Dell Technologies

TPC Benchmark H Full Disclosure Report
For
Dell Technologies PowerEdge MX740c Modular Server
While Using Microsoft SQL Server 2019 Enterprise Edition
and
Red Hat® Enterprise Linux® 8.0

First Edition: March 2021

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Abstract

Overview

This report documents the methodology and results of the TPC Benchmark H test conducted on Dell Technologies PowerEdge MX740c server that was using Microsoft SQL Server 2019 Enterprise Edition in conformance with the requirements of the TPC Benchmark H Standard Specification, Revision 3.0.0. The operating system used for the benchmark was Red Hat® Enterprise Linux® 8.0.

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−vii contain the Executive Summary and Numerical Quantities Summary of the benchmark results for the PowerEdge MX740c server.

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."

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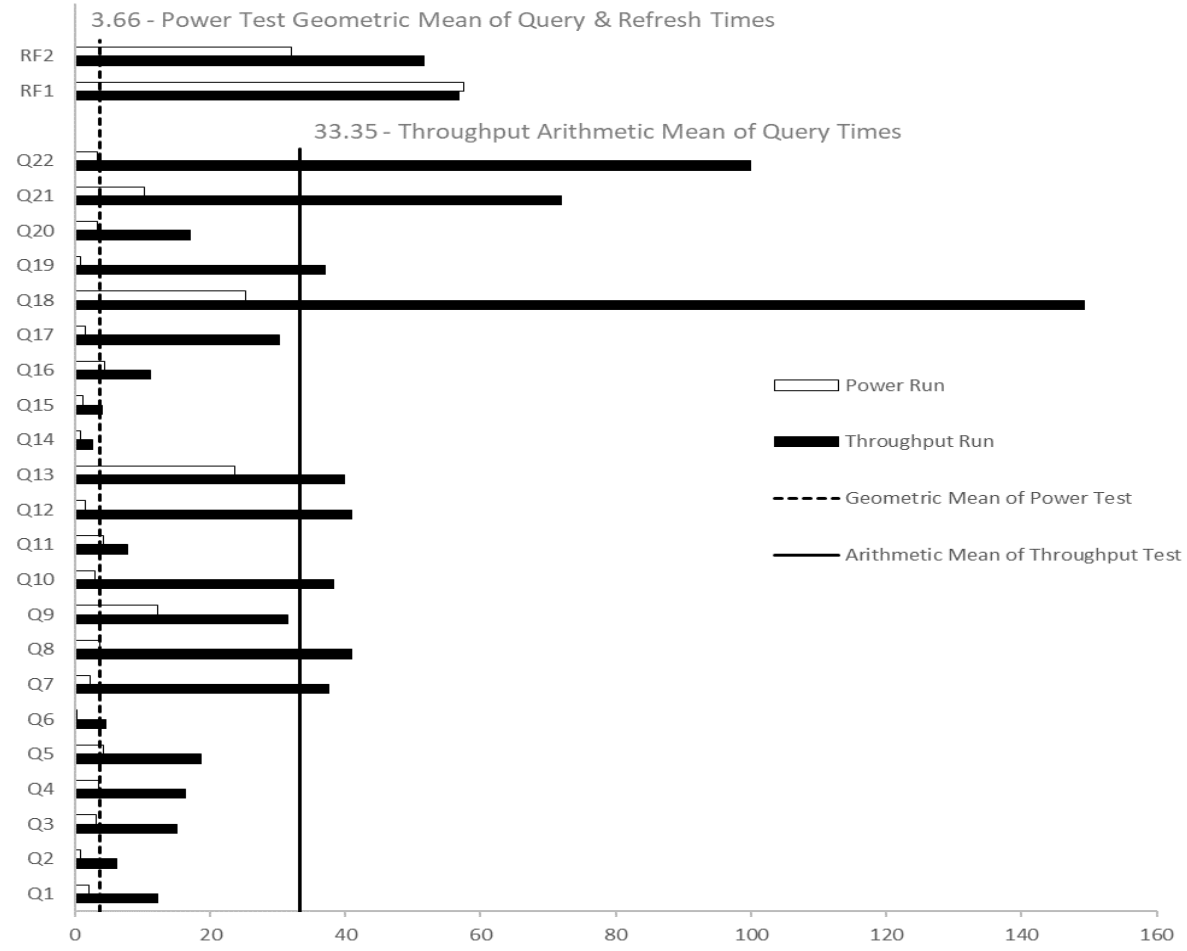
DELL Technologies	**PowerEdge MX740c Modular Server**	TPC-H Rev. 3.0.0 TPC Pricing Rev. 2.6.0 Report Date: March 3, 2021
Total System Cost	Composite Query per Hour Rating	Price/Performance
$378,974.00	**824,693.5** QphH@1000 GB	**$459.53** $/kQphH@1000GB

Database Size	Database Manager	Operating System	Other Software	Availability Date
1,000 GB	Microsoft® SQL Server 2019 Enterprise Edition	Red Hat® Enterprise Linux® 8.0	N/A	March 3, 2021



Database load Time = 00d 01h 32m 26s	Storage Redundancy Level	
Load Includes Backup: **Y**	Base Tables and Auxiliary Data Structures	**No RAID**
Total Data Storage/Database Size = **8.49**	DBMS Temporary Space	**No RAID**
Percentage Memory/ Database size = **76.8** %	OS and DBMS Software	**RAID 1**
	Log	**RAID 1**
System Configuration:	Dell PowerEdge MX740c Modular Server	
Processors/Model:	2x Intel Xeon Platinum 8268 2.9G, 24C/48T, 10.4GT/s, 35.75M Cache, Turbo, HT (205W) DDR4-2933	
Cores/Threads:	**48C/96T**	
Memory:	**768GB (12x 64GB)**	
Storage:	**3x Dell 1.6TB, NVMe, Mixed Use Express Flash, 2.5 SFF Drive, U.2, PM1725b with Carrier.** **BOSS controller card + with2 M.2 Sticks 480G (RAID 1), Blade** **2x 480GB SSD SAS Mixed Use 12Gbps 512e 2.5in Hot-Plug Drive, PM5-V** **2.4TB 10K RPM SAS 12Gbps 512e 2.5in Hot-plug Hard Drive**	
Total Storage:	**8,493.66**	

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PowerEdge MX740c Modular Server

TPC-H Rev. 3.0.0
TPC Pricing Rev. 2.6.0
Report Date: March 3, 2021

Description	Part Number	Source	Unit Price	Qty	Ext. Price $	3 Yr Maint. Price
PowerEdge MX7000 CHASSIS						
PowerEdge MX7000 Enclosure	210-ANYY	1	4,450.00	1	4,450.00	
PowerEdge MX7000 Chassis Configuration	321-BDJT	1	0.00	1	0.00	
PowerEdge MX7000 Shipping	340-BZNC	1	0.00	1	0.00	
PowerEdge MX7000 Shipping Material	343-BBIQ	1	99.00	1	99.00	
No Media Required	605-BBFN	1	0.00	1	0.00	
Unique Random Password	389-CGLD	1	0.00	1	0.00	
PowerEdge MX7000 Redundant Power Supply, 6 x 3000W, (3+3)	450-AGXF	1	3,650.00	1	3,650.00	
LCD, no Quick Sync	350-BBPG	1	220.00	1	220.00	
ReadyRail II for MX7000	770-BCPC	1	99.00	1	99.00	
Redundant Management Module for PowerEdge MX7000 Chassis	403-BBTY	1	2,100.00	1	2,100.00	
Pass Through Module Filler Blank	544-BBCK	1	0.00	1	0.00	
C20 to C21, PDU Style, 16 AMP, 8 Feet, Power Cord	450-AGXK	1	30.00	6	180.00	
PowerEdge MX7000 10/25Gb Pass Through Module	542-BBDD	1	3,200.00	2	6,400.00	
No I/O Module, Filler Blank	543-BBDP	1	0.00	2	0.00	
MX7000 Sled Blank	321-BDND	1	0.00	7	0.00	
Basic Next Business Day 36 Months	709-BBFM	1	200.00	1		200
Prosupport Plus and 4Hr Mission Critical Initial, 36 Month(s)	865-BBNF	1	3,131.64	1		3131.64
ProDeploy Plus Training Credits 1300 Redeem at education.dellemc.com Expires 1Yr from Or	812-4020	1	1,300.00	1		1300
ProDeploy Plus Dell EMC Poweredge MX7000 Chassis	822-1675	1	7,634.36	1		7634.36
ProDeploy Plus Dell EMC Poweredge MX7000 Deployment Verification	822-1677	1	279.48	1		279.48
				Sub Total	17,198.00	12545.48
Large Purchase Discount (44.2% for Chassis)				Discounted Price	-7,601.52	-5545.102
				Chassis Subtotal	9,596.48	7000.378
PowerEdge MX740C						
PowerEdge MX740C Server	210-AOFH	1	1,937.00	1	1,937.00	
No Trusted Platform Module	461-AADZ	1	0.00	1	0.00	
2.5" Chassis with up to 6 SAS/SATA/NVMe Hard Drives MLK	321-BERL	1	165.00	1	165.00	
No System Documentation, No OpenManage DVD Kit	343-BBDG	1	0.00	1	0.00	
System ordered as part of Multipack order	750-AADI	1	0.00	2	0.00	
PowerEdge MX740C Regulatory Label	389-DKXC	1	0.00	1	0.00	
Intel Xeon Platinum 8268 2.9G, 24C/48T, 10.4GT/s, 35.75M Cache,Turbo, HT (205W) DDR4-	338-BRVJ	1	9,609.00	1	9,609.00	
Intel Xeon Platinum 8268 2.9G, 24C/48T, 10.4GT/s, 35.75M Cache,Turbo, HT (205W) DDR4-	338-BRVJ	1	9,609.00	1	9,609.00	
Additional Processor Selected	379-BDCO	1	0.00	1	0.00	
2 CPU Heatsink	412-AANK	1	309.00	1	309.00	
3200MT/s RDIMMs	370-AEVR	1	0.00	1	0.00	
Performance Optimized	370-AAIP	1	0.00	1	0.00	
No RAID	780-BCDI	1	0.00	1	0.00	
PERC H730P RAID Controller	405-AARS	1	849.00	1	849.00	
BOSS controller card + with 2 M.2 Sticks 480G (RAID 1), Blade	403-BBYN	1	1,499.00	1	1,499.00	
No Operating System	611-BBBF	1	0.00	1	0.00	
No Media Required	605-BBFN	1	0.00	1	0.00	
iDRAC9,Enterprise	385-BBKT	1	489.00	1	489.00	
OpenManage Enterprise Advanced	528-BIYY	1	299.00	1	299.00	
iDRAC Group Manager, Enabled	379-BCQV	1	0.00	1	0.00	
Redundant Power Supply on Chassis (X+3 PSU Configuration)	450-AJPS	1	0.00	1	0.00	
Performance BIOS Settings	384-BBBL	1	0.00	1	0.00	
UEFI BIOS Boot Mode with GPT Partition	800-BBDM	1	0.00	1	0.00	
No Systems Documentation, No OpenManage DVD Kit	631-AACK	1	0.00	1	0.00	
Fabric C Filler Blank	544-BBCL	1	0.00	1	0.00	
64GB RDIMM, 3200MT/s, Dual Rank	370-AEVP	1	2,124.00	12	25,488.00	
2.4TB 10K RPM SAS 12Gbps 512e 2.5in Hot-plug Hard Drive	400-AYSF	1	1,179.00	1	1,179.00	
480GB SSD SAS Mixed Use 12Gbps 512e 2.5in Hot-Plug Drive, PM5-V	400-BGHS	1	1,399.00	2	2,798.00	
Dell 1.6TB, NVMe, Mixed Use Express Flash, 2.5 SFF Drive, U.2, PM1725b with Carrier	400-BEFB	1	2,425.00	3	7,275.00	
QLogic FastLinQ 41262 Dual Port 10/25GbE Mezzanine Card with Storage Offloads (iSCSI, F	543-BBDI	1	729.00	1		
Basic Next Business Day 36 Months	709-BBFL	1	200.00	1		200.00
Prosupport Plus and 4Hr Mission Critical Initial, 36 Month(s)	865-BBNF	1	9,365.85	1		9,365.85
On-Site Installation Declined	900-9997	1	0.00	1		0.00
				Sub Total	61,505.00	9,565.85
Large Purchase Discount (60% for Server)				Discounted Price	-36,903.00	-5,739.51
				Server Subtotal	24,602.00	3,826.34
Logitech MK120 USB Keyboard and Mouse Combo	A6999510	1	$19.99	3	59.97	
				Discounted Price	-8.40	
Dell 19S Monitor - P1917S	210-AIIJ	1	$239.99	1	$239.99	
				Discounted Price	-69.60	
				Peripheral Subtotal	221.96	
				Hardware Subtotal	34,420.45	10,826.72
SOFTWARE						
SQL SERVER 2019 Enterprice Edition for RHEL (2 cores license, 24 Cores)	NA	2	13,748.00	24	329,952.00	
Red Hat Enterprise Linux Server, Premium (Physical or Virtual Nodes), 3 Year x 1	RH00003F3	1			3,515.20	
Microsoft Problem Resolution Services	NA	2	259.00	1		259.00
				Software Subtotal	333,467.20	259.00
				Total	367,887.65	11,085.72

Source: 1: DELLEMC 2. MICROSOFT Audited by Doug Johnson of InfoSizing (www.sizing.com)	Three Year cost Ownership	$378,974.00
All discounts are based on US list prices and for similar quantities and configurations. The discounts was based on the overall specific components pricing from respective vendors 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.	QphH @1000	824,693.50
	$/kQphH @1000	$459.53

Dell EMC Sales Contact: Microsoft.Assist@dell.com

SQL Server Sales Contact: 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 the TPC at pricing@tpc.org. Thank you.

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Numerical Quantities

Measurement Results

Database Scale Factor	: 1000
Total Data Storage / Database Size	: 8.49
Percentage Memory / Database Size	: 76.8%
Start of Database Load	: 2021-02-17 00:04:05
End of Database Load	: 2021-02-17 01:36:32
Database Load Time h m s	: 00d 01h 32m 26s
Query Streams for Throughput Test	: 7
TPC-H Power	: 982,578.7
TPC-H Throughput	: 692,178.0
TPC-H Composite Query-per-Hour (QphH@1000 GB)	: 824,693.5
Total System Price over 3 Years ($ USD)	: USD 378,974.00
TPC-H Price/Performance Metric ($ USD / kQphH@1000 GB)	: USD 459.53

Measurement Interval

Measurement Interval in Throughput Test (Ts) : 800.95

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
	217013632	2021-02-17 10:44:06 2021-02-17 10:46:03	00:01:57	2021-02-17 10:43:07 2021-02-17 10:44:04	2021-02-17 10:46:06 2021-02-17 10:46:38
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	217013633	2021-02-17 10:46:37 2021-02-17 10:58:20	00:11:43	2021-02-17 10:46:37 2021-02-17 10:47:35	2021-02-17 10:47:35 2021-02-17 10:48:28
2	217013634	2021-02-17 10:46:37 2021-02-17 10:59:59	00:13:22	2021-02-17 10:48:28 2021-02-17 10:49:22	2021-02-17 10:49:22 2021-02-17 10:50:08
3	217013635	2021-02-17 10:46:37 2021-02-17 10:59:29	00:12:52	2021-02-17 10:50:08 2021-02-17 10:51:06	2021-02-17 10:51:06 2021-02-17 10:51:52
4	217013636	2021-02-17 10:46:37 2021-02-17 10:58:35	00:11:58	2021-02-17 10:51:53 2021-02-17 10:52:52	2021-02-17 10:52:52 2021-02-17 10:53:44
5	217013637	2021-02-17 10:46:37 2021-02-17 10:59:44	00:13:07	2021-02-17 10:53:44 2021-02-17 10:54:41	2021-02-17 10:54:41 2021-02-17 10:55:36
6	217013638	2021-02-17 10:46:37 2021-02-17 10:58:35	00:11:58	2021-02-17 10:55:36 2021-02-17 10:56:34	2021-02-17 10:56:34 2021-02-17 10:57:28
7	217013639	2021-02-17 10:46:37 2021-02-17 10:57:20	00:10:43	2021-02-17 10:57:29 2021-02-17 10:58:24	2021-02-17 10:58:24 2021-02-17 10:59:19

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TPC-H Timing Intervals (Seconds)

Stream ID	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12
0	2.17	0.84	3.21	3.58	4.18	0.22	2.27	3.61	12.24	3.04	4.17	1.51
1	3.11	5.21	17.14	11.75	21.77	4.92	28.05	61.58	40.86	30.71	4.82	9.13
2	29.04	4.88	13.10	12.20	28.56	0.63	18.45	33.02	42.41	35.14	4.95	57.51
3	19.26	5.74	8.50	39.16	22.10	6.47	60.74	43.30	25.13	70.82	7.88	7.06
4	5.32	14.79	11.10	11.38	16.86	4.69	56.93	43.55	26.59	46.25	8.96	11.09
5	11.11	3.47	34.73	6.01	7.77	3.68	42.89	15.00	15.92	7.99	10.64	35.23
6	3.05	1.63	12.01	7.75	7.86	5.58	33.55	31.02	42.98	36.81	10.20	86.43
7	14.38	8.01	9.70	26.59	26.26	5.86	21.96	59.10	26.91	40.60	7.60	80.39
QI Min	2.17	0.84	3.21	3.58	4.18	0.22	2.27	3.61	12.24	3.04	4.17	1.51
QI Avg	10.93	5.57	13.69	14.80	16.92	4.01	33.11	36.27	29.13	33.92	7.40	36.04
QI Max	29.04	14.79	34.73	39.16	28.56	6.47	60.74	61.58	42.98	70.82	10.64	86.43

Stream ID	Q13	Q14	Q15	Q16	Q17	Q18	Q19	Q20	Q21	Q22	RF1	RF2
0	23.72	0.87	1.26	4.41	1.64	25.29	0.88	3.41	10.35	3.40	57.45	32.08
1	48.39	1.83	5.42	14.95	20.86	150.76	64.99	16.14	113.89	25.42	57.55	52.08
2	35.07	1.66	3.72	14.64	40.18	179.77	47.45	10.37	10.70	177.45	54.34	46.16
3	28.82	4.55	5.31	6.41	20.02	117.61	9.19	20.80	47.12	195.42	57.16	46.74
4	35.09	2.59	4.49	13.31	34.90	183.90	42.01	18.78	92.59	32.08	59.40	51.64
5	33.92	1.97	2.61	9.13	12.26	161.78	41.55	18.36	115.19	195.07	56.79	55.51
6	43.23	2.67	3.03	7.79	59.58	119.75	46.48	20.49	86.05	49.32	57.37	54.64
7	54.66	2.66	3.80	11.97	24.11	131.43	7.67	14.59	38.57	24.67	55.53	54.38
QI Min	23.72	0.87	1.26	4.41	1.64	25.29	0.88	3.41	10.35	3.40	54.34	32.08
QI Avg	37.86	2.35	3.71	10.33	26.69	133.79	32.53	15.37	64.31	87.85	56.95	49.15
QI Max	54.66	4.55	5.42	14.95	59.58	183.90	64.99	20.80	115.19	195.42	59.40	55.51

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Contents

Abstract ... 3
Overview ... 3
Standard and Executive Summary Statements ... 3
Auditor ... 3
Preface ... 1
TPC Benchmark H Overview ... 1
0.0 General Items ... 3
0.1 Test Sponsor ... 3
0.2 Parameter Settings ... 3
0.3 Configuration Items ... 3
1.0 Clause 1: Logical Database Design ... 5
1.1 Table Definitions ... 5
1.2 Physical Organization of Database ... 5
1.3 Horizontal Partitioning ... 5
1.4 Replication ... 5
2.0 Clause 2: Queries and Refresh Functions - Related Items ... 6
2.1 Query Language ... 6
2.2 Verifying Method for Random Number Generation ... 6
2.3 Substitution Parameters Generation ... 6
2.4 Query Text and Output Data from Database ... 6
2.5 Query Substitution Parameters and Seeds Used ... 6
2.6 Isolation Level ... 6
2.7 Refresh Functions ... 6
3.0 Clause 3: Database System Properties ... 7
3.1 ACID Properties ... 7
3.2 Atomicity Requirements ... 7
3.2.1 Atomicity of the Completed Transactions ... 7
3.2.2 Atomicity of Aborted Transactions ... 7
3.3 Consistency Requirements ... 7
3.3.1 Consistency Tests ... 7
3.4 Isolation Requirements ... 8
3.4.1 Isolation Test 1—Read-Write Conflict with Commit ... 8
3.4.2 Isolation Test 2—Read-Write Conflict with Rollback ... 8
3.4.3 Isolation Test 3—Write-Write Conflict with Commit ... 8
3.4.4 Isolation Test 4—Write-Write Conflict with Rollback ... 8
3.4.5 Isolation Test 5—Concurrent Read and Write Transactions on Different Tables ... 9
3.4.6 Isolation Test 6—Update Transactions During Continuous Read-Only Query Stream ... 9
3.5 Durability Requirements ... 9
3.5.1 Permanent Unrecoverable Failure of Any Durable Medium and Loss of System Power ... 9
3.5.2 System Crash ... 10
3.5.3 Memory Failure ... 10
4.0 Clause 4: Scaling and Database Population ... 11
4.1 Initial Cardinality of Tables ... 11
4.2 Distribution of Tables and Logs Across Media ... 11
4.3 Mapping of Database Partitions/Replications ... 12
4.4 Implementation of RAID ... 12

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4.5 DBGEN Modifications 12
4.6 Database Load time 12
4.7 Data Storage Ratio 12
4.8 Database Load Mechanism Details and Illustration 13
4.9 Qualification Database Configuration 14
4.10 Memory to Database Size Percentage 14
5.0 Clause 5: Performance Metrics and Execution Rules Related Items 15
5.1 Steps after the Load Test 15
5.2 Steps in the Power Test 15
5.3 Timing Intervals for Each Query and Refresh Function 15
5.4 Number of Streams for The Throughput Test 15
5.5 Start and End Date/Times for Each Query Stream 15
5.6 Total Elapsed Time for the Measurement Interval 15
5.7 Refresh Function Start Date/Time and Finish Date/Time 15
5.8 Timing Intervals for Each Query and Each Refresh Function for Each Stream 16
5.9 Performance Metrics 16
5.10 The Performance Metric and Numerical Quantities from Both Runs 16
5.11 System Activity Between Tests 16
5.12 Documentation to satisfy Clause 5.2.7 16
5.13 Query Validation Output 16
6.0 Clause 6: SUT and Driver Implementation Related Items 17
6.1 Driver 17
6.2 Implementation Specific Layer (ISL) 17
6.3 Profile-Directed Optimization 17
7.0 Clause 7: Pricing Related Items 18
7.1 Hardware and Software Used 18
7.2 Three-Year Cost of System Configuration 18
7.3 Availability Date 18
7.4 Orderability Date 18
7.5 Country-Specific Pricing 18
8.0 Clause 8: Support Files Index Table 19
8.1 Supporting Files Index Table 19
9.0 Clause 9: Audit Related Items 20
9.1 Auditors' Report 20
Appendix A: Price Quotes 23

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Preface
TPC Benchmark H Overview

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

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

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

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

The TPC-H operations are modeled as follows:

- The database is continuously available 24 hours a day, 7 days a week, for ad-hoc queries from multiple end users and data modifications against all tables, except possibly during infrequent (for example, once a month) maintenance sessions
- The TPC-H database tracks, possibly with some delay, the state of the OLTP database through on-going refresh functions which batch together several modifications impacting some part of the decision support database
- Due to the world-wide nature of the business data stored in the TPC-H database, the queries and the refresh functions July be executed against the database at any time, especially in relation to each other. In addition, this mix of queries and refresh functions is subject to specific Acidity requirements, since queries and refresh functions July execute concurrently
- To achieve the optimal compromise between performance and operational requirements, the database administrator can set, once and for all, the locking levels and the concurrent scheduling rules for queries and refresh functions

The performance metric reported by TPC-H is called the TPC-H Composite Query-per-Hour Performance Metric (QphH@Size) and reflects multiple aspects of the capability of the system to process queries. These aspects include the selected database size against which the queries are run, the query processing power when queries are submitted by a single stream and the query throughput when queries are submitted by multiple concurrent users. The TPC-H Price/Performance metric is expressed as $/kQphH@Size. To be compliant with the TPC-H standard, all references to TPC-H results for a given configuration must include all required reporting components. The TPC believes that comparisons of TPC-H results measured against different database sizes are misleading and discourages such comparisons.

The TPC-H database must be implemented using a commercially available database management system (DBMS) and the queries executed via an interface using dynamic SQL. The specification provides for variants of SQL, as implementers are not required to have implemented a specific SQL standard in full.

TPC-H uses terminology and metrics that are like other benchmarks, originated by the TPC and others. Such similarity in terminology does not in any way imply that TPC-H results are comparable to other benchmarks. The only benchmark results comparable to TPC-H are other TPC-H results compliant with the same revision.

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

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

Further information is available at **www.tpc.org**.

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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 Dell Technologies. The benchmark was developed and engineered by Dell Technologies. Testing took place at the Dell Technologies, Durham lab.

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, if 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 (for example, DBMS, query processing tools /languages, middle-ware components, and software drivers).

The System Under Test (SUT), a PowerEdge MX740c server depicted in Figure 0.1, consisted of:

- Dell Technologies PowerEdge MX740c server
  - 2x Intel(R) Xeon(R) Platinum 8268 2.90G, 24C/48T.
  - 12x 64GB memory.

- Disk Drives (HDDs)
  - 3x Dell 1.6TB, NVMe, Mixed Use Express Flash, 2.5 SFF Drive, U.2, PM1725b with Carrier.
  - 2x 480GB SSD SAS Mixed Use 12Gbps 512e 2.5in Hot-Plug Drive, PM5-V.
  - 1x 2.4TB 10K RPM SAS 12Gbps 512e 2.5in Hot-plug Hard Drive.

- Controllers
  - PERC H730P RAID Controller
  - BOSS controller card + with2 M.2 Sticks 480G (RAID 1), Blade

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MX740c MX7000 Chassis front view

Figure 0.3 Benchmark and priced configuration for PowerEdge MX740c server

Note—There were no differences between the tested and priced configurations.

- Dell Technologies PowerEdge MX740c server
  - 2x Intel(R) Xeon(R) Platinum 8268 2.90G, 24/48T.
  - 12x 64GB memory.

- Disk Drives (HDDs)
  - 3x Dell 1.6TB, NVMe, Mixed Use Express Flash, 2.5 SFF Drive, U.2, PM1725b with Carrier.
  - 2x 480GB SSD SAS Mixed Use 12Gbps 512e 2.5in Hot-Plug Drive, PM5-V.
  - 1x 2.4TB 10K RPM SAS 12Gbps 512e 2.5in Hot-plug Hard Drive.

- Controllers
  - PERC H730P RAID Controller
  - BOSS controller card + with2 M.2 Sticks 480G (RAID 1), Blade

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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.

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.

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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 Verifying Method for Random Number Generation

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

The TPC source based DBGEN version 3.0.0 and QGEN was 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 3.0.0 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 as 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.

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3.0 Clause 3: Database System Properties

3.1 ACID Properties

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

All ACID tests were conducted according to specification. The Supporting Files Archive contains the source code of the ACID test scripts.

3.2 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.

3.2.1 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.

3.2.2 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.

3.3 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)

3.3.1 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.

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The following steps were performed to verify consistency:
1. The consistency of the ORDER and LINEITEM tables was verified based on a sample of O_ORDERKEYs.
2. At least 100 ACID Transactions were submitted.
3. The consistency of the ORDER and LINEITEM tables was re-verified.

The Consistency test was performed as part of the Durability test explained in section 3.5.

3.4 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.

3.4.1 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.

3.4.2 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.

3.4.3 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))

3.4.4 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.

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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.

3.4.5 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 to verify isolation of concurrent read and write transactions on different tables:
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.

3.4.6 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 to verify isolation of update transaction during continuous read-only query:

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.

3.5 Durability Requirements

The tested system must guarantee durability: the ability to preserve the effects of committed transactions and ensure database consistency after recovery from any one of the failures listed in Clause 3.5.2.

3.5.1 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:
1. Removal of a Log disk.
2. Removal of Data disk
3. 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.

Log Removal Test
1. The complete database was backed up.
2. The Consistency of the ORDERS and LINEITEM tables were verified.
3. Eight streams of ACID transactions were started. Each stream executed a minimum of 100 transactions.
4. While the test was running, one of the RAID-1 configured log disk (slot 1) was removed.
5. It was determined that the test kept on running. SQL Server did not error.
6. The pulled disk was replaced with a new disk. Log disk eventually completed its RAID rebuild process without any issues.

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Data Disk Removal Test

1. The complete database was backed up.
2. The Consistency of the ORDERS and LINEITEM tables were verified.
3. Eight streams of ACID transactions were started. Each stream executed a minimum of 100 transactions.
4. While the test was running, one of the data disks (Non-RAID) was removed.
5. The eight streams of ACID transactions failed and recorded their number of committed transactions in success files.
6. Stop the SQL server and start the SQL server with -f option.
7. The Database log was backed up and the Database was dropped.
8. The pulled disk was replaced with a new one.
9. Stopped the SQL Server and removed -f option.
10. Formatted the drive and Created new volume with same letter and file structure
11. Started the SQL Server, the database was restored.
12. When database restore completed, issued a command to apply the backed-up log file.
13. 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. The Consistency of the ORDERS and LINEITEM tables were verified.
2. Eight streams of ACID transactions were started. Each stream executed a minimum of 100 transactions.
3. While the streams of ACID transactions were running the System was powered off by pulling power plugs.
4. When power was restored the system booted and the Database engine was restarted.
5. The database went through a recovery period.
6. Rolled-forward, Rolled-backward transactions captured by the DB ERRORLOG file.
7. Recovery complete.
8. The counts in the history table and success files were compared and verified, and the consistency of the ORDERS and LINEITEM tables was verified.

3.5.2 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 3.5.1.

3.5.3 Memory Failure

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

See section 3.5.1

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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 PowerEdge MX740c server with the following storage configuration:
The storage system consisted of:

- 2.4TB 10K RPM SAS 12Gbps 512e 2.5in Hot-plug Hard Drive
- 3x Dell 1.6TB, NVMe, Mixed Use Express Flash, 2.5 SFF Drive, U.2, PM1725a with carrier
- PERC H730P RAID Controller
    - 2x 480GB SSD SAS Mixed Use 12Gbps 512e 2.5in Hot-Plug Drive, PM5-V
- BOSS controller card + with2 M.2 Sticks 480G (RAID 1), Blade

The drives were distributed as follows:
- 447.13 GB disks were used for the OS, DB root file
- 1490.42 GBdisks were used to hold Test DB table data, temporary database (TempDB).
- 446.63 GB disks were used to hold DB Log and tempdb log.
- 2235 GB disks were used to hold backup

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A description of distribution of database file groups and log can be found in the Table below.

# of Disks	Drive Description	RAID Format	Size (GB)	Partition Format	Drive Letter	Content
1	BOSS controller card + with2 M.2 Sticks 480G (RAID 1)	RAID 1	447.13	XFS	/var/opt/mssql	OS, SQL, Client Kit, & DB root
1	1.6TB, NVMe, Mixed Use Express Flash	No RAID	1490.42	XFS	/opt/db/data1	DB & Tempdb
1	1.6TB, NVMe, Mixed Use Express Flash	No RAID	1490.42	XFS	/opt/db/data2	DB & TempDB
1	1.6TB, NVMe, Mixed Use Express Flash	No RAID	1490.42	XFS	/opt/db/data3	DB & TempDB
2	480GB SSD SAS Mixed Use 12Gbps 512e 2.5in Hot-Plug Drive, PM5-V	RAID 1	446.63	XFS	/opt/db/log	DB Log and TempDB Log
1	2.4TB 10K RPM SAS 12Gbps	RAID 0	2235	XFS	/opt/db/backup	Backup

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 database partitions are evenly distributed across 3 spindles

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.

The database tables were hosted on three 1.6TB Dell NVMe drives. The temporary files were hosted on the same drives as the database tables. The database log files resided on a RAID-1 array of two 480GB SATA SSDs. OS on BOSS controller card + with2 M.2 Sticks 480G (RAID 1). The database backup was hosted on another RAID-0 array made of one 2.4TB HDD.

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. If a program other than DBGEN was used to populate the database, it must be disclosed in its entirety.

DBGEN version 3.0.0 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 1hr 32 min and 26 seconds.

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.

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Storage Devices	Space per Disk (GB)	Total Disk Space (GB)	Total Storage Capacity (GB)	Scale factor	Data Storage Ratio
3x1.6TB, NVMe, Mixed Use Express Flash	1490.42	4,471.26	8493.66	1,000	8.49
2x480GB SSD SAS Mixed Use 12Gbps 512e 2.5in Hot-Plug Drive, PM5-V	446.63	2235			
2.4TB 10K RPM SAS 12Gbps	2235	1,489.26			
BOSS controller card + with2 M.2 Sticks 480G (RAID 1)	447.13	894.26			

Size of test database: 1,000 GiB Data Storage Ratio: 8.49

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.

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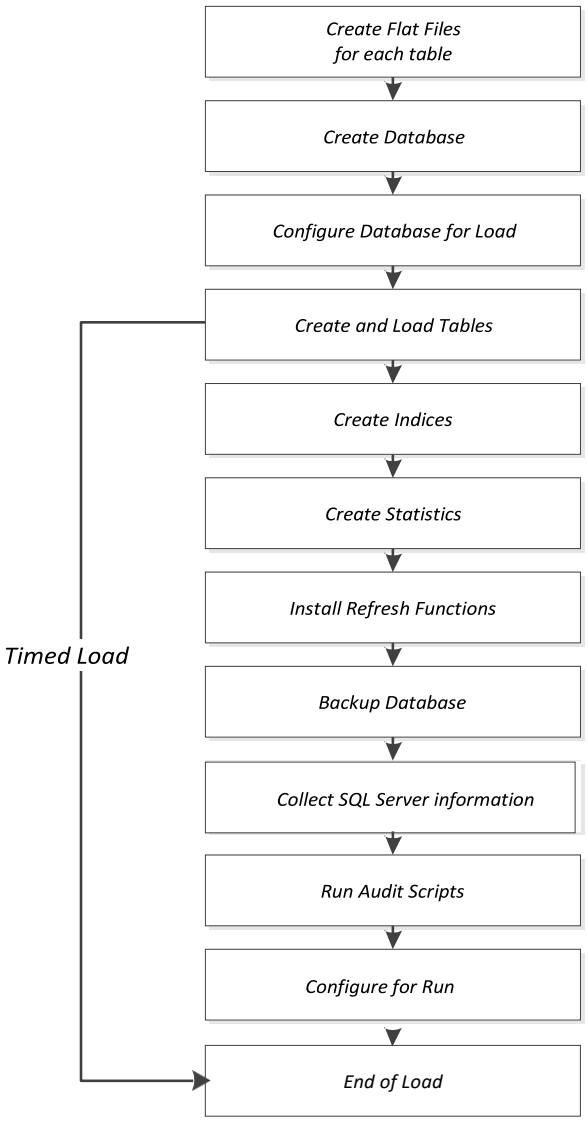

Figure 4.8: Block Diagram of Database Load Process

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.

- Available Memory=768 GB
- Scale Factor=1,000
- The memory to database size percentage=76.8%

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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.

- There were few hours between the load and the run
- Trace flag -T834 was enabled at SQL Server
- Min/Max Memory configurations were changed at SQL Server
- SQL Services were restarted to take effect of Memory and Trace flag settings

5.2 Steps in the Power Test

The details of the steps followed to implement the power test (for example, system boot, and database restart) must be disclosed.

The following steps were used to implement the power test:

- RF1 Refresh Function
- Stream 00 Execution
- RF2 Refresh Function

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.

See the Numerical Quantities Summary in the Executive Summary at the beginning of this report.

5.4 Number of Streams for The Throughput Test

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

Seven query streams and one refresh stream were used for the Throughput test.

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.

See the Numerical Quantities Summary in the Executive Summary at the beginning of this report.

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.

See the Numerical Quantities Summary in the Executive Summary at the beginning of this report.

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.

See the Numerical Quantities Summary in the Executive Summary at the beginning of this report.

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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.

See the Numerical Quantities Summary in the Executive Summary at the beginning of this report.

5.9 Performance Metrics

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

See the Numerical Quantities Summary in the Executive Summary at the beginning of this report.

5.10 The Performance Metric and Numerical Quantities from Both Runs

A description of the method used to determine the reproducibility of the measurement results must be reported. This must include the performance metrics (QppH and QthH) from the reproducibility runs.

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

Run ID	QppH@1,000GB	QthH@1,000GB	QphH@1,000GB
Run 1	970,684.0	719,943.9	835,965.3
Run 2	982,578.7	692,178.0	824,693.5

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.

There was no activity between Run1 and Run2.

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 be reported in the supporting files archive.

The supporting files archive contains the documentation.

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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.

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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.

A detailed list of all hardware and software, including the 3-year support, is provided in the Executive Summary in the Abstract section of this report. The price quotations are included 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.

A detailed list of all hardware and software, including the 3-year support, is provided in the Executive Summary in the Abstract section of this report. The price quotations are included in Appendix A. This purchase qualifies for a 44.2% discount on Chassis and 60% discount on Server from Dell Technologies.

7.3 Availability Date

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.

The total system availability date is March 3, 2021.

7.4 Orderability Date

For each of the components that are not orderable on the report date of the FDR, the following information must be included in the FDR:

- Name and part number of the item that is not orderable
- The date when the component can be ordered (on or before the Availability Date)
- The method to be used to order the component (at or below the quoted price) when that date arrives
- The method for verifying the price

All components are orderable at the time of publication date.

7.5 Country-Specific Pricing

Additional Clause 7 related items July be included in the Full Disclosure Report for each country-specific priced configuration. Country-specific pricing is subject to Clause 7.1.7.

The configuration is priced for the United States of America.

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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*
Clause 1	OS and DB parameter settings	*SupportingFilesArchive\Clause1*
Clause 2	DB creation scripts	*SupportingFilesArchive\Clause2*
Clause 3	ACID scripts, ACID output	*SupportingFilesArchive\Clause3*
Clause 4	DB Load scripts, Qualification output	*SupportingFilesArchive\Clause4*
Clause 5	Query output results	*SupportingFilesArchive\Clause5*
Clause 6	Implementation Specific layer source code	*SupportingFilesArchive\Clause6*
Clause 7	There are no files required to be included for Clause 7	*SupportingFilesArchive\Clause7*
Clause 8	Query substitution parameters, RF function source	*SupportingFilesArchive\Clause8*

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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:

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.

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InfoSizing

TPC Certified Auditor

Benchmark sponsor:

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Senior Manager, Systems Development Engineering
Dell Technologies
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Bagmane Tech Park
Bairasandra Main Rd
CV Raman Nagar
Bengaluru, Karnataka,
India 560093

March 2, 2021

I verified the TPC Benchmark H (TPC-H™ v2.18.0) performance of the following configuration:

Platform:	Dell PowerEdge MX740c Server
Operating System:	Red Hat Enterprise Linux 8
Database Manager:	Microsoft SQL Server 2019 Enterprise Edition

The results were:

Performance Metric	**824,693.5 QphH@1,000GB**
TPC-H Power	982,578.7
TPC-H Throughput	692,178.0
Database Load Time	0d 1h 32m 26s

Server	**Dell PowerEdge MX740c Server, with:**		
CPUs	2x Intel® Xeon® Platinum 8268 @2.9 GHz (24 cores, 48 threads)		
Memory	768 GiB		
Disks	***Qty***	***Size***	***Type***
	1	480 GB	Boss Controller Card + with 2 M.2 sticks (RAID 1)
	3	1.6 TB	NVMe
	2	480 GB	SAS SSD
	1	2.4 TB	10K RPM SAS 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

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- 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 7 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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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

January 27, 2021

Venkateswara Reddy Vatam
Dell
No. 65/2
Bagmane Tech Park
Bairasandra Main Rd
C V Raman Nagar
Bengaluru, Karnataka, India 560093

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 2019 Enterprise Edition 2 Core License Open Program – No Level - ERP	$13,748.00	24	$329,952.00
Database Server Operating System			
Red Hat Enterprise Linux Server, Premium (Physical or Virtual Nodes), 3 Year x 1	$3,515.20	1	$3,515.20
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 90 days.

Reference ID:TPCH_hsetmflp3693936_2019

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