 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 ititiates 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.

Server Hardware          Currently Available
Server Software          Currently Available
Storage                  Currently Available
Ingres VectorWise 1.6    Available June 30, 2011
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/sysinfo/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>tpcch_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>benchmark_scripts.zip</td>
<td>scripts/ingres_vectorwise/acid/[atom cons iso dur]/*.sh</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>scripts/ingres_vectorwise/acid/[atom cons iso dur]/&lt;output&gt;</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>tpcch_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></td>
<td></td>
<td></td>
<td>scripts/ingres_vectorwise/output/10</td>
</tr>
<tr>
<td></td>
<td></td>
<td></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></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/10</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>scripts/ingres_vectorwise/output/11</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>scripts/ingres_vectorwise/output/13</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>scripts/ingres_vectorwise/output/14</td>
</tr>
<tr>
<td></td>
<td>implementation scripts</td>
<td>benchmark_scripts.zip</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/output/<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/output/<em>/queries/stream</em>/_param</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>scripts/ingres_vectorwise/output/*/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 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
Mr. David J Morse  
Director, Systems Performance Analysis  
Dell Enterprise Product Group  
200 Dell Way  
Round Rock TX, 78682  

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

<table>
<thead>
<tr>
<th>Platform:</th>
<th>PowerEdge R910</th>
</tr>
</thead>
<tbody>
<tr>
<td>Database Manager:</td>
<td>VectorWise R1.6</td>
</tr>
<tr>
<td>Operating System</td>
<td>Red Hat Enterprise Linux 6.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CPU’s</th>
<th>Memory</th>
<th>Total Disks</th>
<th>Qphh@300GB</th>
<th>QthH@300GB</th>
<th>QphH@300GB</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 x Intel Xeon E7-8837 @ 2.67 Ghz</td>
<td>512 GB</td>
<td>16 @ 146 GB</td>
<td>416,862.3</td>
<td>385,610.0</td>
<td>400,931.8</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 300GB using DBGEN. The version of DBGEN was 2.14.0.
- 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 2.14.0.
- 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 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.

Sincerely,

Steve Barrish
Auditor

[Signature]

TPC Certified Auditor
Appendix A Price Quotes

INGRES Order Confirmation

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

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

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

Message:

PREPARED FOR (BILL TO)          SHIP TO
David J. Morse
Director, Systems Performance Analysis
Dell | Enterprise Product Group
office + 1 512 723 2758

Dell | Enterprise Product Group
Attn. David J. Morse
Mail Stop: RR5-18
200 Dell Way
Round Rock, TX, 78682

<table>
<thead>
<tr>
<th>Product item</th>
<th>Memo</th>
<th>Contract Start</th>
<th>Contract End</th>
<th>Unit</th>
<th>Qty</th>
<th>Price</th>
<th>Discount</th>
<th>Extended Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>ING-VW-3Y-GB-DELL</td>
<td>3 year license, 1 GB source data, Dell server</td>
<td>30-June-2011</td>
<td>29-June-2014</td>
<td>GB</td>
<td>300</td>
<td>USD 250</td>
<td>0</td>
<td>USD 75,000</td>
</tr>
<tr>
<td>ING-VW-3Y-GB-DELL-MNT</td>
<td>1 year professional support, bug fixes only, 1 GB source data, Dell server</td>
<td>30-June-2011</td>
<td>29-June-2014</td>
<td>GB</td>
<td>900</td>
<td>USD 25</td>
<td>0</td>
<td>USD 22,500</td>
</tr>
</tbody>
</table>

Grand Total: USD 97,500

*Fees herein are exclusive of taxes, withholding, levies, impost, and duties (“Taxes”), and Customer, not Ingres, is responsible for any such Taxes.
Appendix B TPC-Energy Report

B.1. TPC-Energy Clause 2-related items (Methodology)

B.1.1. Minimum ambient temperature
The minimum ambient temperature must be disclosed

The minimum ambient temperature during the measured run was 22.88 C.

B.1.2. External electric power source characteristics
The characteristics of the external electric power source must be disclosed. In particular, the voltage, frequency in Hertz, and phase information must be reported.

The external electric power source has the following characteristics: 120V, 60Hz, single phase.

B.1.3. Air-pressure alterations
A statement is required that assures that nothing was done to alter the air-pressure in the measurement environment.

The measurement environment was a machine room with forced air cooling. The air pressure at the SUT was the same as the rest of the room.

B.1.4. Temperature measurement
A description of where the temperature was measured and how it was determined that this was representative of the lowest ambient temperature is required.

Temperature was measured at the SUT air inlet and this is representative because it was a single system.

B.1.5. Cooling method
If a method of cooling other than circulation of ambient air is employed in the REC, a statement describing this method must be included.

No other method of cooling was used.

B.1.6. PTD license
To be compliant with licenses associated with EMS, the following statement must be included in every FDR which contains a TPC-Energy Metric:

The power and temperature characteristics of the MEC were measured using TPC’s Energy Measurement Software (EMS). This includes the EMS-PTD, a modified version of the SPEC PTDaemon, which is provided under license from the Standard Performance Evaluation Corporation (SPEC).

B.2. TPC-Energy Clause 3-related items (Metrics)

B.2.1. Primary Metric
The normalized work derived from the Performance Metric (as described in Clause 3.2.1) must be disclosed

The computation for total energy used for each measurement segment that contributes to a Performance Metric must be disclosed. If the energy of the entire Priced Configuration is not derived from direct measurements, the methods for deriving the energy for components that were not measured must be disclosed (See Clause 7.3.3.4)

The duration of each measurement that produces a Performance Metric must be disclosed
The average power requirement for each measurement that produces one of these metrics,

The TPC-Energy Primary Metric must be disclosed, including the calculation that is used to derive it.
B.2.2. Secondary Metrics At Reported Performance

If the TPC-Energy Secondary Metrics are reported, the components of the REC that are included in each subsystem must be identified. This can be achieved with separate lists to be included in the FDR or with a specific designation in the price spreadsheet. Every component in the REC that consumes energy must be included in exactly one subsystem.

No TPC-Energy secondary metrics are reported.

For each defined subsystem, the calculations defined for the TPC-Energy Secondary Metrics in Clause 3.3 must be reported, using the Performance Metric of the entire SUT and the energy consumption for each REC subsystem.

No TPC-Energy secondary metrics are reported.
B.2.3. Idle Power reporting

The Idle Power measurement/calculation for the REC must be reported as numerical quantities.

<table>
<thead>
<tr>
<th>PMU</th>
<th>Full Load Average Watts Reading</th>
<th>% of Reading Uncertainty</th>
<th>Watts Reading Correction</th>
<th>% of Range Uncertainty</th>
<th>Watts Range Setting</th>
<th>% of Range Uncertainty</th>
<th>Watts Range Correction</th>
<th>Total Watts Uncertainty</th>
<th>Accuracy Correction Factor</th>
<th>Reported Watt/Seconds</th>
<th>Adjusted Watt/Seconds</th>
<th>Reported Seconds</th>
<th>Adjusted Average Watts</th>
</tr>
</thead>
<tbody>
<tr>
<td>DB Server PMU-1</td>
<td>317.7</td>
<td>0.18%</td>
<td>+0.33</td>
<td>1069</td>
<td>0.16%</td>
<td>+1.68</td>
<td>1.53%</td>
<td>0.8%</td>
<td>230.6335</td>
<td>299.0175</td>
<td>651.6</td>
<td>651.6</td>
<td>651.6</td>
</tr>
<tr>
<td>DB Server PMU-2</td>
<td>334.1</td>
<td>0.18%</td>
<td>+0.33</td>
<td>1069</td>
<td>0.16%</td>
<td>+1.68</td>
<td>1.53%</td>
<td>0.9%</td>
<td>217.4970</td>
<td>219.7961</td>
<td>651.6</td>
<td>651.6</td>
<td>651.6</td>
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<tr>
<td>DB Server PMU-3</td>
<td>0.0</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.06%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>DB Server Total</td>
<td>651.8</td>
<td></td>
<td></td>
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<td></td>
<td>651.6</td>
<td>651.6</td>
</tr>
<tr>
<td>Storage PMU-1</td>
<td>0.0</td>
<td>0.16%</td>
<td>+0.00</td>
<td>0.0%</td>
<td>0.0%</td>
<td>+0.00</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
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<tr>
<td>Storage PMU-2</td>
<td>0.0</td>
<td>0.16%</td>
<td>+0.00</td>
<td>0.0%</td>
<td>0.0%</td>
<td>+0.00</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
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<tr>
<td>Storage PMU-3</td>
<td>0.0</td>
<td>0.0%</td>
<td>-</td>
<td>0.0%</td>
<td>0.0%</td>
<td>-</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>-</td>
<td>-</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>Storage PMU-4</td>
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<td>0.0%</td>
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<td>-</td>
<td>0.0%</td>
<td>0.0%</td>
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<td>-</td>
<td>-</td>
<td>0.0%</td>
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</tr>
<tr>
<td>Storage Total</td>
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<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
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<td>0.0%</td>
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</tr>
<tr>
<td>Monitor Name Plate</td>
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<td>+0.00</td>
<td>0.0%</td>
<td>0.0%</td>
<td>+0.00</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>Misc PMU-1</td>
<td>0.0</td>
<td>0.0%</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>Misc PMU-2</td>
<td>0.0</td>
<td>0.0%</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>Misc PMU-3</td>
<td>0.0</td>
<td>0.0%</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>Misc Total</td>
<td>0.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>REC Total</td>
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<td></td>
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<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>651.6</td>
<td>651.6</td>
</tr>
</tbody>
</table>

If TPC-Energy Secondary Metrics are reported, then the Idle Power measurement/calculation for each subsystem must also be reported as numerical quantities.

No TPC-Energy secondary metrics are reported.

The length of time between the conclusion of the performance measurement and the start of the idle measurement must be reported.

Idle measurement started immediately after the conclusion of the performance measurement.

The duration of the idle measurement must be reported

Idle measurement duration was 651 seconds.

A statement is required that assures that the system is in a state that is ready to run the Application(s) of the benchmark for the duration of the idle measurement.

There were no changes to the system after the performance run. During the idle measurement the system was ready to process any query and the acid query performed after the idle period met the requirements of clause 3.3.3.

B.2.4. Disclosure requirements when only part of the REC is measured for power

If all PMU’s of the REC are not measured for energy use, the FDR must include a description of which PMUs of REC were measured with a power analyzer. The FDR must disclose which PMUs of the REC were computed based on the energy measurements of similar PMUs. A diagram must be included that identifies the portions of the configuration which were measured for energy use and which were calculated. This diagram may be combined with other diagrams required by the TPC Benchmark Standard.

- The method used to determine which PMUs were measured must be disclosed.
- The power values for the each partial-REC measurement for duration of the performance and idle measurements must be disclosed.
- The calculation for the power requirements of the entire REC and, if applicable, each subsystem must be disclosed.

The values used for the monitor were based on the vendor’s max wattage specifications (name plate value).

B.2.5. Disclosure requirements when component substitution is used

If the TPC Benchmark Standard allows the Priced Configuration to differ from the Measured Configuration, the methods used to assign energy or power characteristics to the substitute components must be disclosed.
There were no substitutions. The Priced Configuration was identical to the Measured Configuration.

*The method used to determine which PMUs were measured must be disclosed*

The monitor was the only component not measured. All other components were internal to the SUT.

*The power values for the each partial-REC measurement for duration of the performance and idle measurements must be disclosed.*

See values presented in spreadsheet form in previous section of this report.

**B.3. TPC-Energy Clause 4-related items (Drivers /Controller)**

A statement indicating the version of EMS used must be included in the FDR, including a statement that no alterations of this code were made for the benchmark, except as specified by Clause 7.3.4.3. This includes levels for the EMS-PTD Manager, EMS-PTD and EMS-controller.

EMS version was 1.2.0 and no alterations were made.

*Input parameters for the EMS software must be disclosed*

The followig EMS script was used to configure the EMS software:

```bash
start log temp > temp
start log power1 >power1
start log power2 >power2
start data "..."
```

*Any changes in the EMS components must be documented. Documentation must include a description of the issue, the reason the change was necessary for disclosure of the Result, and the changes made to resolve it. Any change to TPC-Provided Code must be included with the submission as a Supporting File.*

No changes to EMS components were made.

**B.4. TPC-Energy Clause 6-related items (Instrumentation)**

**B.4.1. Power Analyzer information**

- **Power analyzer #1**
  Instek GPM-8212  Serial Number: CK160090
  Certification date : 6/22/2010
  Amperage Range setting: 10A Manual
  Voltage Range setting: 160V Manual
  Reading accuracy: 0.1% from manufacturer’s documentation
  Range accuracy: 0.1% from manufacturer’s documentation

- **Power analyzer #1**
  Instek GPM-8212  Serial Number: CK210085
  Certification date : 11/15/2010
  Amperage Range setting: 10A Manual
  Voltage Range setting: 160V Manual
  Reading accuracy: 0.1% from manufacturer’s documentation
  Range accuracy: 0.1% from manufacturer’s documentation
B.4.2. Temperature Sensor information

InsideOut Networks WatchPort/H USB Humidity/Temperature Sensor
Accuracy: +/-0.5°C at (-10°C to 85°C) (from Vendor website)
B.5. TPC-Energy Clause 8-related items

B.5.1. Auditor’s attestation letter.

May 3, 2011

Mr. David J Morse
Director, Systems Performance Analysis
Dell Enterprise Product Group
200 Dell Way
Round Rock TX, 78682

I have verified by remote the TPC Benchmark™ H for the following configuration:

<table>
<thead>
<tr>
<th>Platform:</th>
<th>PowerEdge R910</th>
</tr>
</thead>
<tbody>
<tr>
<td>Database Manager:</td>
<td>VectorWise R1.6</td>
</tr>
<tr>
<td>Operating System:</td>
<td>Red Hat Enterprise Linux 6.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CPU’s</th>
<th>Memory</th>
<th>Total Disks</th>
<th>Qpph@300GB</th>
<th>QthH@300GB</th>
<th>QphH@300GB</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 x Intel Xeon E7-8837 @ 2.67 Ghz</td>
<td>512 GB</td>
<td>16 @ 146 GB</td>
<td>416,862.3</td>
<td>385,610.0</td>
<td>400,931.8</td>
</tr>
</tbody>
</table>

In addition to the performance metric, the energy consumption was measured during the performance runs in compliance with the TPC-Energy specification.

- The power analyzer used was verified to be approved and calibrated within one year prior to this measurement.
- The energy measurements met all requirements of the specification unless an exception is noted below.
- The calculations for the TPC-Energy Primary Metric were verified as completed correctly.
- The EMS software was verified to be the correct version and without any changes.
- The executive summary page and the FDR were verified for accuracy.

Auditor’s Notes: None

Sincerely,

Steve Banish
### B.6. TPC-Energy Supporting Files Index

<table>
<thead>
<tr>
<th>Clause</th>
<th>Description</th>
<th>Pathname</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clause 7</td>
<td>Energy Measurement Log Files</td>
<td>SupportingFiles/Energy</td>
</tr>
<tr>
<td></td>
<td>Energy Measurement Configuration Files</td>
<td>SupportingFiles/Energy/CollectData.ems</td>
</tr>
</tbody>
</table>