Hewlett Packard Enterprise

Hewlett-Packard Enterprise

TPC Benchmark™ H
Full Disclosure Report
for
HPE ProLiant DL560 Gen11
using
Microsoft® SQL Server 2022 Enterprise Edition
and
Windows Server 2022

First Edition
Aug 2023

Printed in the United States, Aug 2023

Abstract

Overview

This report documents the methodology and results of the TPC Benchmark™ H test conducted on the HPE ProLiant DL560 Gen11 using Microsoft SQL Server 2022 Enterprise Edition in conformance with the requirements of the TPC Benchmark™ H Standard Specification, Revision 3.0.1. The operating system used for the benchmark was Windows Server 2022.

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 DL560 Gen11.

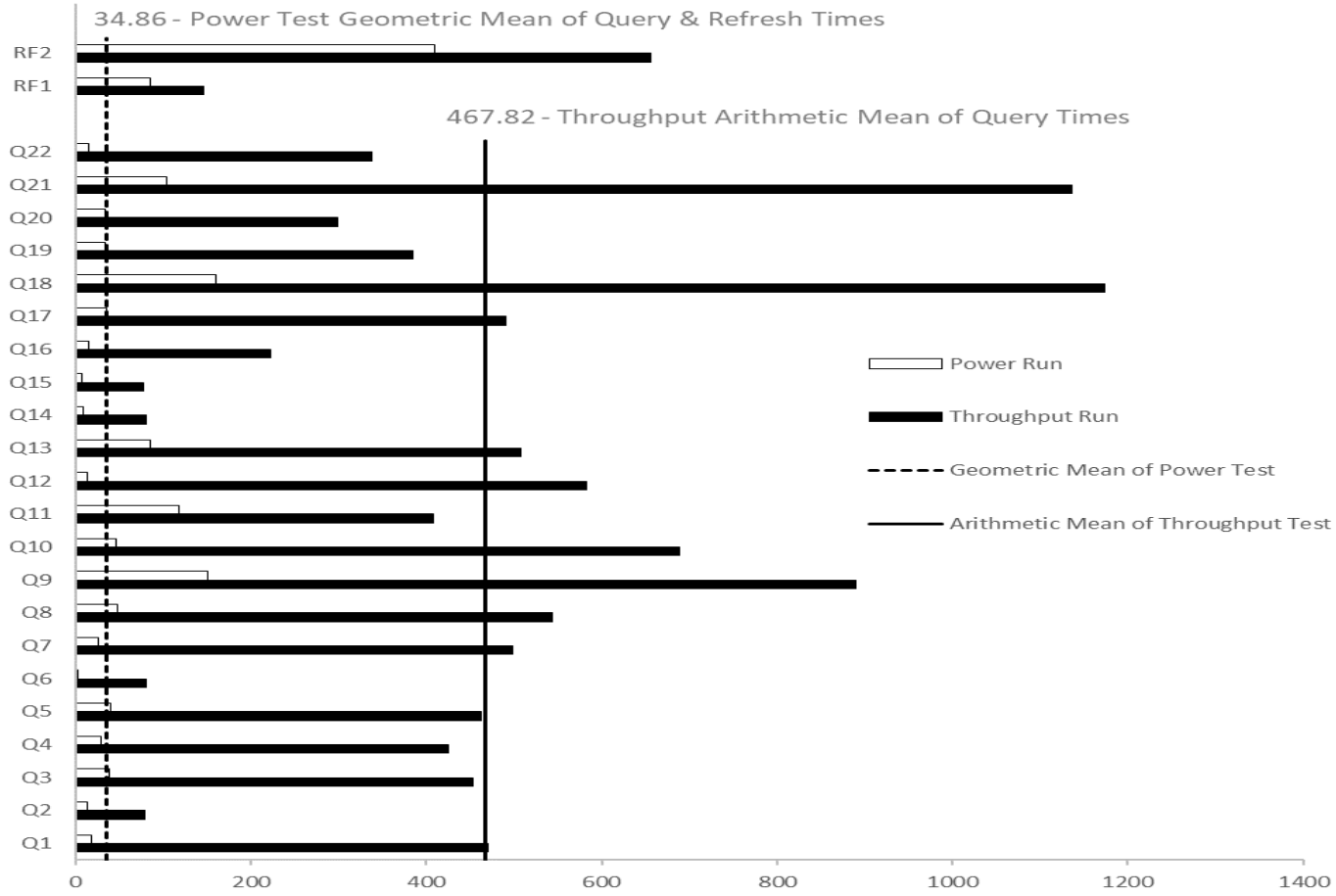
Auditor

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 Doug Johnson of InfoSizing to verify compliance with the relevant TPC specifications.

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

Hewlett Packard Enterprise	HPE ProLiant DL560 Gen11	TPC-H Rev. 3.0.1 TPC Pricing Rev. 2.8.0 Report Date: Aug 03, 2023
Total System Cost	Composite Query per Hour Rating	Price/Performance
$2,593,590 USD	**2,604,288.3** QphH @ 30,000GB	**$995.90 USD** $ / kQphH @ 30,000GB

Database Size	Database Manager	Operating System	Other Software	Availability Date
30,000GB	**Microsoft® SQL Server 2022 Enterprise Edition**	**Windows Server 2022**	**None**	**May 01, 2023**



Database Load Time = 03d 02h 15m 51s	**Storage Redundancy Level**	
Load included backup: **Y**	Base Tables and Auxiliary Data Structures	**No RAID**
Total Data Storage / Database Size = 1.42	DBMS Temporary Space	**No RAID**
Memory/Database Size = **27.31%**	OS, DBMS Software and Transaction Log	**RAID 1**

System Components	**System Total**
Nodes:	1
Intel Xeon-Platinum 8490H 1.9GHz:	4
Cores/Threads:	240/480
Memory:	8,192 GiB
6.4TB/3.2TB/1.6TB NVMe Drives	2/4/12 (18 in total)
HPE NS204i-u Gen11 Boot Controller w/ 2 x 480GB Drives	1
MR416i-p Tri-mode controller	1
MCX631102AS-ADAT Ethernet 10/25Gb 2-port SFP28 Adapter for HPE	1
Total Storage:	**42,617.36 GiB**

Hewlett Packard Enterprise	HPE ProLiant DL560 Gen11	TPC-H Rev. 3.0.1 TPC Pricing Rev. 2.8.0 Report Date: Aug 03, 2023

Description	Price Key	Part Number	Unit Price	Qty	Extended Price	3 Yr Maint Price
HPE ProLiant DL560 Gen11 Liquid Cooling Configure-to-order Server	1	P55182-B21	$9,064.00	1	$9,064.00	
Intel Xeon-Platinum 8490H 1.9GHz 60-core 350W Processor for HPE	1	P49630-B21	$44,200.00	4	$176,800.00	
HPE 128GB (1x128GB) Quad Rank x4 DDR5-4800 CAS-46-39-39 EC8 Registered	1	P63345-B21	$13,497.00	64	$863,808.00	
HPE DL560 Gen11 8SFF x1 TM Kit	1	P54798-B21	$389.00	2	$778.00	
HPE 1.6TB NVMe Gen4 High Performance Mixed Use SFF BC U.3 PM1735a SSD	1	P50227-B21	$4,025.00	12	$48,300.00	
HPE 3.2TB NVMe Gen4 High Performance Mixed Use SFF BC U.3 PM1735a SSD	1	P50230-B21	$6,476.00	4	$25,904.00	
HPE 6.4TB NVMe Gen4 High Performance Mixed Use SFF BC U.3 PM1735a SSD	1	P50233-B21	$12,250.00	2	$24,500.00	
HPE DL560 Gen11 2SFF U.3 Kit	1	P54801-B21	$485.00	1	$485.00	
HPE DL560 Gen11 SFF Univ Media Bay Kit	1	P60500-B21	$261.00	1	$261.00	
HPE DL560 Gen11 x8/x16/x8 Riser Kit	1	P54779-B21	$254.00	2	$508.00	
HPE MR416i-p Gen11 x16 Lanes 8GB Cache PCI SPDM Plug-in Storage Controller	1	P47777-B21	$3,955.00	1	$3,955.00	
Mellanox MCX631102AS-ADAT Ethernet 10/25Gb 2-port SFP28 Adapter for HP	1	P42044-B21	$1,500.00	1	$1,500.00	
HPE 96W Smart Storage Lithium-ion Battery with 260mm Cable Kit	1	P01367-B21	$234.00	1	$234.00	
HPE 1600W Flex Slot Platinum Hot Plug Low Halogen Power Supply Kit	1	P38997-B21	$685.00	4	$2,740.00	
HPE DL560 Gen11 TM Box 1/2 Cbl Kit	1	P55320-B21	$117.00	1	$117.00	
HPE DL560 Gen11 TM Box 3 Cbl Kit	1	P59144-B21	$106.00	1	$106.00	
HPE NS204i-u Gen11 NVMe Hot Plug Boot Optimized Storage Device	1	P48183-B21	$1,994.00	1	$1,994.00	
HPE DL560 Gen11 LC FIO Heat Sink Kit	1	P54791-B21	$1,652.00	2	$3,304.00	
HPE DL560 Gen11 4P CPU Mezzanine Kit	1	P54803-B21	$3,736.00	1	$3,736.00	
HPE DL560 Gen11 4xPS Enable Kit	1	P54812-B21	$354.00	1	$354.00	
HPE ProLiant DL380a/DL560 Gen11 NS204i-u Rear Enablement Kit	1	P55710-B21	$108.00	1	$108.00	
HPE Gen 11 DL560 BB Rail Kit 8	1	P61501-B21	$546.00	1	$546.00	
HPE 3Y TC Bas DL560 Gen11 HW SVC	1	H40HYE	$5,206.00	1		$5,206.00
			Subtotal		**$1,169,102**	**$5,206**
Other						
HP M24fw Monitor + Wireless Mouse + Keyboard kit	3	2D9K1AA#ABA, 3ML04AA#ABL	$169.99	3	$509.97	
			Subtotal		**$510**	
Server Software						
SQL Server 2022 Enterprise Edition (2 core license)	2	NA	$15,123.00	120	$1,814,760.00	
Microsoft Problem Resolution Services	2	NA	$259.00	1		$259.00
Windows Server 2022 Standard Edition (16 Core License)	2	NA	$984.00	15	$14,760.00	
			Subtotal		**$1,829,520**	**$259**
		Total Extended Price			$2,999,132	$5,465
		Total Discounts			$409,185	$1,822
Price Key: 1 - HPE , 2 - Microsoft. 3 - Hewlett Packard Inc. **Audited by Doug Johnson of InfoSizing (www.sizing.com)**		**Grand Total**			**$2,589,947**	**$3,643**
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:**				**$2,593,590**
		QphH @ 30000GB:				**2,604,288.30**
		$ USD/kQphH @ 30000GB				**$995.90**

Numerical Quantities

Measurement Results

Database Scale Factor	**30,000**
Total Data Storage / Database Size	**1.42**
Percentage Memory / Database Size	**27.31%**
Start of Database Load	**2023-07-23 23:18:59**
End of Database Load	**2023-07-27 07:24:20**
Database Load Time	**03d 02h 15m 51s**
Query Streams for Throughput Test	**10**
TPC-H Power	**3,097,946.2**
TPC-H Throughput	**2,189,294.8**
TPC-H Composite Query-per-Hour (QphH@30,000GB)	**2,604,288.3**
Total System Price over 3 Years ($ USD)	**$2,593,590**
TPC-H Price/Performance Metric ($ USD / kQphH@30,000GB)	**$995.90**

Measurement Interval

Measurement Interval in Throughput Test	**10852.8 seconds**

Duration of Stream Execution

Power Run	Seed	Query Start Time Query End Time	Total Time (hh:mm:ss)	RF1 Start Time RF1 End Time	RF2 Start Time RF2 End Time
	727072420	2023-07-27 11:17:01 2023-07-27 11:34:30	00:17:29	2023-07-27 11:15:35 2023-07-27 11:17:01	2023-07-27 11:34:30 2023-07-27 11:41:19
Throughput Stream	**Seed**	**Query Start Time Query End Time**	**Total Time (hh:mm:ss)**	**RF1 Start Time RF1 End Time**	**RF2 Start Time RF2 End Time**
1	727072421	2023-07-27 11:41:18 2023-07-27 14:25:50	02:44:32	2023-07-27 11:41:18 2023-07-27 11:43:37	2023-07-27 11:43:37 2023-07-27 11:52:36
2	727072422	2023-07-27 11:41:18 2023-07-27 14:23:03	02:41:45	2023-07-27 11:52:36 2023-07-27 11:54:33	2023-07-27 11:54:33 2023-07-27 12:02:58
3	727072423	2023-07-27 11:41:18 2023-07-27 14:40:54	02:59:36	2023-07-27 12:02:58 2023-07-27 12:04:58	2023-07-27 12:04:58 2023-07-27 12:13:08
4	727072424	2023-07-27 11:41:18 2023-07-27 14:41:45	03:00:27	2023-07-27 12:13:08 2023-07-27 12:16:46	2023-07-27 12:16:46 2023-07-27 12:26:30
5	727072425	2023-07-27 11:41:18 2023-07-27 14:38:43	02:57:25	2023-07-27 12:26:30 2023-07-27 12:28:38	2023-07-27 12:28:38 2023-07-27 12:38:42
6	727072426	2023-07-27 11:41:19 2023-07-27 14:18:40	02:37:21	2023-07-27 12:38:42 2023-07-27 12:40:46	2023-07-27 12:40:46 2023-07-27 12:51:04
7	727072427	2023-07-27 11:41:19 2023-07-27 14:20:41	02:39:22	2023-07-27 12:51:04 2023-07-27 12:53:21	2023-07-27 12:53:21 2023-07-27 13:05:46
8	727072428	2023-07-27 11:41:19 2023-07-27 14:42:12	03:00:53	2023-07-27 13:05:47 2023-07-27 13:07:49	2023-07-27 13:07:49 2023-07-27 13:23:58
9	727072429	2023-07-27 11:41:19 2023-07-27 14:40:25	02:59:06	2023-07-27 13:23:58 2023-07-27 13:26:42	2023-07-27 13:26:42 2023-07-27 13:38:19
10	727072430	2023-07-27 11:41:19 2023-07-27 14:36:24	02:55:05	2023-07-27 13:38:19 2023-07-27 13:41:31	2023-07-27 13:41:31 2023-07-27 13:54:57

TPC-H Timing Intervals (in seconds):

Stream ID	0	1	2	3	4	5	6	7	8	9	10	Ql Min	Ql Avg	Ql Max
Q1	18.31	393.47	258.81	437.72	751.00	329.09	526.61	471.36	359.78	664.32	519	18.31	429.95	751.00
Q2	14.33	121.03	121.64	47.16	97.31	55.97	65.24	63.92	48.24	74.81	90.31	14.33	72.72	121.64
Q3	39.04	456.79	252.35	60.69	447.81	766.88	694.68	261.30	842.44	580.75	167.68	39.04	415.49	842.44
Q4	29.13	737.79	585.00	327.43	313.62	447.61	193.40	385.49	227	512.93	527.05	29.13	389.68	737.79
Q5	39.63	463.24	208.81	903.46	305.48	691.07	314.47	639.44	276.89	450.91	372.16	39.63	424.14	903.46
Q6	2.03	88.32	5.38	72.27	112.99	83.08	52.26	116.06	71.28	123.18	79.54	2.03	73.31	123.18
Q7	26.48	328.08	508.25	755.97	569.63	1,027.96	217.73	616.81	317.11	495.65	152.74	26.48	456.04	1,027.96
Q8	48.10	837.63	387.19	426.76	654.13	876.46	628.88	440.05	370.47	469.1	341.72	48.10	498.23	876.46
Q9	151.08	533.72	790.80	1,299.75	404.21	648.96	732.06	933.07	1348.99	1180.75	1031.27	151.08	823.15	1,348.99
Q10	47.02	899.05	563.05	921.60	524.02	973.37	569.70	315.27	1270.1	468.88	391.09	47.02	631.20	1,270.10
Q11	118.83	178.64	639.00	436.97	498.67	440.35	173.14	376.33	234.9	737.03	359.94	118.83	381.25	737.03
Q12	13.51	762.49	565.50	483.38	307.67	431.39	519.52	698.04	426.88	369.04	1261.98	13.51	530.85	1,261.98
Q13	85.41	342.19	677.72	499.27	668.47	655.00	233.75	571.26	193.38	648.77	587.09	85.41	469.30	677.72
Q14	8.78	41.92	86.90	145.32	125.55	14.61	101.61	102.25	61.23	35.79	93.27	8.78	74.29	145.32
Q15	7.26	126.84	104.91	129.80	56.94	62.63	60.03	22.65	70.14	46.78	87.16	7.26	70.47	129.80
Q16	14.60	359.23	329.15	124.38	154.80	177.35	354.66	357.34	222.68	49.66	90.54	14.60	203.13	359.23
Q17	34.74	379.03	458.20	517.54	466.73	598.96	716.96	131.25	768.4	363.72	506.67	34.74	449.29	768.40
Q18	160.70	1,336.83	876.65	1,349.44	1,733.87	485.12	562.82	833.78	1752.74	1223.2	1585.93	160.70	1,081.92	1,752.74
Q19	34.09	189.12	397.88	575.93	475.75	596.91	395.47	577.87	125.29	419.94	89.51	34.09	352.52	596.91
Q20	34.14	264.13	266.88	119.86	136.04	320.52	378.00	158.29	546.83	218.52	574.36	34.14	274.32	574.36
Q21	104.69	951.93	813.82	881.87	1,952.71	865.91	1,256.87	1,441.41	737.74	1148.6	1307.93	104.69	1,042.13	1,952.71
Q22	15.75	79.00	805.50	257.68	67.93	94.62	692.22	48.51	580.01	462.65	287.52	15.75	308.31	805.50
RF1	85.40	137.69	116.51	120.14	218.19	127.60	124.28	137.23	122.68	164.17	192.08	85.40	140.54	218.19
RF2	409.53	538.83	505.02	489.67	584.30	603.68	617.22	745.37	968.51	696.73	805.24	409.53	633.10	968.51

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 DL560 Gen11, depicted in Fig. 0.1, consisted of :

HPE ProLiant DL560 Gen11
04 Intel Xeon 8490H Processors (1.9GHz/120-cores)
64 HPE 128 GB DIMMs (DDR5)

Storage adapters
01 MR416i-pi-a Gen11 Tri-mode Controller

Network Adapters
01 Mellanox 10/25Gbps 2p NIC

Disk Drives
02 480GB M.2 SSDs
02 6.4 TB Mixed Use NVMe Drives
04 3.2 TB Mixed Use NVMe Drives
12 1.6 TB Mixed Use NVMe Drives

Note: The same system is used as both measured and priced configuration.

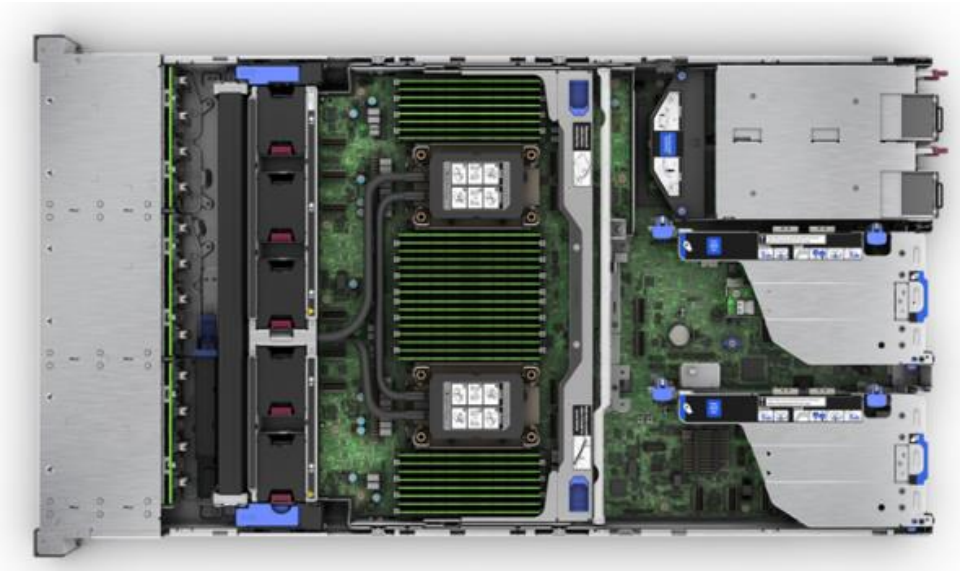


Figure 0.1 Benchmark and priced configuration for HPE ProLiant DL560 Gen11

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 3.0 and QGEN version 3.0 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 3.0 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:

- The “dateadd” function is used to perform date arithmetic in Q1, Q4, Q5, Q6, Q10, Q12, Q14 , Q15 and Q20.
- The “datepart” function is used to extract part of a date (“YY”) in Q7, Q8 and Q9.
- The “top” function is used to restrict the number of output rows in Q2, Q3, Q10, Q18 and Q21
- 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 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 T1 was started for a randomly selected O_KEY, L_KEY and DELTA. The ACID Transaction was suspended prior to Rollback.
2. An ACID query T2 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 T1 was ROLLED BACK.
4. The ACID query T2 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 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 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.
2. Before T1 completed, an ACID Transaction T2 was started using randomly selected values of O_KEY, L_KEY and DELTA.
3. Third transaction T3 was started before T1 completed, which executes a modified Q1 against the qualification database.
4. Fourth transaction T4 was started before T3 completed, which executes a modified Q1 against the qualification database.
5. T2 completed before T1 and T3 completed.
6. 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

Two tests were completed in this section.
1st test was the loss of a data disk & loss of a disk from RAID1 volume hosting transaction log
2nd test was the the power Loss test

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.

Data Disk and Log disk loss Test
1. Eleven streams of ACID transactions were started. Each stream executed a minimum of 100 transactions.
2. While the test was running, one of the log disks (under RAID1) was removed.
3. Waited for the device loss to be reported in IML. SQL Server did not log errors and transaction continued.
4. Waited for few more iteration of streams to complete.
5. Acid transaction loop counts were within range allowing for the immediate testing of data disk removal.
6. One of the drives hosting data files was removed.
7. A checkpoint was issued to ensure the failure is detected by SQL server. Due to a large set of data files and drive count, SQL Server did not detect the disk loss.
8. Backup of transaction log was followed by a backup of the database. This triggered SQL Server to detected the disk loss.
9. The eleven streams of ACID transactions failed and recorded their number of committed transactions in success files.
10. The Database was dropped.
11. The pulled disks were replaced.
12. The database was restored.
13. When database restore completed, issued a command to apply the backed up log file.
14. 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. Eleven 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 issuing a “cold boot” command.
3. When power was restored the system booted and the Database engine was restarted.
4. The database went through a recovery.
5. Count of Rolled-forward/Rolled-back transactions were captured by DB ERRORLOG file.
6. Once the reovery was complete, 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	179,999,978,268
Orders	45,000,000,000
Partsupp	24,000,000,000
Part	6,000,000,000
Customer	4,500,000,000
Supplier	300,000,000
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 DL560 Gen11 with the following configuration:

NVMe Storage Configuration:					
Physical Device	**OS Device**	**Mount**	**Physical Size In TB/GB**	**Available Size in TiB**	**Usage Comments**
Box 3 Bay 1	Disk 3	G:\Backup\	3.2 TB	1490 GiB	**Windows Spanned Volume:** Database backup 18 x extra tempdb files
Box 3 Bay 2	Disk 4		3.2 TB	1490 GiB	
Box 2 Bay 7	Disk 5		3.2 TB	1490 GiB	
Box 2 Bay 8	Disk 6		3.2 TB	1490 GiB	
Box 3 Bay 3	Disk 13	G:\Data\Data1	1.6 TB	2980 GiB	480 x database data files 480 x tempdb data files
Box 3 Bay 4	Disk 2	G:\Data\Data2	1.6 TB	2980 GiB	
Box 3 Bay 5	Disk 14	G:\Data\Data3	1.6 TB	2980 GiB	
Box 3 Bay 6	Disk 1	G:\Data\Data4	1.6 TB	2980 GiB	
Box 3 Bay 7	Disk 15	G:\Data\Data5	1.6 TB	2980 GiB	
Box 3 Bay 8	Disk 10	G:\Data\Data6	1.6 TB	2980 GiB	
Box 2 Bay 1	Disk 16	G:\Data\Data7	1.6 TB	2980 GiB	
Box 2 Bay 2	Disk 9	G:\Data\Data8	1.6 TB	2980 GiB	
Box 2 Bay 3	Disk 8	G:\Data\Data9	1.6 TB	2980 GiB	
Box 2 Bay 4	Disk 11	G:\Data\Data10	1.6 TB	2980 GiB	
Box 2 Bay 5	Disk 7	G:\Data\Data11	1.6 TB	2980 GiB	
Box 2 Bay 6	Disk 12	G:\Data\Data12	1.6 TB	2980 GiB	
Box 1 Bay 1	Disk 17	R:\ G:\Logs	6.4 TB	5960 GiB	02 x db transaction log files 01 x tempdb transaction log file
Box 1 Bay 2			6.4 TB	5960 GiB	

Controller	**Device Location**	**RAID Level**	**Usage Comments**	**Physical Size**	**Available Size**
NS204i-u Ctlr	Internal Slim SAS Port (Slot 53)	RAID1	OS/Boot Drive (Disk 0)	480GB	447 GiB
				480GB	
MR2416i-p Ctlr (Box 1 Bay 1, Box 1 Bay 2)	PCIe Slot 6	RAID1	Transaction logs (Disk 17)	6.4TB	5960 GiB
				6.4TB	

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 08 drives.

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.

No RAID was used for database file groups and TempDB. RAID1 for the database recovery logs, DB root file 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 3.0 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 03d 02h 15m 51s

Load Test Times	
Load Start	2023-07-23 23:18:59
Load End	2023-07-27 07:24:20
Load Delay	00d 05h 49m 31s
Load Time	03d 02h 15m 51s

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.

Desc	Drive Qty	Capacity in GiB	Extended Capacity in GiB
HPE 6.4TB NVMe Gen4 High Performance MU Drives	2	5960.46	11920.92
HPE 3.2TB NVMe Gen4 High Performance MU Drives	4	2980.23	11920.92
HPE 1.6TB NVMe Gen4 High Performance MU Drives	12	1490.12	17881.44
HPE 480GB M.2 Drives on Boot Controller	2	447.04	894.08
Total Capacity			**42617.36**

Size of test database: 30,000GiB Data Storage Ratio: 1.42

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.

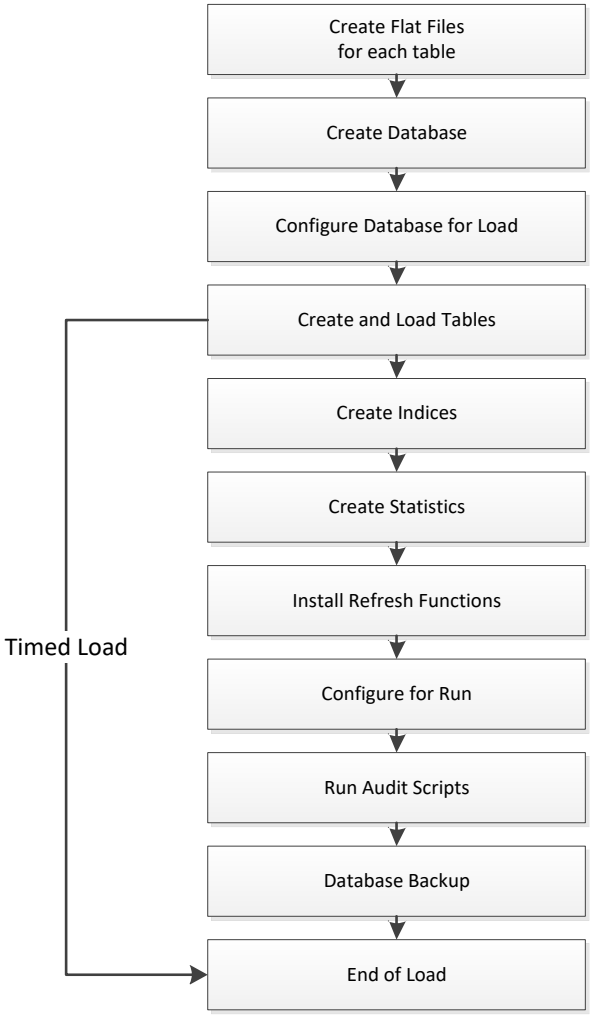


Figure 4.8: Block Diagram of Database Load Process

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 quoted in below table.

Memory/Database Size		
Physical Mem GB	**Scale Factor**	**Percentage**
8192	**30,000**	**27.31%**

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. The system sat idle, without any interruption until the performance tests were triggered.

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.

10 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@30,000G	QthH@30,000G	QphH@30,000G
Run 1	3,421,900.2	2,361,392.4	2,842,613.1
Run 2	3,097,946.2	2,189,294.8	2,604,288.3

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.

There was only a couple minutes 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 on the date specified in Clause 7.3.

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	Now
Storage	Now
Server Software	Now
SQL Server 2022	Now

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	Qual-database-build.zip	SupportingFiles/Clause1/DB_Creation_QualDB
	DB Creation/Load Scripts – TEST	Perf-database-build.zip	SupportingFiles/Clause1/DB_Creation_TestDB
	OS_DB_Settings	DB_Settings.txt SystemInfo.zip	SupportingFiles/Clause1/OS_DB_Settings
Clause 2	Query Validation Output	QGen.zip Qual Queries.zip	SupportingFiles/Clause2/QueryValidationOutput SupportingFiles/Clause2/
Clause 3	Atomicity	ACID - Atomicity.zip	SupportingFiles/Clause3/Atomicity
	Consistency	n/a	n/a
	Isolation	ACID - Isolation.zip	SupportingFiles/Clause3/Isolation
	Durability	ACID - Durability - Data_Log_DiskLoss.zip ACID - Durability - Powerloss.zip	SupportingFiles/Clause3/Durability
Clause 4	DB Load Scripts	DB_Creation_TestDB.zip	SupportingFiles/Clause4/DB_Load_Scripts
Clause 5	Query Output Run 1	First Run.zip	SupportingFiles/Clause5/
	Query Output Run 2	Second Run.zip	SupportingFiles/Clause5/
	Queries	Queries.zip	SupportingFiles/Clause5/Queries
Clause 6	Implementation Specific layer source code and Driver	StepMaster_FDR.zip	SupportingFiles/Clause6/ClientReadme.txt
Clause 7	There are no files required to be included for Clause 7.	n/a	n/a
Clause 8	There are 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 Doug Johnson of InfoSizing, a certified TPC-H auditor. Further information regarding the audit process may be obtained from:

Doug Johnson
InfoSizing (www.sizing.com)
63 Lourdes Dr
Leominster, MA 01453
(978) 343-6562

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

InfoSizing

TPC Certified Auditor

Benchmark sponsor:	Rajesh Tadakamadla Hewlett Packard Enterprise Survey 192, Whitefield Road, Bangalore, India – 560 048

August 3, 2023

I verified the TPC Benchmark H (TPC-H™ v3.0.1) performance of the following configuration:

Platform:	HPE ProLiant DL560 Gen11
Operating System:	Windows Server 2022 Standard Edition
Database Manager:	Microsoft SQL Server 2022 Enterprise Edition
Other Software:	n/a

The results were:

Performance Metric	**2,604,288.3 QphH@30000GB**
TPC-H Power	3,097,946.2
TPC-H Throughput	2,189,294.8
Database Load Time	03d 02h 15m 51s

Server	**HPE ProLiant DL560 Gen11, with:**		
CPUs	4x Intel Xeon-Platinum 8490H (1.9 GHz, 60-core)		
Memory	8,192 GiB		
Disks	***Qty***	***Size***	***Type***
	2	480 GB	M.2 SSD
	2	6.4 TB	Mixed Use NVMe
	4	3.2 TB	Mixed Use NVMe
	12	1.6 TB	Mixed Use NVMe

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 30,000GB and populated accordingly
- The compliance of the database auxiliary data structures was verified
- The database load time was correctly measured and reported

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- 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 10 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,

Doug Johnson, TPC Certified Auditor

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Microsoft

July 12, 2023

Rajesh Tadakamadla
Hewlett Packard Enterprise
192, Mahadevapura
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Bangalore, India 560048

Here is the information you requested regarding pricing for several 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 2022 Enterprise Edition *2 Core License* *Open Program – No Level - ERP*	$15,123.00	120	$1,814.760.00
Database Server Operating System			
Windows Server 2022 Standard *16 Core License* *Open Program – No Level – ERP*	$984.00	15	$14,760.00
Support			
Microsoft Problem Resolution Services *Professional Support* *(1 Incident).*	$259.00	1	$259.00

All 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 120 days.

Reference ID: TPCH_kxtaollp945607241_2023

(0) Ask a question

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