# Hewlett-Packard Enterprise

TPC Benchmark™ H
Full Disclosure Report
for
HPE ProLiant DL380 Gen10
using
Microsoft SQL Server 2017 Enterprise Edition
and
SUSE Linux Enterprise Server 12 SP3

**First Edition**
**November 2017**

**Hewlett Packard Enterprise (HPE)**, the Sponsor of this benchmark test, believes that the information in this document is accurate as of the publication date. The information in this document is subject to change without notice. The Sponsor assumes no responsibility for any errors that may appear in this document.

The pricing information in this document is believed to accurately reflect the current prices as of the publication date. However, the Sponsor provides no warranty of the pricing information in this document.

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, the 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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# Abstract

## Overview

This report documents the methodology and results of the TPC Benchmark™ H test conducted on the HPE ProLiant DL380 Gen10 using Microsoft SQL Server 2017 Enterprise Edition in conformance with the requirements of the TPC Benchmark™ H Standard Specification, Revision 2.17.3. The operating system used for the benchmark was SUSE Linux Enterprise Server 12 SP3.

The TPC Benchmark™ H was developed by the Transaction Processing Performance Council (TPC). The TPC was founded to define transaction processing benchmarks and to disseminate objective, verifiable performance data to the industry.

TPC Benchmark™ H Full Disclosure Report and other information can be downloaded from the Transaction Processing Performance Council web site at www.tpc.org.

## Standard and Executive Summary Statements

Pages iv - viii contain the Executive Summary and Numerical Quantities Summary of the benchmark results for the HPE ProLiant DL380 Gen10.

## 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 QppH and QthH were audited by Francois Raab of InfoSizing to verify compliance with the relevant TPC specifications.

The auditor's letter of attestation is attached in Section 9.1 "Auditors' Report."

| | **HPE ProLiant DL380 Gen10** | TPC-H Rev. 2.17.3 TPC Pricing Rev. 2.1.1 |
|---|---|---|
| **Hewlett Packard Enterprise** | | Report Date: November 17, 2017 |
| Total System Cost | Composite Query per Hour Rating | Price/Performance |
| **$472,069 USD** | **1,009,065.5** QphH @ 1000GB | **$0.47 USD** $ / QphH @1000GB |

| Database Size | Database Manager | Operating System | Other Software | Availability Date |
|---|---|---|---|---|
| **1000GB** | **SQL Server 2017 Enterprise Edition** | **SUSE Linux Enterprise Server 12 SP3** | **None** | **28th February 2018** |



Query Times in seconds

- - - - - Geometric Mean of Power Test
───── Arithmetic Mean of Throughput Test

□ Power Run   ■ Throughput Run

3.1   27.6
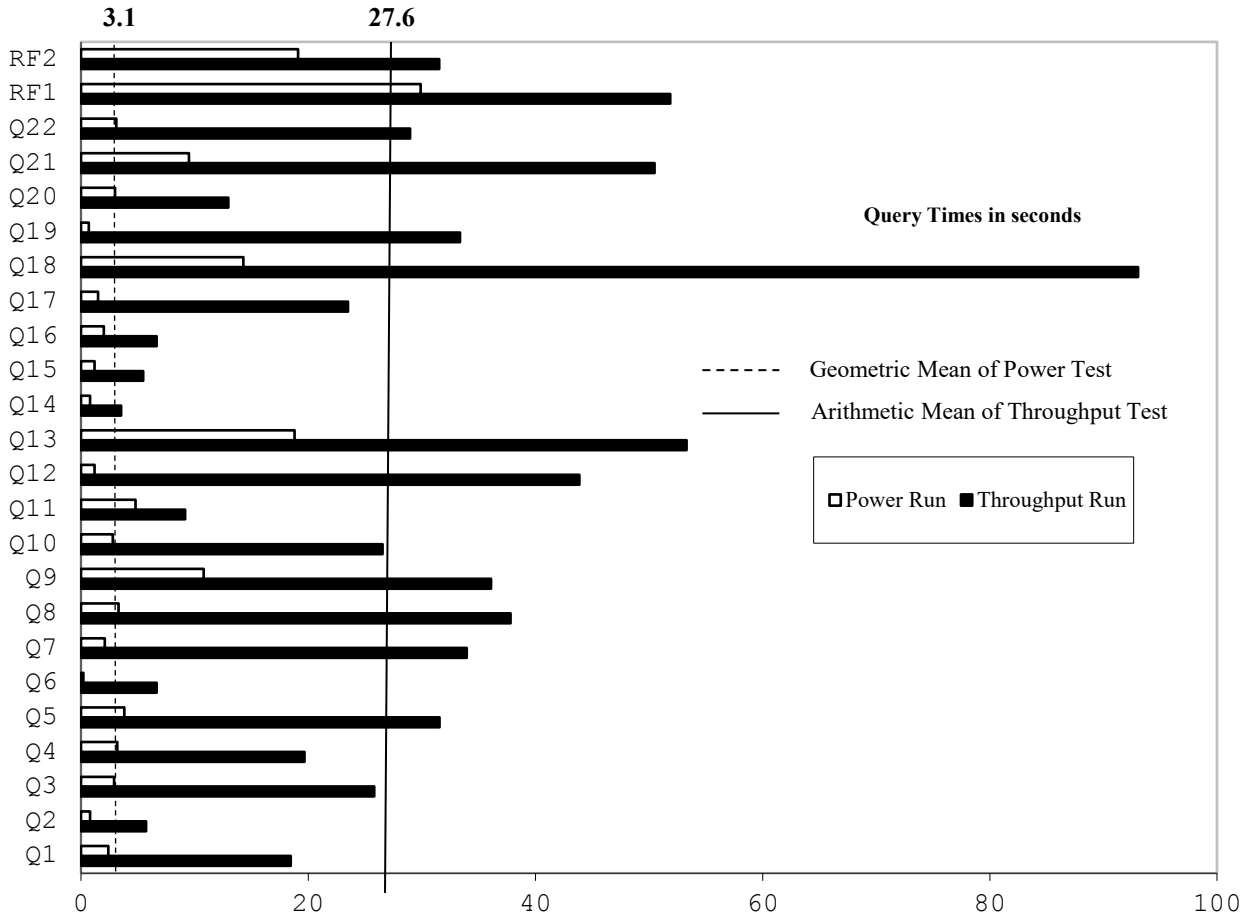
| Database Load Time = 00d 02h 36m 04s | Storage Redundancy Level | |
|---|---|---|
| Load included backup: Y | Base Tables and Auxiliary Data Structures | 0 |
| Total Data Storage / Database Size = 2.70 | DBMS Temporary Space | 0 |
| Memory/Database Size = 51.2% | OS and DBMS Software | 1 |

| System Components | System Total |
|---|---|
| Nodes: | 1 |
| Intel(R) Xeon(R) Platinum 8180 @ 2.50GHz: | 2 |
| Cores/Threads: | 56/112 |
| Memory: | 512GB |
| Network Interfaces (10 Gbps): | 1 |
| Persistent Memory Capacity | 1024 GB (2 x 282GB, 2 x 102GB, 1 x unused 256GB) |
| Persistent Memory Devices | 5 |
| 400 GB SAS SSDs | 2 |
| 1TB SATA HDD | 1 |
| Total Storage: | 2,700.64 GB |

**Hewlett Packard Enterprise**

| Description | Price Key | Part Number | Unit Price | Qty | Extended Price | 3 Yr Maint Price |
|---|---|---|---|---|---|---|
| **Server Hardware** | | | | | | |
| HPE DL380 Gen10 8SFF CTO Server (Customer to Order) | 1 | 868703-B21 | $2,359 | 1 | $2,359 | |
| HPE DL380 Gen10 Intel® Xeon® Platinum 8180 (2.50GHz/28-core) Kit | 1 | 871619-B21 | $18,089 | 1 | $18,089 | |
| HPE DL380 Gen10 Intel® Xeon®Platinum 8180 (2.50GHz/28-core) FIO Kit | 1 | 871619-L21 | $18,089 | 1 | $18,089 | |
| HPE 3Y FC 24x7 DL380 Gen10 SVC | 1 | H8QP7E | $2,127 | 1 | | $2,127 |
| HPE Eth 10/25Gb 2p 631FLR-SFP28 Adptr | 1 | 817709-B21 | $779 | 1 | $779 | |
| HP 17" FlatPanel Monitor | 1 | GV537A8 | $130 | 1 | $130 | |
| HP PS/2 Keyboard And Mouse Bundle | 1 | RC464AA | $39 | 1 | $39 | |
| HPE Scalable Persistent Memory 1024GB 2 Socket Server SKU | 1 | 876403-B21 | $89,445 | 1 | $89,445 | |
| Note: Persistent Memory Kit Includes 1024GB  persistent memory, 512GB of volatile memory, battery backed power supplies, high performance fan, 4p NVMe riser, NVMe SSDs, and BIOS configuration settings) | | | | | | |
| HPE Universal Rack 11642 1075mm Shock Rack | 1 | H6J66A | $1,699 | 1 | $1,699 | |
| HPE 24A High Voltage Core Only Corded PDU | 1 | 252663-D74 | $259 | 1 | $259 | |
| | | | **Subtotal** | | **$130,888** | **$2,127** |
| **Storage** | | | | | | |
| HPE 400GB SAS 12G MU SFF SC DS SSD | 1 | 872374-B21 | $1.399 | 2 | $2,798 | |
| HPE 400GB SAS 12G MU SFF SC DS SSD (10% Spare) | 1 | 872374-B21 | $1,399 | 2 | $2,798 | |
| HPE 1TB 6G SATA 7.2K rpm SFF (2.5-inch) SC Midline Hard Drive | 1 | 655710-B21 | $499 | 1 | $499 | |
| HPE 1TB 6G SATA 7.2K rpm SFF (2.5-inch) SC Midline Hard Drive (10% spares) | 1 | 655710-B21 | $499 | 2 | $998 | |
| | | | **Subtotal** | | **$7,093** | **$0** |
| **Server Software** | | | | | | |
| SQL Server 2017 Enterprise Edition for Linux (2 core license, 28 cores) | 2 | N/A | $13,472.50 | 28 | $377,230 | included |
| SLES 12 Server 2 Sockets w/ 3Y Subscription 24x7 Support Flx LTU | 1 | M6K28A | $3,509.00 | 1 | $3,509 | included |
| Microsoft Problem Resolution Services | 2 | N/A | $259.00 | 1 | | $259 |
| | | | **Subtotal** | | **$380,739** | **$259** |

| Price Key: | | | |
|---|---|---|---|
| 1 - Hewlett Packard Enterprise | **Total Extended Price** | **$518,720** | **$2,386** |
| 2 - Microsoft Corportation | **Total Discounts** | **$48,293** | **$744** |

Audited by Francois Raab of InfoSizing  (www.sizing.com)

| **Grand Total** | **$470,428** | **$1,642** |
|---|---|---|

All discounts are based on US list prices and for similar quantities and configurations. A 35% discount was based on the overall specific components pricing from vendor 1 in this single quotation. Discounts for similarly sized configurations will be similar to those quoted here, but may vary based on the components in the configuration.

| | |
|---|---|
| 3 year cost of ownership USD: | $472,069 |
| QphH @ 1000GB: | 1,009,065.5 |
| $ USD/QphH @ 1000GB | $0.47 |

Sales contact: HPE WW Headquarters, 3000 Hanover St., Palo Alto, CA 94304-1185  (855) 472-5233 / (800) 786-7967 / (888) 269-4073 (US)

Microsoft Corporation, One Microsoft Way, Redmond, WA 98052-6399  (425) 882 8080

Prices used in TPC benchmarks reflect the 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 that the stated prices are not available according to these terms, please inform at pricing@tpc.org. Thank you.

| | HPE ProLiant DL380 Gen10 | TPC-H Rev. 2.17.3 TPC Pricing Rev. 2.1.1 |
|---|---|---|
| Hewlett Packard Enterprise | | Report Date: November 17, 2017 |

# Numerical Quantities

## Measurement Results

| | |
|---|---|
| Database Scale Factor | 1,000 |
| Total Data Storage / Database Size | 2.70 |
| Percentage Memory / Database Size | 51.2% |
| Start of Database Load | 2017-11-11 05:23:05 |
| End of Database Load | 2017-11-11 08:27:56 |
| Database Load Time | 00d 02h 36m 04s |
| Query Streams for Throughput Test | 7 |
| TPC-H Power | 1,177,263.0 |
| TPC-H Throughput | 864,898.6 |
| TPC-H Composite Query-per-Hour (QphH@1000GB) | 1,009,065.5 |
| Total System Price over 3 Years ($ USD) | $472,069 |
| TPC-H Price/Performance Metric ($ USD / QphH@1000GB) | $0.47 |

## Measurement Interval

| | |
|---|---|
| Measurement Interval in Throughput Test | 641 seconds |

## Duration of Stream Execution

| Power Run | Seed | Query Start Time Query End Time | Duration (sec) | RF1 Start Time RF1 End Time | RF2 Start Time RF2 End Time |
|---|---|---|---|---|---|
| | 1111082756 | 2017-11-11 08:55:06 2017-11-11 08:56:40 | 94 | 2017-11-11 08:54:36 2017-11-11 08:55:06 | 2017-11-11 08:56:40 2017-11-11 08:56:59 |
| **Throughput Stream** | **Seed** | **Query Start Time** **Query End Time** | **Duration (sec)** | **RF1 Start Time** **RF1 End Time** | **RF2 Start Time** **RF2 End Time** |
| 1 | 1111082757 | 2017-11-11 08:56:58 2017-11-11 09:06:54 | 596 | 2017-11-11 08:56:58 2017-11-11 08:57:53 | 2017-11-11 08:57:53 2017-11-11 08:58:24 |
| 2 | 1111082758 | 2017-11-11 08:56:58 2017-11-11 09:07:39 | 641 | 2017-11-11 08:58:24 2017-11-11 08:59:17 | 2017-11-11 08:59:17 2017-11-11 08:59:51 |
| 3 | 1111082759 | 2017-11-11 08:56:58 2017-11-11 09:06:06 | 548 | 2017-11-11 08:59:51 2017-11-11 09:00:45 | 2017-11-11 09:00:45 2017-11-11 09:01:19 |
| 4 | 1111082760 | 2017-11-11 08:56:58 2017-11-11 09:06:57 | 599 | 2017-11-11 09:01:19 2017-11-11 09:02:11 | 2017-11-11 09:02:11 2017-11-11 09:02:44 |
| 5 | 1111082761 | 2017-11-11 08:56:58 2017-11-11 09:07:31 | 633 | 2017-11-11 09:02:45 2017-11-11 09:03:35 | 2017-11-11 09:03:35 2017-11-11 09:04:03 |
| 6 | 1111082762 | 2017-11-11 08:56:59 2017-11-11 09:07:25 | 626 | 2017-11-11 09:04:03 2017-11-11 09:04:51 | 2017-11-11 09:04:51 2017-11-11 09:05:21 |
| 7 | 1111082763 | 2017-11-11 08:56:59 2017-11-11 09:07:09 | 610 | 2017-11-11 09:05:21 2017-11-11 09:06:13 | 2017-11-11 09:06:13 2017-11-11 09:06:45 |

**TPC-H Timing Intervals (in seconds):**

| Query | Stream 0 | Stream 1 | Stream 2 | Stream 3 | Stream 4 | Stream 5 | Stream 6 | Stream 7 | Min Qi | Max Qi | Avg. Qi |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Q1 | 2.4 | 13.8 | 15.2 | 17.7 | 32.0 | 19.8 | 27.2 | 3.5 | 2.4 | 32.0 | 16.5 |
| Q2 | 0.8 | 11.5 | 4.9 | 4.3 | 4.2 | 4.8 | 4.9 | 5.5 | 0.8 | 11.5 | 5.1 |
| Q3 | 2.9 | 23.9 | 4.3 | 17.5 | 12.1 | 50.7 | 31.3 | 40.8 | 2.9 | 50.7 | 22.9 |
| Q4 | 3.2 | 7.4 | 8.3 | 6.1 | 43.3 | 20.5 | 13.4 | 38.7 | 3.2 | 43.3 | 17.6 |
| Q5 | 3.8 | 29.0 | 26.5 | 9.5 | 26.2 | 43.9 | 30.5 | 55.4 | 3.8 | 55.4 | 28.1 |
| Q6 | 0.2 | 4.6 | 2.7 | 6.1 | 12.8 | 6.8 | 6.3 | 7.3 | 0.2 | 12.8 | 5.9 |
| Q7 | 2.1 | 21.4 | 17.5 | 41.9 | 28.9 | 39.4 | 28.8 | 59.8 | 2.1 | 59.8 | 30.0 |
| Q8 | 3.3 | 90.7 | 28.0 | 29.6 | 9.8 | 12.5 | 45.4 | 48.6 | 3.3 | 90.7 | 33.5 |
| Q9 | 10.8 | 51.4 | 16.5 | 37.1 | 36.7 | 20.5 | 49.5 | 41.0 | 10.8 | 51.4 | 32.9 |
| Q10 | 2.8 | 9.2 | 42.2 | 18.2 | 45.3 | 11.8 | 38.9 | 20.2 | 2.8 | 45.3 | 23.6 |
| Q11 | 4.8 | 7.8 | 6.0 | 14.5 | 15.1 | 6.0 | 7.0 | 7.8 | 4.8 | 15.1 | 8.6 |
| Q12 | 1.2 | 34.6 | 84.3 | 51.8 | 13.3 | 12.6 | 101.6 | 8.8 | 1.2 | 101.6 | 38.5 |
| Q13 | 18.8 | 46.3 | 68.3 | 57.5 | 31.5 | 66.3 | 52.8 | 50.5 | 18.8 | 68.3 | 49.0 |
| Q14 | 0.8 | 5.5 | 1.6 | 3.6 | 3.7 | 3.7 | 4.8 | 1.9 | 0.8 | 5.5 | 3.2 |
| Q15 | 1.2 | 7.4 | 5.4 | 2.9 | 8.0 | 4.3 | 8.2 | 2.2 | 1.2 | 8.2 | 5.0 |
| Q16 | 2.0 | 5.8 | 8.8 | 6.5 | 5.3 | 10.3 | 5.0 | 4.9 | 2.0 | 10.3 | 6.1 |
| Q17 | 1.5 | 28.5 | 30.0 | 21.7 | 28.7 | 20.3 | 23.4 | 11.9 | 1.5 | 30.0 | 20.8 |
| Q18 | 14.3 | 67.6 | 145.7 | 57.6 | 111.0 | 120.5 | 77.6 | 71.4 | 14.3 | 145.7 | 83.2 |
| Q19 | 0.7 | 34.2 | 42.9 | 44.1 | 34.1 | 27.4 | 23.1 | 27.7 | 0.7 | 44.1 | 29.3 |
| Q20 | 3.0 | 20.6 | 8.5 | 19.0 | 13.6 | 6.9 | 8.8 | 13.4 | 3.0 | 20.6 | 11.7 |
| Q21 | 9.5 | 54.4 | 22.9 | 41.6 | 69.4 | 73.2 | 26.3 | 65.7 | 9.5 | 73.2 | 45.4 |
| Q22 | 3.1 | 19.3 | 48.9 | 38.3 | 13.0 | 49.9 | 10.6 | 22.8 | 3.1 | 49.9 | 25.7 |
| RF1 | 29.9 | 53.8 | 53.1 | 54.1 | 52.2 | 49.9 | 47.9 | 52.1 | 29.9 | 54.1 | 49.1 |
| RF2 | 19.1 | 30.7 | 33.7 | 33.5 | 33.2 | 28.4 | 29.2 | 32.0 | 19.1 | 33.7 | 30.0 |

# 0 General Items

## 0.1 Test Sponsor

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

This benchmark was sponsored by Hewlett Packard Enterprise. The benchmark was developed and engineered by Hewlett Packard Enterprise. Testing took place at HPE facilities in Houston, TX.

## 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*

*This requirement can be satisfied by providing a full list of all parameters and options, as long as all those which have been modified from their default values have been clearly identified and these parameters and options are only set once.*

The supporting files archive contains a list of all database parameters and operating system parameters.

## 0.3 Configuration Items

*Diagrams of both measured and priced configurations must be provided, accompanied by a description of the differences. This includes, but is not limited to:*
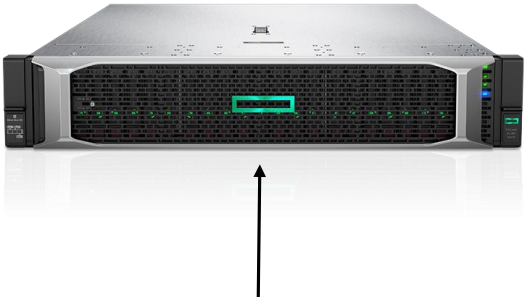
- *Number and type of processors*
- *Size of allocated memory, and any specific mapping/partitioning of memory unique to the test.*
- *Number and type of disk units (and controllers, if applicable).*
- *Number of channels or bus connections to disk units, including their protocol type.*
- *Number of LAN (e.g. Ethernet) Connections, including routers, workstations, terminals, etc., that were physically used in the test or are incorporated into the pricing structure.*
- *Type and the run-time execution location of software components (e.g., DBMS, query processing tools /languages, middle-ware components, software drivers, etc.).*

**The System Under Test (SUT), an HPE ProLiant DL380 Gen10, depicted in Figure 0.1, consisted of :**

| HPE ProLiant DL380 Gen 10 | |
|---|---|
| 2 Xeon Platinum 8180 (2.50GHz/28-core) | |
| **HPE Scalable Persistent Memory 1024GB 2 Socket Server kit** (Includes 24 x 64GB DIMMs : 512GB volatile + 1024GB non-volatile) | |
| **512GB Main Memory (volatile)** | **A total of 1536GB** |
| **1024GB Persistent Memory (non-volatile)** | |
| 1 x 282GB PMEM device from Socket0 | Data files/Tempdb files |
| 1 x 102GB PMEM device from Socket0 | Transaction logs - mirror 1 (RAID1) |
| 1 x 282GB PMEM device from Socket1 | Data files/Tempdb files |
| 1 x 102GB PMEM device from Socket1 | Transaction logs - mirror 2 (RAID1) |
| 1 x 256GB Spanned PMEM device | Unused |
| **1 x P408i-a on board controller** | |
| 2 x 400GB SAS SSD in RAID1 | OS Disk |
| 1 x 1TB SATA HDD | Database Backup |

**Note:** This system is the same system used for both the measured and priced configurations.

Figure 0.1 Benchmark and priced configuration for HPE ProLiant DL380 Gen10

# 1.0 Clause 1: Logical Database Design

## 1.1 Table Definitions

*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 table definitions and the program used to load the database.

## 1.2 Physical Organization of Database

*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 column reordering was used.
The Supporting Files Archive contains the DDL for the index definitions.

## 1.3 Horizontal Partitioning

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

Horizontal partitioning is used on LINEITEM and ORDERS tables and the partitioning columns are L_SHIPDATE and O_ORDERDATE. The partition granularity is by week.

## 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.

# 2.0 Clause 2: Queries and Refresh Functions - Related Items

## 2.1 Query Language

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

T-SQL was the query language used.

## 2.2 Random Number Generation

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

DBGEN version 2.17.0 and QGEN version 2.17.0 were used to generate all database populations.

## 2.3 Substitution Parameters Generation

*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.*

The TPC source based QGEN version 2.17.0 was used to generate the substitution parameters

## 2.4 Query Text and Output Data from 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 definitions 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 query text and query output. The following modifications were used:

o The "dateadd" function is used to perform date arithmetic in Q1, Q4, Q5, Q6, Q10, Q12, Q14 , Q15 and Q20.
o The "datepart" function is used to extract part of a date ("YY") in Q7, Q8 and Q9.
o The "top" function is used to restrict the number of output rows in Q2, Q3, Q10, Q18 and Q21
o The "count_big" function is used in place of "count" in Q1

## 2.5 Query Substitution Parameters and Seeds Used

*All the query substitution parameters used during the performance test 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 used.

## 2.6 Isolation Level

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

The queries and transactions were run with isolation level Read Committed.

## 2.7 Refresh Functions

*The details of how the refresh functions were implemented must be disclosed*

The Supporting Files Archive contains the source code for the refresh functions.

# 3.0 Clause 3: Database System Properties

## 3.1 Atomicity Requirements

*The results of the ACID tests must be disclosed along with a description of how the ACID requirements were met. This includes disclosing the code written to implement the ACID Transaction and Query.*

All ACID tests were conducted according to specification. The steps performed are outlined below.

### 3.1.1 Atomicity of the Completed Transactions

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

The following steps were performed to verify the Atomicity of completed transactions:
1. The total price from the ORDER 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 ORDER 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.

### 3.1.2 Atomicity of Aborted Transactions

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

The following steps were performed to verify the Atomicity of the aborted ACID transaction:
1. The total price from the ORDER 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 ORDER table and the extended price from the LINEITEM table were retrieved for the same order key used in steps 1 and 2. It was verified that the appropriate rows had not been changed.

## 3.2 Consistency Requirements

*Consistency is the property of the application that requires any execution of transactions to take the database from one consistent state to another. A consistent state for the TPC-H database is defined to exist when:*

$$O\_TOTALPRICE = SUM(trunc(trunc((L\_EXTENDEDPRICE - L\_DISCOUNT) * (1 + L\_TAX))))$$

*for each ORDER and LINEITEM defined by (O_ORDERKEY = L_ORDERKEY)*

### 3.2.1 Consistency Tests
*Verify that ORDER and LINEITEM tables are initially consistent as defined in Clause 3.3.2.1, based upon a random sample of at least 10 distinct values of O_ORDERKEY.*

Consistency was tested as part of the durability tests.

## 3.3 Isolation Requirements

*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.*

### 3.3.1 Isolation Test 1 - 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)*

The following steps were performed to satisfy the test of isolation for a read-only and a read-write committed transaction:
1. An ACID Transaction was started for a randomly selected O_KEY, L_KEY and DELTA. The ACID Transaction was suspended prior to Commit.
2. An ACID query was started for the same O_KEY used in step 1. The ACID query blocked and did not see any uncommitted changes made by the ACID Transaction.
3. The ACID Transaction was resumed and committed. The ACID query completed. It returned the data as committed by the ACID Transaction.

### 3.3.2 Isolation Test 2 - 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.*

The following steps were performed to satisfy the test of isolation for read-only and a rolled back read-write transaction:
1. An ACID transaction was started for a randomly selected O_KEY, L_KEY and DELTA. The ACID Transaction was suspended prior to Rollback.
2. An ACID query was started for the same O_KEY used in step 1. The ACID query did not see any uncommitted changes made by the ACID Transaction.
3. The ACID Transaction was ROLLED BACK.
4. The ACID query completed.

### 3.3.3 Isolation Test 3 - Write-Write Conflict with Commit
*Demonstrate isolation for the write-write conflict of two update transactions when the first transaction is committed.*

The following steps were performed to verify isolation of two update transactions:
1. An ACID Transaction T1 was started for a randomly selected O_KEY, L_KEY and DELTA. The ACID transaction T1 was suspended prior to Commit.
2. Another ACID Transaction T2 was started using the same O_KEY and L_KEY and a randomly selected DELTA.
3. T2 waited.
4. The ACID transaction T1 was allowed to Commit and T2 completed.
5. It was verified that: T2.L_EXTENDEDPRICE = T1.L_EXTENDEDPRICE +(DELTA1*(T1.L_EXTENDEDPRICE/T1.L_QUANTITY))

### 3.3.4 Isolation Test 4 - Write-Write Conflict with Rollback
*Demonstrate isolation for the write-write conflict of two update transactions when the first transaction is rolled back.*

The following steps were performed to verify the isolation of two update transactions after the first one is rolled back:
1. An ACID Transaction T1 was started for a randomly selected O_KEY, L_KEY and DELTA. The ACID Transaction T1 was suspended prior to Rollback.
2. Another ACID Transaction T2 was started using the same O_KEY and L_KEY used in step 1 and a randomly selected DELTA.
3. T2 waited.
4. T1 was allowed to ROLLBACK and T2 completed.
5. It was verified that T2.L_EXTENDEDPRICE = T1.L_EXTENDEDPRICE.

### 3.3.5 Isolation Test 5 – Concurrent Read and Write Transactions on Different Tables

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

The following steps were performed:
1. An ACID Transaction T1 for a randomly selected O_KEY, L_KEY and DELTA. The ACID Transaction T1 was suspended prior to Commit.
2. Another ACID Transaction T2 was started using random values for PS_PARTKEY and PS_SUPPKEY.
3. T2 completed.
4. T1 completed and the appropriate rows in the ORDER, LINEITEM and HISTORY tables were changed.

### 3.3.6 Isolation Test 6 – Update Transactions During Continuous Read-Only Query Stream

*Demonstrate 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.*

The following steps were performed:
1. An ACID Transaction T1 was started, executing a modified Q1 against the qualification database. The substitution parameter was chosen from the interval [0..2159] so that the query ran for a sufficient amount of time.
2. Before T1 completed, an ACID Transaction T2 was started using randomly selected values of O_KEY, L_KEY and DELTA.
3. T2 completed before T1 completed.
4. It was verified that the appropriate rows in the ORDER, LINEITEM and HISTORY tables were changed.

## 3.4 Durability Requirements

*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 3.5.2.*

### 3.4.1 Permanent Unrecoverable Failure of Any Durable Medium and Loss of System Power
*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*

Three tests were completed in this section.
1st test was to simulate loss of a mirror copy of log device
2nd test was to simulate loss of device holding datafiles
3rd test was to simulate a power loss

Each of these tests were performed against the qualification database. The qualification database is identical to the test database in virtually every regard except size.

Log Device mirror loss test.
1. Eight streams of ACID transactions were started. Each stream executed a minimum of 100 transactions.
2. While the test was running, one of the device from the log's RAID1 array was failed.
3. The system crashed as an end result of the device failure.
4. The failed device was fixed, the SUT was restarted.
5. The previously failed device was rejoined to the log RAID, mirroring was re-established using data from the surviving device.
6. The counts in the history table and success files were compared and verified, and the consistency of the ORDERS and LINEITEM tables was verified.

Data device loss test
1. The complete database was backed up.
2. Eight streams of ACID transactions were started. Each stream executed a minimum of 100 transactions.
3. While the test was running, one of the devices with data files (Non RAID) was failed.
4. The system crashed as an end result of the device failure.
5. The failed device was fixed, the SUT was restarted.
6. The database log was backed up and the Database was dropped.
7. The previously failed device was formatted (wiping all existing data) and restored back into the configuration.
8. The database was restored.
9. When database restore completed, issued a command to apply the backed up log file.
10. The counts in the history table and success files were compared and verified, and the consistency of the ORDERS and LINEITEM tables was verified.

System Crash test.
1. Eight streams of ACID transactions were started. Each stream executed a minimum of 100 transactions.
2. While the streams of ACID transactions were running the System was powered off by pulling power plugs.
3. When power was restored the system booted and the Database engine was restarted.
4. The database went through a recovery period.
5. Rolled forward, Rolled backward transactions captured by DB ERRORLOG file.
6. Reovery complete.
7. The counts in the history table and success files were compared and verified, and the consistency of the ORDERS and LINEITEM tables was verified.

### 3.4.2 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.*
See section 3.4.1

### 3.4.3 Memory Failure
*Guarantee the database and committed updates are preserved across failure of all or part of memory (loss of contents).*
See section 3.4.1

# 4.0 Clause 4: Scaling and Database Population

## 4.1 Initial Cardinality of Tables

*The cardinality (i.e., 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 4.1 lists the TPC-H Benchmark defined tables and the row count for each table as they existed upon completion of the build.

| TABLE | # of Rows |
|---|---|
| Lineitem | 5,999,989,709 |
| Orders | 1,500,000,000 |
| Partsupp | 800,000,000 |
| Part | 200,000,000 |
| Customer | 150,000,000 |
| Supplier | 10,000,000 |
| Nation | 25 |
| Region | 5 |

Table 4.1 Initial Number of Rows

## 4.2 Distribution of Tables and Logs Across Media

*The distribution of tables and logs across all media must be explicitly described for the tested and priced systems.*

Microsoft SQL Server was configured on an HPE ProLiant DL380 Gen10 with the following configuration:

| HPE Scalable Persistent Memory Configuration | | | | | |
|---|---|---|---|---|---|
| Physical Devvice | OS Device | Mount | Physical Size (in GB) | Available Size (in GB) | 1024GB Persistent Memory (non-volatile) |
| Processor 1 NVDIMM1 | /dev/pmem1 | /mnt/data0 | 282 | 282 | 56 x data files<br>56 x tempdb data files |
| Processor 1 NVDIMM2 | /dev/pmem2 | /mnt/log(M1) | 102 | 102 | 1 x transaction log<br>1 x tempdb transaction log<br>1 x database root file |
| Processor 2 NVDIMM1 | /dev/pmem3 | /mnt/data1 | 282 | 282 | 56 x data files<br>56 x tempdb data files |
| Processor 2 NVDIMM2 | /dev/pmem4 | /mnt/log(M2) | 102 | 102 | Mirror of PMEM2 device |
| Processor 1,2 NVDIMM | /dev/pmem0 | NA | 256 | 256 | Unused |
| **Total Persistent Memory consumed (in GB) : 1024** | | | | | |

| Traditional SATA Disk Configuration | | | | | | |
|---|---|---|---|---|---|---|
| Controller | Device Location | SSA Array/ Logical Drive | RAID Level | Mount Point | Spec Size(GB) | Available Size(GB) |
| Internal SATA Controller | Port:1i Box:2 Bay:1 | Array A/ Logical Drive 1 | RAID1 | OS Mounts | 400 | 372.58 |
| | Port:1i Box:2 Bay:1 | Array A/ Logical Drive 1 | | | 400 | 372.58 |
| | Port:1i Box:2 Bay:1 | Array B/ Logical Drive 1 | RAID0 | /var/opt/mssql/data/backup | 1000 | 931.48 |
| **Total Disk Storage consumed (in GB) : 1676.64** | | | | | | |

Persistent Memory      : 1024 GB
SATA Disk Storage    : 1676.64 GB
**Grand Total          : 2700.64 GB**

## 4.3 Mapping of Database Partitions/Replications

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

Horizontal partitioning is used on LINEITEM and ORDERS tables and the partitioning columns are L_SHIPDATE and O_ORDERDATE. The partition granularity is by week.

The database partitions are evenly distributed across 2 HPE Scalable Persistent Memory devices.

## 4.4     Implementation of RAID

*Implementations 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 used must be disclosed for each device.*

RAID 0 was used for database file groups, TempDB and backup drives. RAID 1 for the database recovery logs and tempDB recovery logs.

## 4.5     DBGEN Modifications

*The version number, release number, modification number, and patch level of DBGEN must be disclosed. 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.*

DBGEN version 2.17.0 was used, no modifications were made.

## 4.6     Database Load time

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

The database load time was 00d 02h 36m 04s

| Database Load Time | |
|---|---|
| | |
| Load Start | 11/11/2017 05:23:05 |
| Load End | 11/11/2017 08:27:56 |
| Load Delay | 00d 00h 28m 47s |
| Load Time | 00d 02h 36m 04s |
| | |

## 4.7    Data Storage Ratio

*The data storage ratio must be disclosed. It is computed by dividing the total data storage of the priced configuration (expressed in GB) by the size chosen for the test database as defined in 4.1.3.1. The ratio must be reported to the nearest 1/100ᵗʰ, rounded up.*

| Device | Physical Size (in GB) | Available Size (in GB) |
|---|---|---|
| /dev/pmem1 | 282 | 282 |
| /dev/pmem2 | 102 | 102 |
| /dev/pmem3 | 282 | 282 |
| /dev/pmem4 | 102 | 102 |
| /dev/pmem0 | 256 | 256 |
| Port:1i Box:2 Bay:1 (SAS SSD) | 400 | 372.58 |
| Port:1i Box:2 Bay:1 (SAS SSD) | 400 | 372.58 |
| Port:1i Box:2 Bay:1 (SATA HDD) | 1000 | 931.48 |
| **Total Storage in GB** | | **2700.64** |

Size of test database: 1000GB          Data Storage Ratio: 2.70

## 4.8 Database Load Mechanism Details and Illustration

*The details of the database load must be disclosed, including a block diagram illustrating the overall process. Disclosure of the load procedure includes all steps, scripts, input and configuration files required to completely reproduce the test and qualification databases.*

Flat files for each of the tables were created using DBGEN. The tables were loaded as depicted in Figure 4.8. All steps, scripts and configuration files are included in the Supporting Files.
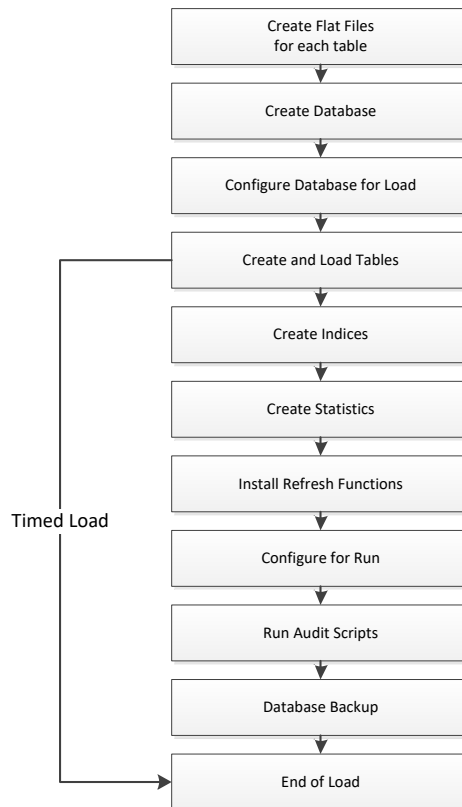
## 4.9 Qualification Database Configuration

*The details of the database load must be disclosed, including a block diagram illustrating the overall process. Disclosure of the load procedure includes all steps, scripts, input and configuration files required to completely reproduce the test and qualification databases.*

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 8.3.6.10, must be disclosed.*

The memory to database size percentage is 51.20%

| Memory/Database Size | | |
|---|---|---|
| **Physical Mem GB** | **Scale Factor** | **Percentage** |
| | | |
| **512GB** | **1000** | **51.20%** |
| | | |

# 5.0 Clause 5: Performance Metrics and Execution Rules Related Items

## 5.1 Steps after the Load Test

*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 including listings of scripts or command logs.*

The queries were generated using QGen with the seed collected at the end of the load test.
There was a 00 hr 11min 57sec delay between End of Load and start of first performance test.
The system sat idle, without any interruption during this time frame.

## 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. Execute RF1 from the update stream
2. Execute Power queries from the query stream
3. Execute RF2 from the update stream

## 5.3 Timing Intervals for Each Query and Refresh Function

*The timing intervals (see Clause 5.3.6) for each query of the measured set and for both refresh functions must be reported for the power test.*

The timing intervals for each query and both refresh functions are given in the Numerical Quantities Summary earlier in this document on page vii.

## 5.4 Number of Streams for The Throughput Test

*The number of execution streams used for the throughput test must be disclosed.*

7 query streams were used for the Throughput Test. Each stream running all 22 queries.
1 stream was used for RF.

## 5.5 Start and End Date/Times for Each Query Stream

*The start time and finish time for each query execution stream must be reported for the throughput test.*

The Numerical Quantities Summary on page vii contains the start and stop times for the query execution streams run on the system reported.

## 5.6 Total Elapsed Time for the Measurement Interval

*The total elapsed time of the measurement interval(see Clause 5.3.5) must be reported for the throughput test.*

The Numerical Quantities Summary on page vii contains the timing intervals for the throughput test run on the system reported.

## 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.*

The Numerical Quantities Summary on page vii contains the start and finish times for the refresh functions of each stream.

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

*The timing intervals (see Clause 5.3.6) for each query of each stream and for each update function must be reported for the throughput test.*

The timing intervals for each query and each update function are given in the Numerical Quantities Summary earlier in this document on page vii.

## 5.9 Performance Metrics

*The computed performance metrics, related numerical quantities and the price performance metric must be reported.*

The Numerical Quantities Summary contains the performance metrics, related numerical quantities, and the price/performance metric for the system reported.

## 5.10 The Performance Metric and Numerical Quantities from Both Runs

*The performance metric (QphH@Size) and the numerical quantities (TPC-H Power@Size and TPC-H Throughput@ Size) from both of the runs must be disclosed*

| Run ID | QppH@1000GB | QthH@1000GB | QphH@1000GB |
|--------|-------------|-------------|-------------|
| Run 1 | 1,217,913.3 | 904,404.6 | 1,049,517.2 |
| Run 2 | 1,177,263.0 | 864,898.6 | 1,009,065.5 |

## 5.11 System Activity Between Tests

*Any activity on the SUT that takes place between the conclusion of Run1 and the beginning of Run2 must be disclosed.*

Less than 00 min 36 sec of idle time between Run1 and Run2. The Database log confirmed that no database activity took place during that time.

## 5.12 Documentation to satisfy Clause 5.2.7

*All documentation necessary to satisfy Clause 5.2.7 must be made available upon request*

The supporting files archive contains the documentation

## 5.13 Query Validation Output

*The output of the Query Output Validation Test must reported in the supporting files archive*

The supporting files archive contains the documentation

# 6.0 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 TPC-H benchmark was implemented using a Microsoft tool called StepMaster. StepMaster is a general purpose test tool which can drive ODBC and shell commands. Within StepMaster, the user designs a workspace corresponding to the sequence of operations (or steps) to be executed. When the workspace is executed, StepMaster records information about the run into a database as well as a log file for later analysis.

StepMaster provides a mechanism for creating parallel streams of execution. This is used in the throughput tests to drive the query and refresh streams. Each step is timed using a millisecond resolution timer. A timestamp T1 is taken before beginning the operation and a timestamp T2 is taken after completing the operation. These times are recorded in a database as well as a log file for later analysis.

Two types of ODBC connections are supported. A dynamic connection is used to execute a single operation and is closed when the operation finishes. A static connection is held open until the run completes and may be used to execute more than one step. A connection (either static or dynamic) can only have one outstanding operation at any time.

In TPC-H, static connections are used for the query streams in the power and throughput tests. StepMaster reads an Access database to determine the sequence of steps to execute. These commands are represented as the Implementation Specific Layer. StepMaster records its execution history, including all timings, in the Access database. Additionally, StepMaster writes a textual log file of execution for each run.

The stream refresh functions were executed using multiple batch scripts. The initial script is invoked by StepMaster, subsequent scripts are called from within the scripts.

The source for StepMaster and the RF Scripts is disclosed in the supported file archive.

## 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 supplied, including any related source code or scripts. This description should allow an independent reconstruction of the implementation-specific layer.*

See Section 6.1 for details.

## 6.3 Profile-Directed Optimization

*If profile-directed optimization as described in Clause 5.2.9 is used, such use must be disclosed.*

Profile-directed optimization was not used.

# 7.0 Clause 7: Pricing Related Items

## 7.1 Hardware and Software Used

*A detailed list of hardware and software used in the priced system must be reported. Each item must have a vendor part number, description, and release/revision level, and indicate 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.*

The pricing summary sheet is given on page *v* in the Executive Summary at the front of this report. The source for all prices is indicated.

Server and all storage components are available 28th Feburary 2018.

The pricing and availability of the Microsoft software used is given in a quote from Microsoft, which is included in this report in Appendix A.

## 7.2 Three-Year Cost of System Configuration

*The total 3-year price of the entire configuration must be reported, including: hardware, software, and maintenance charges. Separate component pricing is required.*

The pricing summary sheet on page v in the front of this report contains all details.

## 7.3 Availability Dates

*The committed delivery date for general availability (availability date) of products used in the priced calculations must be reported. When the priced system includes products with different availability dates, the single availability date reported on the first page of the executive summary must be the date by which all components are committed to being available. The full disclosure report must report availability dates individually for at least each of the categories for which a pricing subtotal must be provided (see Clause 7.3.1.4). All availability dates, whether for individual components or for the SUT as a whole, must be disclosed to a precision of 1 day, but the precise format is left to the test sponsor.*

| Category | Available |
| --- | --- |
| Server Hardware | 28th Feburary 2018 |
| Storage | Now (date of publication) |
| Server Software | Now (date of publication) |
| SQL Server 2017 | Now (date of publication) |

# 8.0 Clause 8: Support Files Index Table

## 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.*

| Clause | Description | Archive File | Pathname |
|---|---|---|---|
| Clause 1 | DB Creation/Load Scripts – QUAL | benchmark_scripts.zip | SupportingFiles/Clause1/DB_Creation_QualDB |
| | DB Creation/Load Scripts – TEST | benchmark_scripts.zip | SupportingFiles/Clause1/DB_Creation_QualDB |
| | OS_DB_Settings | benchmark_scripts.zip | SupportingFiles/Clause1/OS_DB_Settings |
| Clause 2 | Queries and Output | benchmark_scripts.zip | SupportingFiles/Clause2/QueriesandOutput |
| | QueryParams_Seeds | benchmark_scripts.zip | SupportingFiles/Clause2/QueryParams_Seeds |
| | Refresh Functions | benchmark_scripts.zip | SupportingFiles/Clause2/RefreshFunctions |
| Clause 3 | ACID Test scripts | benchmark_scripts.zip | SupportingFiles/Clause3/ACID |
| | ACID Test Results | benchmark_scripts.zip | SupportingFiles/Clause3/ACID |
| Clause 4 | DB Load Scripts | benchmark_scripts.zip | SupportingFiles/Clause4/DBLoadScripts |
| | Qualification Test Results | benchmark_scripts.zip | SupportingFiles/Clause4/QualResults |
| | Misc Data | benchmark_scripts.zip | SupportingFiles/Clause4/Clause4.docx |
| Clause 5 | Query Output Run 1 | Run1Run2Results.zip | SupportingFiles/Clause5/QueryOutputRun1 |
| | Query Output Run 2 | Run1Run2Results.zip | SupportingFiles/Clause5/QueryOutputRun2 |
| | PDO, EndOfLoad, more | benchmark_scripts.zip | SupportingFiles/Clause5/Clause5.docx |
| | Refresh Function Start/Stop | benchmark_scripts.zip | SupportingFiles/Clause5/RF_StartStop.txt |
| Clause 6 | Implementation Specific layer source code and Driver | benchmark_scripts.zip | SupportingFiles/Clause6/Clause6.docx |
| Clause 7 | No files required to be included for Clause 7. | n/a | n/a |
| Clause 8 | No files required to be included for Clause 8. | n/a | n/a |

# 9.0 Clause 9: Audit Related Items

## 9.1 Auditors' 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 Francois Raab of InfoSizing, a certified TPC-H auditor. Further information regarding the audit process may be obtained from:

Francois Raab
InfoSizing (www.sizing.com)
20 Kreg Ln.
Manitou Springs, CO 80829
(719) 473-7555

TPC Benchmark™ H Full Disclosure Report and other information can be downloaded from the Transaction Processing Performance Council web site at www.tpc.org.

Benchmark sponsor:        Rajesh Tadakamadla
                                   Hewlett-Packard Enterprise
                                   11445 Compaq Center Dr. West
                                   Houston, TX  77070

November 17, 2017

I verified the TPC Benchmark H (TPC-H$^{TM}$ v2.17.3) performance of the following configuration:
Platform:                  HPE ProLiant DL380 Gen10
Operating System:      SUSE Linux Enterprise Server 12 SP3
Database Manager:      Microsoft SQL Server 2017 Enterprise Edition
Other Software:          n/a

The results were:

| **Performance Metric** | **1,009,065.5 QphH@1,000GB** |
|---|---|
| TPC-H Power | 1,177,263.0 |
| TPC-H Throughput | 864,898.6 |
| Database Load Time | 02h 36m 04s |

| **Server** | **HPE ProLiant DL380 Gen10** | | |
|---|---|---|---|
| CPUs | 2 x Intel® Xeon® Platinum 8180 (2.50GHz, 28-core) | | |
| Memory | 512 GB | | |
| Storage | *Qty* | *Size* | *Type* |
| | 1 | 1,024 GB | Scalable Persistent Memory |
| | 2 | 400 GB | SAS SFF SSD |
| | 1 | 1 TB | SATA 7.2K SFF HDD |

In my opinion, these performance results were produced in compliance with the TPC requirements for the benchmark.

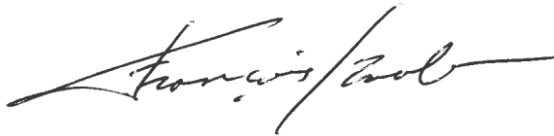The following verification items were given special attention:
•      The database records were defined with the proper layout and size

•      The database population was generated using DBGen

•      The database was properly scaled to 1,000GB and populated accordingly

•      The compliance of the database auxiliary data structures was verified

•      The database load time was correctly measured and reported

- The required ACID properties were verified and met

- The query input variables were generated by QGen

- The query text was produced using minor modifications and no query variant

- The execution of the queries against the SF1 database produced compliant answers

- A compliant implementation specific layer was used to drive the tests

- The throughput tests involved 8 query streams

- The ratio between the longest and the shortest query was such that no query timings were adjusted

- The execution times for queries and refresh functions were correctly measured and reported

- The repeatability of the measured results was verified

- The system pricing was verified for major components and maintenance

- The major pages from the FDR were verified for accuracy


Additional Audit Notes:

None.

Respectfully Yours,

François Raab, TPC Certified Auditor

# Appendix A: Price Quotes

Microsoft Corporation
One Microsoft Way
Redmond, WA   98052-6399

Tel 425 882 8080
Fax 425 936 7329
http://www.microsoft.com/

*Microsoft*
November 17, 2017

Hewlett-Packard Enterprise
Rajesh Tadakamadla
Survey 192, Whitefield Road
Mahadevapura Port
Bengaluru, India 560048

Here is the information you requested regarding pricing for Microsoft products to be used in conjunction with your TPC-H benchmark testing.

All pricing shown is in US Dollars ($).

| Description | Unit Price | Quantity | Price |
|---|---|---|---|
| **Database Management System** | | | |
| **SQL Server 2017 Enterprise Edition** *2 Core License* *Open Program - Level C* Unit Price reflects a 6% discount from the retail unit price of $14,256.00 | $13,472.50 | 28 | $377,230.00 |
| **Support** | | | |
| **Microsoft Problem Resolution Services** *Professional Support* *(1 Incident).* | $259.00 | 1 | $259.00 |

All Microsoft software components are currently orderable and available. A list Of Microsoft's resellers can be found in the Microsoft Product Information Center at http://www.microsoft.com/products/info/render.aspx?view=22&type=how

Defect support is included in the purchase price. Additional support is available from Microsoft PSS on an incident by incident basis at $259 Call.

This quote is valid for the next 90 days.

Reference ID:  TPCE_qhtplyl298441ZCFWZW9unvR2X7G4Df8k9Q_2017_hrt.doc