

# TPC Benchmark™ E Full Disclosure Report

## HPE ProLiant DL345 Gen11

Using Microsoft SQL Server 2022 Enterprise Edition

On Microsoft Windows 2022 Standard Edition

TPC-E™ Version 1.14.0

First Edition May 8, 2023

Hewlett-Packard Enterprise believes that the information in this document is accurate as of the publication date. The information in this document is subject to change without notice. Hewlett-Packard Enterprise assumes no responsibility for any errors that may appear in this document.

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

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

All performance data contained in this report was obtained in a rigorously controlled environment. Results obtained in other operating environments may vary significantly. Hewlett-Packard Enterprise does not warrant or represent that a user can or will achieve similar performance expressed in transactions per second (tpsE ®) or normalized price/performance (\$/tpsE ®). No warranty of system performance or price/performance is expressed or implied in this report.

© Copyright Hewlett-Packard Enterprise May 8<sup>th</sup>, 2023.

All rights reserved. Permission is hereby granted to reproduce this document in whole or in part provided the copyright notice printed above is set forth in full text on the title page of each item reproduced.

Printed in U.S.A., May 8<sup>th</sup>, 2023.

HPE and HPE StorageWorks are registered trademarks of Hewlett Packard Enterprise.

Microsoft, Windows Server, and SQL Server are registered trademarks of Microsoft Corporation.

TPC Benchmark, TPC-E, and tpsE are registered certification marks of the Transaction Processing Performance Council.

AMD, AMD EPYC, and EPYC are registered trademarks of Advanced Micro Devices, Inc.

All other brand or product names mentioned herein are trademarks or registered trademarks of their respective owners.

## Abstract

HPE conducted the TPC Benchmark E (TPC-E) on the HPE ProLiant DL345 Gen11 system. This report documents the full disclosure information required by the TPC Benchmark E Standard Specification, Revision 1.14.0, including the methodology used to achieve the reported results. All testing fully complied with this revision level.

The software used on the HPE DL345 Gen11 system included Microsoft Windows Server 2022 Standard Edition and Microsoft SQL Server 2022 Enterprise Edition.

Standard metrics, transactions per second-E (tpsE™), price per tpsE (\$/tpsE) and Availability Date, are reported as required by the TPC Benchmark E Standard Specification.

The benchmark results are summarized in the following table:


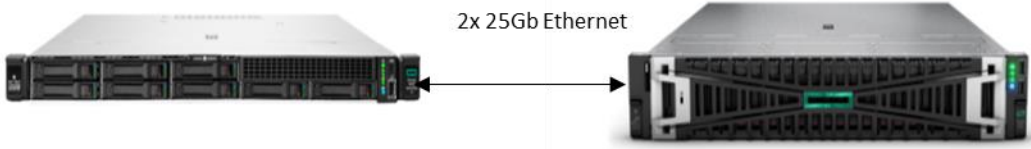
Hardware	Software	Total System Cost (\$USD)	tpsE	\$USD/tpsE	Total Solution Availability Date
HPE ProLiant DL345 Gen11	Microsoft SQL Server 2022 Enterprise Edition Microsoft Windows Server 2022 Standard Edition	\$951,612	12,	\$78.95	May 8, 2023

The Benchmark implementation and results were audited by Doug Johnson for InfoSizing ([www.sizing.com](http://www.sizing.com)). The auditor's attestation letter is contained in this report.

## Executive Summary

*The TPC Executive Summary Statement must be included near the beginning of the Report.*

The Executive Summary Statement is included on the next several pages.

 <b>Hewlett Packard Enterprise</b>	<b>HPE DL345 Gen11</b>		TPC-E™ 1.14.0 TPC Pricing 2.8.0
			Report Date: May 8, 2023 Revision Date: May 8, 2023
TPC-E Throughput <b>12,054.79</b> tpsE™	Price/Performance <b>\$78.95</b> USD per tpsE	Availability Date <b>May 8, 2023</b>	Total System Cost <b>951,612</b> USD
<b>Database Server Configuration</b>			
Operating System <b>Microsoft® Windows Server® 2022 Standard Edition</b>	Database Manager <b>Microsoft SQL Server® 2022 Enterprise Edition</b>	Processors/Cores/Threads <b>1/96/192</b>	Memory <b>1,536 GB</b>
			
<b>Tier-A (Client)</b> 1x HPE DL325 Gen10 Plus V2: <ul style="list-style-type: none"> <li>• 1x 7543P (32C) Processor</li> <li>• 8x32GB DDR4 3200MHz (256 GB total)</li> <li>• 2xM.2 240GB Sata NVMe (O/S)</li> <li>• 8x 7.6 TB NVMe (Samsung) Flat Files and Backup of DB.</li> <li>• 2xDual Port Broadcom 25 GbE Network Card (workload traffic)</li> <li>• 1xIntel Eth Adptr I350T4 OCPv3</li> </ul>		<b>HPE DL345 Gen11 (Tier-B):</b> <ul style="list-style-type: none"> <li>• 1x 9654P (96 core ) processor</li> <li>• 12x128GB DDR4 4800MHz (1.5 TB total)</li> <li>• 1x MR416i-o             <ul style="list-style-type: none"> <li>• 2x 3.2 TB NVMe drives RAID-1 O/S</li> <li>• 4x 3.2 TB NVMe drives RAID-1 Database Logs/master Database file/tempdb runtime</li> <li>• 2x 7.68 TB NVMe drives Raid-0 tempdb during build</li> </ul> </li> <li>• 2x MR416i-p each with             <ul style="list-style-type: none"> <li>• 8x 7.6 TB NVMe drives (Raid-5) containing 2 Logical Volumes</li> </ul> </li> <li>• 1xDual Port Broadcom 25 GbE Network Card (workload traffic)</li> <li>• 1xIntel Eth Adptr I350T4 OCPv3</li> </ul>	
Initial Database Size <b>49,687 GB</b>	Redundancy Level: 1 <b>RAID-10: Log, tempdb</b> <b>Raid-5: Data</b>	Storage: <b>4x 3.2TB 2.5" NVMe</b> <b>2x 3.2TB 2.5" NVMe</b> <b>16x 7.68 TB 2.5" NVMe</b>	



Hewlett Packard Enterprise


HPE DL345 Gen11

TPC-E™ 1.14.0  
TPC Pricing 2.8.0

Report Date: May 8, 2023  
Revision Date: May 8, 2023

Availability Date:  
May 8, 2023

Description	Price Key	Part Number	Unit Price	Qty	Extended Price	3 Yr Maint Price	
<b>Server Hardware</b>							
HPE DL345 Gen11 24SFF CTO Svr	1	P54206-B21	\$3,556	1	\$3,556		
AMD EPYC 9654P CPU for HPE	1	P53597-B21	\$22,951	1	\$22,951		
HPE DL3X5 Gen11 Perf 2U Heat Sink Kit	1	P58459-B21	\$256	1	\$256		
HPE 128GB 4Rx4 PC5-4800B-R 3DS Smart Kit	1	P50313-B21	\$10,999	12	\$131,988		
BCM 57414 10/25GbE 2p SFP28 Adptr	1	P26262-B21	\$1,184	1	\$1,184		
INT I350 1GbE 4p BASE-T OCP3 Adptr	1	P08449-B21	\$958	1	\$958		
HPE 1600W FS Plat Ht Plg LH PS Kit	1	P38997-B21	\$685	2	\$1,370		
HPE DL3X5 Gen11 2U Perf Fan Kit	1	P58465-B21	\$160	6	\$960		
MR416i-o Gen11 SPDM Storage Cntrl	1	P47781-B21	\$3,586	1	\$3,586		
MR416i-p Gen11 SPDM Storage Cntrl	1	P47777-B21	\$3,955	2	\$7,910		
HPE Gen 11 EI Rail Kit 2	1	P52351-B21	\$141	1	\$141		
HPE DL345 G11 4PCIE Enablement Kit	1	P57116-B21	\$666	1	\$666		
HPE 3Y TC Ess DL345 GEN11 SVC	1	H78X5E	\$3,445	1		\$3,445	
		<b>Subtotal</b>			<b>\$175,526</b>	<b>\$3,445</b>	
<b>Server Storage</b>							
HPE 3.2TB NVMe MU SFF BC U.3 PM1735a SSD	1	P50230-B21	\$6,476	6	\$38,856		
HPE 7.68 TB NVMe MU SFF BC U.3 PM1735a SSD	1	P50222-B21	\$13,900	16	\$222,400		
		<b>Subtotal</b>			<b>\$261,256</b>	<b>\$0</b>	
<b>Server Software</b>							
Windows Server 2022 Standard Editions (16 Core license)	4		\$1,069	6	\$6,414		
Microsoft SQL Server 2022 Standard Edition (2 core license)	4		\$15,123	48	\$725,904		
Microsoft Problem Resolution Services (1 Incident)	4		\$259	1		\$259	
		<b>Subtotal</b>			<b>\$732,318</b>	<b>\$259</b>	
<b>Client Hardware</b>							
HPE DL325 G10+ v2 8SFF CTO Svr	1	P38471-B21	\$1,979	1	\$1,979		
AMD EPYC 7543P CPU for HPE	1	P38717-B21	\$4,387	1	\$4,387		
HPE 32GB 1Rx4 PC4-3200AA-R Smart Kit	1	P38454-B21	\$1,661	8	\$13,288		
HPE Universal SATA 6G AIC HHHL M.2 SSD Enablement Kit	1	878783-B21	\$181	1	\$181		
HPE 240GB SATA 6G Read Intensive M.2 Multi Vendor SSD	1	P47817-B21	\$796	2	\$1,592		
BCM 57414 10/25GbE 2p SFP28 Adptr	1	P26262-B21	\$1,184	2	\$2,368		
INT I350 1GbE 4p BASE-T OCP3 Adptr	1	P08449-B21	\$958	1	\$958		
HPE 500W FS Plat Ht Plg LH Pwr Sply Kit	1	865408-B21	\$175	2	\$350		
HPE DL325 G10+ v2 Stnd FIO Fan Kit	1	P41471-B21	\$117	1	\$117		
HPE DL325 G10+ v2 High Perf FIO HS Kit	1	P41197-B21	\$95	1	\$95		
HPE DL300 G10+ 1U SFF Easy Inst Rail Kit	1	P26485-B21	\$214	1	\$214		
HPE 3Y TC Essential DL325 GEN10PLUSHWSVC	1	H29VGE	\$2,179	1		\$2,179	
		<b>Subtotal</b>			<b>\$25,529</b>	<b>\$2,179</b>	
<b>Client Software</b>							
Windows Server 2022 Standard Edition (16 Core license)	4		\$1,069	2	\$2,138		
		<b>Subtotal</b>			<b>\$2,138</b>	<b>\$0</b>	
<b>Infrastructure</b>							
HP V22v G5 FHD Monitor (1 + 2 spare)	3	65P56AA#ABA	\$ 129.99	3	\$ 389.97		
HP 225 Wired Mouse and Keyboard Combo	3	286J4UT#ABA	\$21	3	\$63		
HPE 25Gb SFP28 to SFP28 3m Direct Attach Copper Cable, 2 + 2 spare	1	844477-B21	\$392	4	\$1,568		
HPE 42U 800x1075mm Adv G2 Kit Pilt Rack	1	P9K41A	\$4,026	1	\$4,026		
HPE G2 Basic 3Ph 8.6kVA/L15-30P 24A/208V Outlets (18) C13/Vertical NA/JP PDU	1	P9Q54A	\$583	1	\$583		
		<b>Subtotal</b>			<b>\$6,630</b>	<b>\$0</b>	
		<b>Total Extended Price</b>			<b>\$1,203,397</b>	<b>\$5,883</b>	
		<b>Total Discounts</b>			<b>\$257,668</b>	<b>\$0</b>	
Price Key: 1 - HPE 2 - fs.com 3 hp.factoryoutletstore.com 4. Microsoft Audited by Doug Johnson of Sizing.com					<b>Grand Total</b>	<b>\$945,729</b>	<b>\$5,883</b>
All discounts are based on US list prices and for similar quantities and configurations. A 55% 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.					<b>3 year cost of ownership USD:</b>	<b>\$951,612</b>	
					<b>TPC-E throughput, tps E:</b>	<b>12,054.79</b>	
					<b>\$ USD/tps E:</b>	<b>\$78.95</b>	
Sales contact: HPE WW Headquarters, 3000 Hanover St., Palo Alto, CA 94304-1185 (650) 857-1501 or HPE: 855-472-5233 Microsoft Corporatin, One Microsoft Way, Redmond, WA 98052-6399 (425) 882 8080							
Prices used in TPC benchmarks reflect the actual prices a customer would pay for a one-time purchase of the stated components. Individually negotiated discounts are not permitted. Special prices based on assumptions about past or future purchases are not permitted. All discounts reflect standard pricing policies for the listed components. For complete details, see the pricing sections of the TPC benchmark specifications. If you find that the stated prices are not available according to these terms, please inform at pricing@tpc.org. Thank you.							

 <b>Hewlett Packard Enterprise</b>	<b>HPE DL345 Gen11</b>		TPC-E™ 1.14.0 TPC Pricing 2.8.0	
			Report Date: May 8, 2023 Revision Date: May 8, 2023	
			Availability Date: May 8, 2023	
<b>Numerical Quantities Summary</b>				
Reported Throughput 12054.79 tpsE		Configured Customers 6,050,000		
<b>Response Time (in seconds)</b>		<b>90th</b>		
	Minimum	Average	Percentile	Maximum
Broker-Volume	0.01	0.01	0.01	0.60
Customer-Position	0.01	0.01	0.01	1.30
Market-Feed	0.01	0.01	0.01	2.84
Market-Watch	0.01	0.01	0.01	0.45
Security-Detail	0.01	0.01	0.01	0.34
Trade-Lookup	0.01	0.03	0.05	1.53
Trade-Order	0.01	0.01	0.04	2.77
Trade-Result	0.01	0.01	0.02	9.78
Trade-Status	0.01	0.01	0.01	1.21
Trade-Update	0.01	0.03	0.05	0.92
Data-Maintenance	0.01	0.01	N/A	0.02
<b>Transaction Mix</b>		Transaction Count		Mix %
Broker-Volume	42,522,427		4.900%	
Customer-Position	112,814,803		13.000%	
Market-Feed	8,679,453		1.000%	
Market-Watch	156,205,307		18.000%	
Security-Detail	121,493,133		14.000%	
Trade-Lookup	69,424,422		8.000%	
Trade-Order	87,648,313		10.100%	
Trade-Result	86,794,522		10.001%	
Trade-Status	164,883,613		19.000%	
Trade-Update	17,356,072		2.000%	
Data-Maintenance	120		N/A	
<b>Test Duration and Timings</b>				
Ramp-up Time (hh:mm:ss)			0:22:00	
Measurement Interval (hh:mm:ss)			2:00:00	
Business Recovery Time (hh:mm:ss)			0:27:11	
Total Number of Transactions Completed in Measurement Interval			867,822,065	

# Table of Contents

- Abstract ..... iii
- Executive Summary ..... iii
- Table of Contents ..... vii
- Clause 0 – Preamble ..... 1
  - Introduction ..... 1
  - Goal of the TPC-E Benchmark ..... 1
  - Restrictions and Limitations ..... 2
- Clause 1 – Introduction..... 3
  - Benchmark Sponsor ..... 3
  - Configuration Diagrams ..... 3
    - Measured Configuration ..... 3
    - Figure 1-1. Measured Configuration ..... 3
    - Priced Configuration ..... 3
    - Differences between the Priced and Measured Configurations..... 3
    - Substitution..... 4
  - Hardware and Software Configuration Steps..... 4
- Clause 2 –Database Design, Scaling, and Population ..... 5
  - Database Creation and Table Definitions ..... 5
  - Database Physical Organization ..... 5
  - Horizontal/Vertical Partitioning ..... 6
  - Replication..... 6
  - Table Attributes..... 6
  - Cardinality of Tables..... 6
  - Distribution of Tables, Partitions and Logs..... 8
    - Table 2-2. Data distribution for the Measured and Priced Configurations..... 8
  - Database Interface and Data Model Implemented..... 9
  - Database Load Methodology ..... 9
- Clause 3 – Transaction Related Items ..... 10
  - Vendor-Supplied Code ..... 10
  - Database Footprint ..... 10
- Clause 4 – SUT, Driver, and Network ..... 11

Network Configuration.....	11
Clause 5 – EGen .....	12
EGen Version.....	12
EGen Code and Modifications.....	12
EGen Files.....	12
Clause 6 – Performance Metrics and Response Time .....	13
EGen Driver Instances .....	13
Reported Throughput.....	13
Throughput vs. Elapsed Time for Trade-Result Transaction .....	13
<i>Figure 6-1. Test Run Graph</i> .....	13
Steady State Methodology.....	13
Work Performed During Steady State.....	14
Transaction Statistics.....	14
Clause 7 – Transaction and System Properties.....	16
Atomicity Requirements .....	16
Consistency Requirements.....	16
Isolation Requirements .....	17
Durability Requirements .....	17
Data Accessibility .....	17
Business Recovery.....	19
Clause 8 – Pricing.....	22
60-Day Space.....	22
Configuration Components .....	23
Pricing Methodology .....	24
Pricing Locale.....	24
Currency Conversions.....	24
Pricing Calculations .....	24
Total Price.....	24
Availability Date .....	25
Supporting Files Index .....	25
Auditor’s Attestation Letter .....	25
Appendix A – Price Quotes .....	28



# Clause 0 – Preamble

## Introduction

TPC Benchmark E (TPC-E) is an On-Line Transaction Processing (OLTP) workload. It is a mixture of read-only and update intensive transactions that simulate the activities found in complex OLTP application environments. The database schema, data population, transaction, and implementation rules have been designed to be broadly representative of modern OLTP systems. The benchmark exercises a breadth of system components associated with such environments., which are characterized by:

- The simultaneous execution of multiple transaction types that span a breadth of complexity
- Moderate system and application execution time
- A balanced mixture of disk input/output and processor usage
- Transaction integrity (ACID properties)
- A mixture of uniform and non-uniform data access through primary and secondary keys
- Databases consisting of many tables with a wide variety of sizes, attributes, and relationships with realistic content
- Contention on data access and update.

The TPC-E operations are modeled as follows: The database is continuously available 24 hours a day, 7 days a week, for data processing from multiple sessions and data modifications against all tables, except possibly during infrequent (e.g., once a month) maintenance sessions. Due to the worldwide nature of the application modeled by the TPC-E benchmark, any of the transactions may be executed against the database at any time, especially in relation to each other.

## Goal of the TPC-E Benchmark

The TPC-E benchmark simulates the OLTP workload of a brokerage firm. The focus of the benchmark is the central database that executes transactions related to the firm's customer accounts. In keeping with the goal of measuring the performance characteristics of the database system, the benchmark does not attempt to measure the complex flow of data between multiple application systems that would exist in a real environment.

This mixture and variety of transactions being executed on the benchmark system is designed to capture the characteristic components of a complex system. Different transaction types are defined to simulate the interaction of the firm with its customers as well as its business partners. Different transaction types have varying run-time requirements.

The benchmark defines:

- Two types of transactions to simulate Consumer-to-Business as well as Business-to-Business activities
- Several transactions for each transaction type
- Different execution profiles for each transaction type
- A specific run-time mix for all defined transactions

For example, the database will simultaneously execute transactions generated by systems that interact with customers along with transactions that are generated by systems that interact with financial markets as well as administrative systems. The benchmark system will interact with a set of driver systems that simulate the various sources of transactions without requiring the benchmark to implement the complex environment.

The performance metric reported by TPC-E is a “business throughput” measure of the number of completed Trade-Result transactions processed per second. Multiple transactions are used to simulate the business activity of processing a trade, and each transaction is subject to a response time constraint. The performance metric for the benchmark is expressed in transactions-per-second-E (tpsE). To be compliant with the TPC-E standard, all references to tpsE results must include the tpsE rate, the associated price-per-tpsE, and the availability date of the priced configuration.

TPC-E uses terminology and metrics that are similar to other benchmarks, originated by the TPC and others. Such similarity in terminology does not imply that TPC-E results are comparable to other benchmarks. The only benchmark results comparable to TPC-E are other TPC-E results that conform to a comparable version of the TPC-E specification.

## Restrictions and Limitations

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

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

## Clause 1 – Introduction

### Benchmark Sponsor

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

This benchmark was sponsored by Hewlett Packard Enterprise.

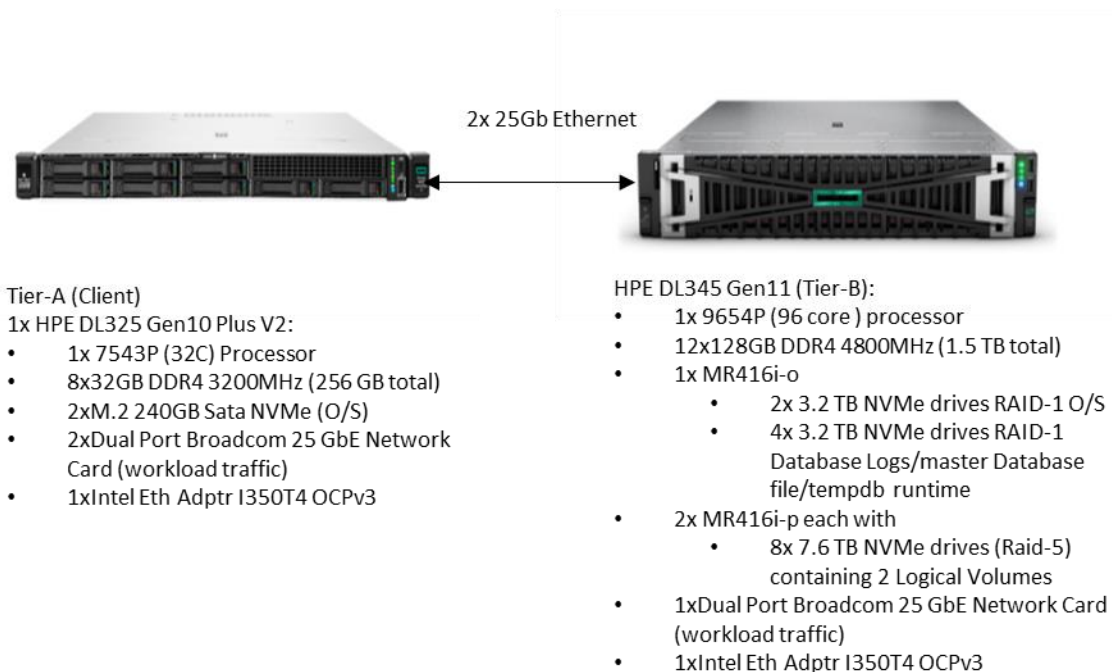
### Configuration Diagrams

*Diagrams of both Measured and Priced Configurations must be reported in the Report, accompanied by a description of the differences.*

### Measured Configuration

The measured configuration is shown in Figure 1-1.

Figure 1-1. Measured Configuration



### Priced Configuration

The Priced configuration is shown above in the Executive Summary

### Differences between the Priced and Measured Configurations

Compared to the Priced Configuration, the Measured Configuration had multiple extra NVMe drives (two in Tier-B used for TempDB during load, 8 in Tier-A used solely for Backup of database). None of these drives were used during the benchmark runs.

## Substitution

*Some hardware components of the Priced Configuration may be substituted after the Test Sponsor has demonstrated to the Auditor's satisfaction that the substituting components do not negatively impact the Reported Throughput. All substitutions must be reported in the Report and noted in the Auditor's Attestation Letter. Any information and/or measurement results used to prove the validity of a component substitution must be included in the section of the FDR that describes the difference between the Measured Configuration and the Priced Configuration. Original and substituted components must be clearly identified.*

No component substitutions were made.

## Hardware and Software Configuration Steps

*A description of the steps taken to configure all of the hardware and software must be reported in the Report.*

*Any and all configuration scripts or step by step GUI instructions are reported in the Supporting Files (see Clauses 9.4.1 and 9.4.1.2). The description, scripts and GUI instructions must be sufficient such that a reader knowledgeable of computer systems and the TPC-E specification could recreate the hardware and software environments.*

Detailed instructions for installing and configuring the SUT hardware and software are included in the supporting files.

- Information specific to the Tier A client can be found in:  
SupportingFiles\Introduction\TierA\_Client\_Setup.pdf
- Information specific to the Tier B database server can be found in:  
SupportingFiles\Introduction\TierB\_Server\_Setup.pdf

## Clause 2 –Database Design, Scaling, and Population

### Database Creation and Table Definitions

*A description of the steps taken to create the database for the Reported Throughput must be reported in the Report. Any and all scripts or step by step GUI instructions are reported in the Supporting Files (see Clause 9.4.2). The description, scripts, and GUI instructions must be sufficient such that a reader knowledgeable of database software environments and the TPC-E specification could recreate the database.*

The database was created and populated using the Microsoft TPC-E benchmark kit. Instructions for doing so are included in the supporting files. See SupportingFiles\Clause2\MSTPCE Database Setup and Reference.pdf.

Changes and customizations were made to some of the kit files. First, the filegroups the database was eventually loaded onto were reduced from three filegroups to two. All the database items that would have been loaded onto the scaling\_fg were loaded instead onto the fixed\_fg. During the load process the News\_Item table is initially loaded onto the scaling\_fg, but during the conversion of NI\_ITEM from varchar to varbinary the table gets moved into the fixed\_fg and the scaling\_fg with all of it's files gets removed from the tpce database.

A second type of change is that all tables that get loaded through the BCP process were rebuilt using the following sql command:

- ALTER TABLE <table\_name> REBUILD

This was done by modifying the VBS script in the kit.

The modified kit files are included as part of SupportingFiles\Clause2:

- Scripts\Utility\Create\_TID\_Ranges\_Table.sql
- Scripts\DDL\Create\_Indexes\_Scaling\_Tables.sql
- Scripts\DDL\Create\_Tables\_Scaling.sql
- Scripts\DDL\RebuildTables.sql
- Scripts\DDL\RebuildTradeHistory.sql
- Scripts\DDL\Convert\_NI\_ITEM\_Data.sql
- SetupVBS\setup\_tpce.vbs

The files that were customized for this specific SUT hardware are included in the folder SupportingFiles\Clause2\6050000.Cust\:

- Create\_Database.sql creates the filegroups and their underlying files for the tpce database.
- Flatfile.txt: defines the locations of the flat files during the database load.
- Backup\_Database.sql: backs up the tpce database to the backup devices.
- TempDB\_load.sql: creates the tempdb files used during the load of the tpce database.
- ShrinkTempdb.sql: removes the tempdb files that were only used for the loading of the database.

### Database Physical Organization

*The physical organization of tables and User-Defined Objects, within the database must be reported in the Report.*

The following tables and related indexes were on the growing\_fg filegroup:

- CASH\_TRANSACTION
- SETTLEMENT
- TRADE

- TRADE\_HISTORY
- TRADE\_REQUEST
- HOLDING
- HOLDING\_HISTORY
- HOLDING\_SUMMARY

The remaining tables and their corresponding indexes were all on the fixed\_fg filegroup.

### Horizontal/Vertical Partitioning

*While few restrictions are placed upon horizontal or vertical partitioning of tables and rows in the TPC-E benchmark (see Clause 2.3.3), any such partitioning must be reported in the Report.*

Partitioning was not used for this benchmark.

### Replication

*Replication of tables, if used, must be reported in the Report (see Clause 2.3.4).*

Replication was not used for this benchmark.

### Table Attributes

*Additional and/or duplicated columns in any table must be reported in the Report along with a statement on the impact on performance (see Clause 2.3.5).*

No additional attributes were used for this benchmark.

### Cardinality of Tables

*The cardinality (e.g., the number of rows) of each table, as it existed after database load (see Clause 2.6), must be reported in the Report.*

The database was built with 6,050,000 customers. The cardinality is shown in Table 2-1.

**Table 2-1. Initial Cardinality of Tables**

Table Name	Rows
ACCOUNT_PERMISSION	42,952,600
ADDRESS	9,075,004
BROKER	60,500
CASH_TRANSACTION	96,180,381,553
CHARGE	15
COMMISSION_RATE	240
COMPANY	3,025,000
COMPANY_COMPETITOR	9,075,000
CUSTOMER	6,050,000
CUSTOMER_ACCOUNT	30,250,000
CUSTOMER_TAXRATE	12,100,000
DAILY_MARKET	5,408,246,250
EXCHANGE	4
FINANCIAL	60,500,000
HOLDING	5,352,289,951
HOLDING_HISTORY	140,106,646,527
HOLDING_SUMMARY	300,875,731
INDUSTRY	102
LAST_TRADE	4,144,250
NEWS_ITEM	6,050,000
NEWS_XREF	6,050,000
SECTOR	12
SECURITY	4,144,250
SETTLEMENT	104,544,000,000
STATUS_TYPE	5
TAXRATE	320
TRADE	104,544,000,000
TRADE_HISTORY	250,905,666,560
TRADE_REQUEST	0
TRADE_TYPE	5
WATCH_ITEM	605,004,786
WATCH_LIST	6,050,000
ZIP_CODE	14,741

## Distribution of Tables, Partitions and Logs

*The distribution of tables, partitions and logs across all media must be explicitly depicted for the Measured and Priced Configurations.*

The OS was stored on one RAID-1 Array create on two 3.2 TB 3.5” NVMe in the server accessed by the MR416i-o Controller in an OCP Slot 22. The OS partition was formatted NTFS.

The database log, runtime-tempdb files, and the tpce database Master database file (MDF) were all stored on a RAID-10 array created on four 3.2TB 3.5” NVMe drives in the server accessed by the MR416i-o controller in OCP Slot 22. There as a single partition on this array, which was formatted with NTFS.

The database data was stored on two 8-drive RAID-5 arrays created on sixteen 7.68TB 2.5” NVMe drives in the server accessed by two MR416i-P controllers in PCIe slots 2 and 5. Each array has two logical volumes on them, each volume is created with a capacity of 24.45 TiB. Each volume consists of a single partition which was formatted NTFS. On each NTFS volume a single file for the fixed\_fg filegroup and two files for the growing\_fg filegroup.

No extra storage was required to meet the 60-day space requirements.

In addition to the priced configuration elements described above, the measured configuration included additional hardware that was used during the database load procedures and to hold the database backup files. This hardware performed no function during the benchmark runs:

- Two 7.68 TB 2.5” NVMe drives were connected to the MR416i-o controller in OCP slot 22. Drive bays 7 and 8. Each drive was treated by the controller as a JBOD drive and presented to the O/S. They each contained one partition and were formatted NTFS. These two drives were used for the tempdb files during the database load.
- Eight 6.4TB 2.4” TB NVMe drives were put in the internal drive bays of the DL325 Gen10 Plus V2 (Tier A) system. A simple striped drive was configured across all 8 of these devices. Which was then formatted with NTFS. This striped drive was used to store the database backup.
- Enough storage was attached to the driver system to hold the flat files for the database build.

Adapter write caching was disabled for all controllers and arrays.

Further details on the storage configuration are available in the supporting files. See the files in the directory SupportingFiles\Intro\TierB.

Table 2.2 depicts the database configuration of the measured and priced systems to meet the 8-hour steady state requirement.

Table 2-2. Data distribution for the Measured and Priced Configurations

Disk#	Controller	Drives RAID Level (Pricing)	Partition (File System)	Size	Use
0	MR416i-p #1	8x 7.68 TB NVMe RAID-5	E: (NTFS)	25039.05 GB	fixed_fg, growing_fg
1	MR416i-p #1	8x 7.68 TB NVMe RAID-5	F: (NTFS)	25034.98 GB	fixed_fg, growing_fg
2	MR416i-p #2	8x 7.68 TB NVMe RAID-5	G: (NTFS)	25039.05 GB	fixed_fg, growing_fg
3	MR416i-p #2	8x 7.68 TB NVMe RAID-5	H: (NTFS)	25034.98 GB	fixed_fg, growing_fg
4	MR416i-o	1x 7.68 TB NVMe RAID-0 (measured)	I: (NTFS)	7153.94 GB	Load space
5	MR416i-o	1x 7.68 TB NVMe RAID-0 (measured)	J: (NTFS)	7153.94 GB	Load space
6	MR416i-o	2x 3.2 TB NVMe (RAID-1)	C: (NTFS)	2979.63 GB	OS
7	MR416i-o	4x 3.2 TB NVMe (RAID-10)	D: (NTFS)	5960.61 GB	Tpce log, master data file, tempdb



## Database Interface and Data Model Implemented

*A statement must be provided in the Report that describes:*

- *The Database Interface (e.g., embedded, call level) and access language (e.g., SQL, COBOL, read/write) used to implement the TPC-E transactions. If more than one interface/access language is used to implement TPC-E, each interface/access language must be described, and a list of which interface/access language is used with which Transaction type must be reported.*
- *The data model implemented by the DBMS (e.g., relational, network, hierarchical).*

Microsoft SQL Server 2022 Enterprise Edition is a relational database. The interface used was Microsoft SQL Server stored procedures accessed with Remote Procedure Calls embedded in C++ code using the Microsoft ODBC interface.

## Database Load Methodology

*The methodology used to load the database must be reported in the Report.*

The database was loaded using the flat files option on the EGenLoader command line. This generates the flat files first, then bulk inserts the data into the tables. A further description is provided in the Supporting Files (SupportingFiles\Clause2\MSTPCE Database Setup Reference.pdf).

## Clause 3 – Transaction Related Items

### Vendor-Supplied Code

*A statement that vendor-supplied code is functionally equivalent to Pseudo-code in the specification (see Clause 3.2.1.6) must be reported in the Report.*

The stored procedure code for the transactions was functionally equivalent to the pseudo-code. The stored procedures can be seen in the Supporting Files (SupportingFiles\Clause3\StoredProcedures).

The code to interface the stored procedures can be found in:

- SupportingFiles\Clasue3\BaseServer
- SupportingFiles\Clause3\TransactionsSP
- SupportingFiles\Clause3\TxnHarness

### Database Footprint

*A statement that the database footprint requirements (as described in Clause 3.3) were met must be reported in the Report.*

The database footprint requirements were met.

## Clause 4 – SUT, Driver, and Network

### Network Configuration

*The network configuration of both the Measured and Priced Configurations must be described and reported in the Report. This includes the mandatory Network between the Driver and Tier A (see Clause 4.1.3.12).*

The network configurations of the measured and priced configurations were the same. Refer to Figure 1-1 for a diagram of the network connections.

The Tier A client has eight ethernet ports. Four of these are provided by the onboard quad-port 1 Gb OCP Ethernet Adapter, and the remaining four are provided by two dual port 25 PCI-e Ethernet adapters.

The Tier B database server has six ethernet ports. Four of these are provided by the onboard quad port 1GbE OCP Ethernet Adapter, and the remaining two are provided by a dual port 25 Gb PCI-e Ethernet Adapter.

The Tier A client and Tier B database server are connected by two 25Gb SFP28 to SFP28 3m Direct Attach Copper Cables. On the Tier A client side these cables were connected to two 25 Gb ports, one in each 25Gb Adapter. On the Tier B database side these cables were both connected to the two 25GbE ports on the 25 Gb Adapter.

Two more 25Gb SFP28 to SFP28 3m Direct Attach Copper Cables were connected between the Tier A client and the Driver. These cables were plugged into the other 25Gb ports on the two 25Gb Adapters in the Tier A client. These networks, which fulfill the mandatory network between the Driver and Tier A, were used by the client to report its results to the Driver as a benchmark run was underway.

Another network connected the Driver, the Tier B database server, the Tier A client, and a time server. This network, which was connected via a 1 Gb Switch, used one of the onboard ethernet ports on the Tier A client and on the Tier B database server. It was used for miscellaneous file sharing and time synchronizing. It was not used during a benchmark run.

## Clause 5 – EGen

### EGen Version

*The version of EGen used in the benchmark must be reported in the Report (see Clause 5.3.1).*

EGen v1.14.0 was used in the benchmark.

### EGen Code and Modifications

*A statement that all required TPC-provided EGen code was used in the benchmark must be reported in the Report.*

*If the Test Sponsor modified EGen, a statement EGen has been modified must be reported in the Report. All formal waivers from the TPC documenting the allowed changes to EGen must also be reported in the Report (see Clause 5.3.7.1). If any of the changes to EGen do not have a formal waiver that must also be reported in the Report.*

*If the Test Sponsor extended EGenLoader (as described in Appendix A.6), the use of the extended EGenLoader and the audit of the extension code by and Auditor must be reported in the Report (see Clause 5.7.4).*

All required TPC-provided EGen code was used in the benchmark.

EGen was not modified for this benchmark.

EGenLoader was not extended for this benchmark.

### EGen Files

*The make/project files used to compile/link EGenLoader and EGenValidate must be reported in the Supporting Files. The compiler/linker options and flags used to compile/link EGen Objects for the SUT must be reported in the Supporting Files.*

See the supporting files directory SupportingFiles\Clause3\prj for the files related to EGenLoader and EGenValidate.

See the supporting files directory SupportingFiles\Clause3\SUT\_CE\_Server for the files related to the SUT\_CE\_Server.

See the supporting files directory SupportingFiles\Clause3\SUT\_MEE\_Server for the files related to the SUT\_MEE\_Server.

## Clause 6 – Performance Metrics and Response Time

### EGen Driver Instances

The number of EGenDriverMEE and EGenDriverCE instances used in the benchmark must be reported in the Report (see Clause 6.2.5).

There were 12 EGenDriverCEs with a total of 720 EGenDriverCE instances used in the benchmark.

There were 12 EGenDriverMEEs with a dynamic number of instances used in the benchmark.

### Reported Throughput

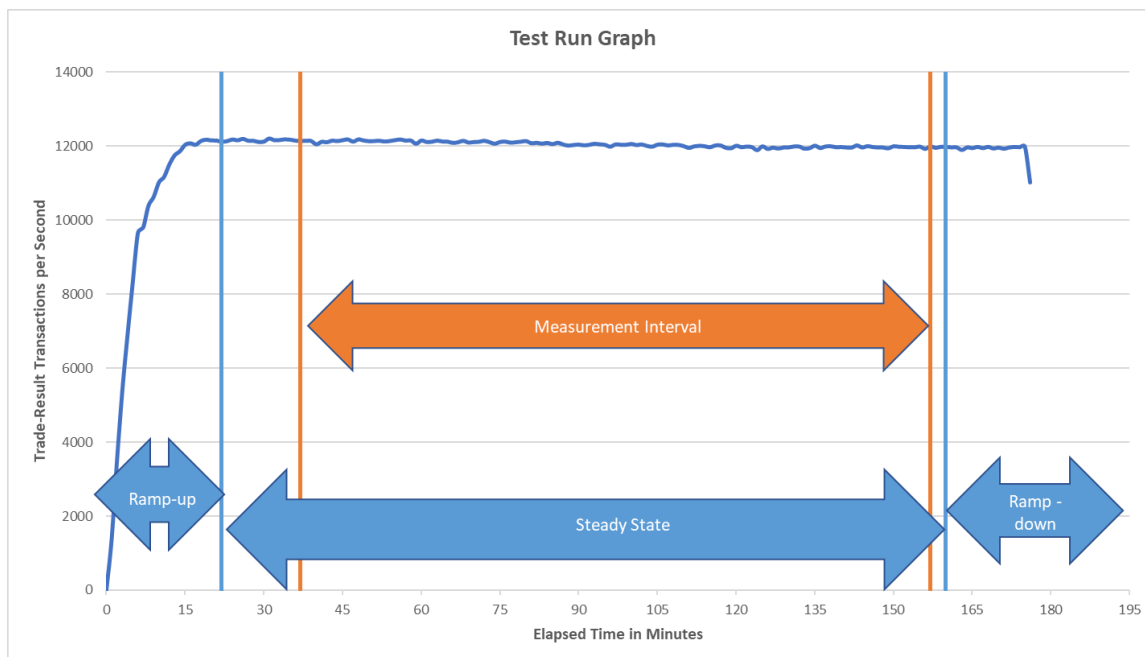
The Reported Throughput must be reported in the Report (see Clause 6.7.1.2).

The Reported Throughput was 12,054.79 tpsE.

### Throughput vs. Elapsed Time for Trade-Result Transaction

A Test Run Graph of throughput versus elapsed wall clock time must be reported in the Report for the Trade-Result Transaction (see Clause 6.7.2).

Figure 6-1. Test Run Graph



### Steady State Methodology

The method used to determine that the SUT had reached a Steady State prior to commencing the Measurement Interval must be reported in the Report.

During the run, Steady State was determined by observation of the Trade-Result transactions per second. After the run, Steady State was confirmed by:

1. Looking at the Test Run Graph and verifying that the Trade-Result transactions per second was steady prior to commencing the Measurement Interval.
2. Calculating the average Trade-Result transactions per second over 60-minute windows during Steady State, with the start of each window 10 minutes apart. Then it was confirmed that the minimum 60-minute average Trade-Result transactions per second was not less than 98% of the Reported Throughput, and that the maximum 60-minute average Trade-Result transactions per second was not greater than 102% of the Reported Throughput.
3. Calculating the average Trade-Result transactions per second over 10-minute windows during Steady State, with the start of each window 1 minute apart. Then it was confirmed that the minimum 10-minute average Trade-Result transactions per second was not less than 80% of the Reported Throughput, and the maximum 10-minute average Trade-Result transactions per second was not greater than 120% of the Reported Throughput.

### Work Performed During Steady State

*A description of how the work normally performed during a Test Run, actually occurred during the Measurement Interval must be reported in the Report (For example checkpointing, writing Undo/Redo Log records, etc.).*

Checkpoints had a duration of 430 seconds and were run scheduled to run every 447 seconds via batch scripts.

Data-Maintenance was run every 60 seconds.

### Transaction Statistics

*The recorded averages over the Measurement Interval for each of the Transaction input parameters specified by the clause 6.4.1 must be reported in the Report.*

*Table 6-1 contains the transaction statistics.*

Table 6-1. Transaction Statistics

Transaction	Input Parameter	Actual Percentage	Required Range
Customer-Position	By Tax ID	50.00%	48% to 52%
	Get History	50.00%	48% to 52%
Market-Watch	By Watch List	60%	57% to 63%
	By Customer Account	35%	33% to 37%
	By Industry	5%	4.5% to 5.5%
Security-Detail	Access LOB	1.00%	0.9% to 1.1%
Trade-Lookup	Frame 1	30.00%	28.5% to 31.5%
	Frame 2	30.01%	28.5% to 31.5%
	Frame 3	30.00%	28.5% to 31.5%
	Frame 4	10.00%	9.5% to 10.5%
Trade Order	By Non-Owner	9.99%	9.50% to 10.50%
	By Company Name	40.00%	38% to 42%
	Buy on Margin	8.00%	7.5% to 8.5%
	Rollback	0.99%	0.94% to 1.04%
	LIFO	35.00%	33% to 37%
	Trade QTY 100	25.00%	24% to 26%
	Trade QTY 200	25.00%	24% to 26%
	Trade QTY 400	25.01%	24% to 26%
	Trade QTY 800	25.00%	24% to 26%
	Market Buy	30.01%	39.7% to 30.3%
	Market Sell	30.00%	39.7% to 30.3%
	Limit Buy	19.99%	19.8% to 20.2%
	Limit Sell	10.00%	9.9% to 10.1%
Stop Loss	10.00%	9.9% to 10.1%	

## Clause 7 – Transaction and System Properties

*The ACID (Atomicity, Consistency, Isolation, and Durability) properties of transaction processing systems must be supported by the System Under Test during the running of this benchmark. It is the intent of this section to define the ACID properties informally and to specify a series of tests that must be performed to demonstrate that these properties are met.*

*The results of the ACID tests must be reported in the Report along with a description of how the ACID requirements were met, and how the ACID tests were run.*

### Atomicity Requirements

*The System Under Test must guarantee that Database Transactions are atomic; the system will either perform all individual operations on the data or will ensure that no partially completed operations leave any effects on the data.*

All ACID tests were conducted according to specification. The following steps were performed to verify the Atomicity of the Trade-Order transactions:

- *Perform a market Trade-Order Transaction with the roll\_it\_back flag set to 0. Verify that the appropriate rows have been inserted in the TRADE and TRADE\_HISTORY tables.*
- *Perform a market Trade-Order Transaction with the roll\_it\_back flag set to 1. Verify that no rows associated with the rolled back Trade-Order have been added to the TRADE and TRADE\_HISTORY tables.*

The procedure for running the Atomicity tests is documented in the Supporting Files (SupportingFiles\Clause7\MSTPCE ACID Procedures.pdf).

The atomicity scripts and outputs are located in the Supporting Files (SupportingFiles\Clause7\Atomicity).

### Consistency Requirements

*Consistency is the property of the Application that requires any execution of a Database transaction to take the database from one consistent state to another. A TPC-E database when first populated by EGenLoader must meet these consistency conditions.*

*These three consistency conditions must be tested after initial database population and after any Business Recovery tests.*

#### **Consistency condition 1**

*Entries in the BROKER and TRADE tables must satisfy the relationship:*

*B\_NUM\_TRADES=count(\*)*

*For each broker defined by:*

*(B\_ID = CA\_B\_ID) and (CA\_ID = T\_CA\_ID) and (T\_ST\_ID="CMPT").*

#### **Consistency condition 2**

*Entries in the BROKER and TRADE tables must satisfy the relationship:*

*B\_COMM\_TOTAL=sum(T\_COMM)*

*For each broker defined by:*

*(B\_ID=CA\_B\_ID and (CA\_ID=T\_CA\_ID) and (T\_ST\_ID="CMPT").*



### **Consistency condition 3**

*Entries in the HOLDING\_SUMMARY and HOLDING tables must satisfy the relationship:*

*HS\_QTY=sum(H\_QTY)*

*For each holding summary defined by:*

*(HS\_CA\_ID=H\_CA\_ID) and (HS\_S\_SYMB=H\_S\_SYMB).*

Consistency conditions 1, 2, and 3 were tested using a batch file to issue queries to the database after the database was loaded and after the Business Recovery Test. The results of the queries demonstrated that the database was consistent for all three tests.

The procedure for running the consistency tests is documented in the Supporting Files (SupportingFiles\Clause7\MSTPCE ACID Procedures.pdf).

The consistency scripts and outputs are located in the Supporting Files (SupportingFiles\Clause7\Consistency).

### **Isolation Requirements**

*The isolation property of a Transaction is the level to which it is isolated from the actions of other concurrently executing Transactions.*

*Systems that implement Transaction isolation using a locking and/or versioning scheme must demonstrate compliance with the isolation requirements by executing the tests described in Clause 7.4.2. These isolation tests are designed to verify that the configuration and implementation of the System Under Test provides the Transactions with the required isolation levels defined in Clause 7.4.1.3.*

Isolation test 1 through 4 were successfully done following the procedure documented in the Supporting Files (SupportingFiles\Clause7\MSTPCE ACID Procedures.pdf).

The isolation scripts and outputs are located in the Supporting Files (SupportingFiles\Clause7\Isolation).

### **Durability Requirements**

*The SUT must provide Durability. In general, state that persists across failures is said to be Durable and an implementation that ensures state persists across failures is said to provide Durability. In the context of the benchmark, Durability is more tightly defined as the SUT's ability to ensure all Committed data persist across any Single Point of Failure.*

### **Data Accessibility**

*The System Under Test must be configured to satisfy the requirements for Data Accessibility. Data Accessibility is demonstrated by the SUT being able to maintain database operations with full data access after the permanent irrecoverable failures of any single Durable Medium containing database tables, recovery log data, or Database Metadata. Data Accessibility tests are conducted by inducing failures of Durable Media within the SUT. The failures of Clause 7.6.3 test the ability of the SUT to maintain access to the data. The specific failures addressed in Clause 7.6.3 are defined sufficiently significant to justify demonstration of Data Accessibility across such failures. However, the limited nature of the tests listed must not be interpreted to allow other unrecoverable single points of failure.*

*The Test Sponsor must report in the Report the Redundancy Level (see Clause 7.6.3.4) and describe the Data Accessibility test(s) used to demonstrate compliance. A list of all combinations of Durable Media technologies tested in Clause 7.6.3.5 must be reported in the Report.*

*A Data Accessibility Graph for each run demonstrating a Redundancy Level must be reported in the Report (see Clause 7.6.4.2).*

This benchmark result used Redundancy Level 1. The test for Redundancy Level 1 is the test for permanent irrecoverable failure of any single Durable Medium.

The combinations of Durable Media technologies that were tested are shown in table 7-1. All unique combinations that contained database data, the database log, and/or the tempdb database were tested.

*Table 7-1. Combinations of Durable Media Technologies Tested for Data Accessibility*

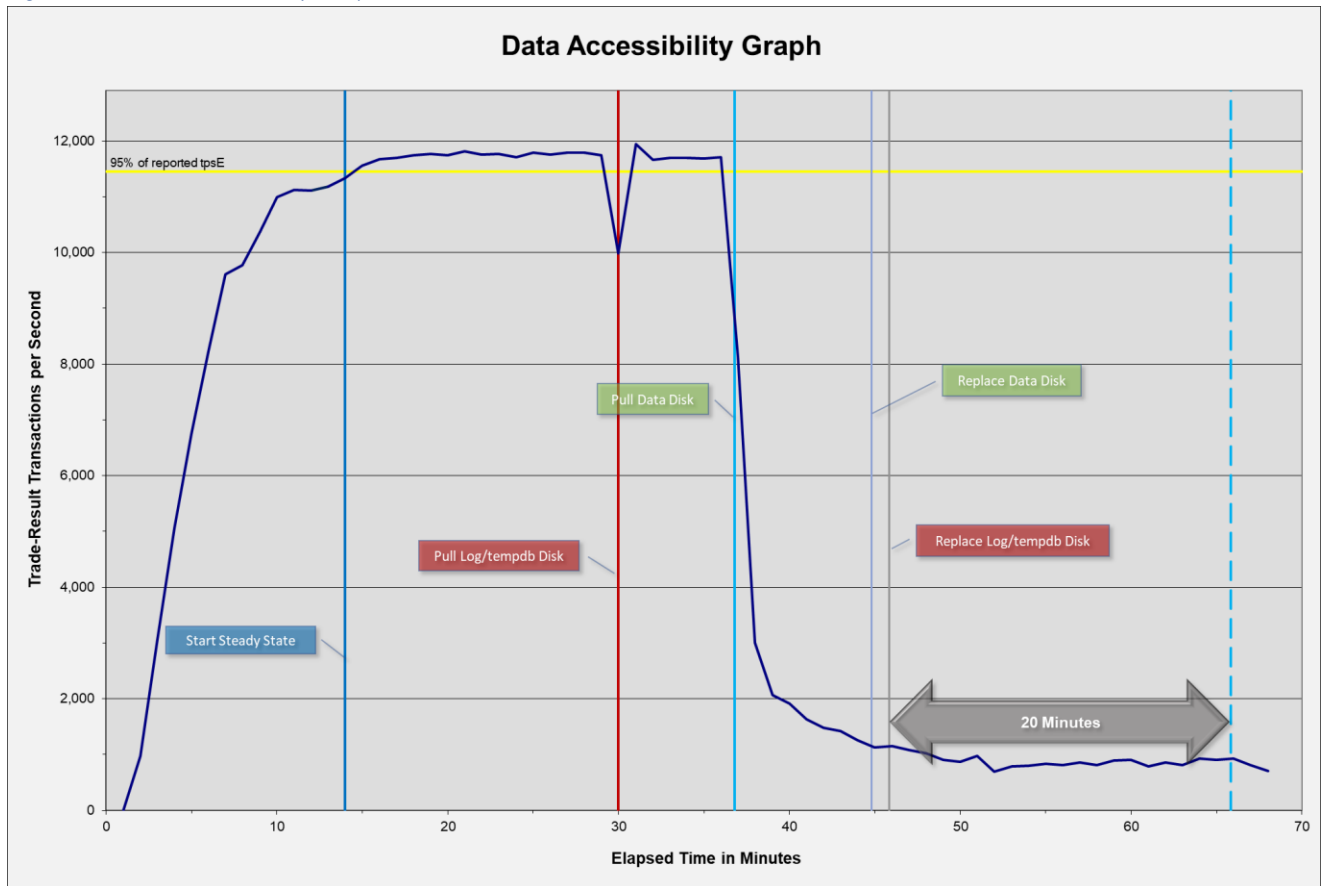
Contents	Durable Media Type	Array Redundancy	Controller
Database Data	NVMe	RAID-5	MR416i-p (PCI-e slot 5)
Database log & TempDB	NVMe	RAID-10	MR416i-o

To prove Redundancy Level 1, the following steps were performed:

1. Restored the database to its freshly loaded, known consistent state.
2. Determined the current number of completed trades in the database by running `select count(*) from SETTLEMENT (settlement count1)`.
3. Started a run, using the profile from the measured run, with checkpoints, and met the Data Accessibility Throughput Requirements for at least 5 minutes.
4. Induced the first failure, by physically removing a drive from the server. In this case the drive contained Database log and TempDB. Since the array was RAID protected, transactions continued to be processed.
5. Waited until the Data Accessibility Throughput Requirements were met again for at least 5 minutes.
6. Induced the second failure, by physically removing a drive from the Server connected to the MR416i-p controller in PCI-e slot 5. This controller's drives contained database data. Since the Array is RAID protected, transactions continued to be processed.
7. After a few minutes, a new drive was inserted into the system to replace the failed data drive. The array rebuilding process was started.
8. After a few more minutes a new drive was inserted into the system to replace the failed log/tempdb drive. The array rebuilding process was started.
9. Continued running the benchmark for at least 20 minutes.
10. Terminated the run gracefully.
11. Determined the new number of completed trades in the database by running `select count(*) from SETTLEMENT (settlement count2)`.
12. Verified that  $(count2-count1)$ , which is the number of actual completed Trade-Result Transactions done during the run, equaled the number of successful Trade-Result transactions reported by the Driver.
13. Allowed the recovery process to complete.

Figure 7-1 is a graph of the measured throughput versus elapsed time for Data Accessibility. The timings of the induced failures as well as the recovery process are indicated.

Figure 7-1. Data Accessibility Graph



The files related to this data accessibility test are in the Supporting Files (SupportingFiles\Clause7\Durability\DataAccessibility).

### Business Recovery

*Business Recovery is the process of recovering from a Single Point of Failure and reaching a point where the business meets certain operational criteria.*

*The Test Sponsor must describe in the Report the test(s) used to demonstrate Business Recovery.*

*The Business Recovery Time must be reported on the Executive Summary Statement and in the Report. If the failures described in Clauses 7.5.3.1, 7.5.3.2, and 7.5.3.3 were not combined into one Durability test (usually powering off the Database Server during the run), then the Business Recovery Time for the failure described for instantaneous interruption is the Business recovery Time that must be reported in the Executive Summary Statement. All the Business Recovery Times for each test requiring Business Recovery must be reported in the Report.*

*The Business Recovery Time Graph (see Clause 7.5.8.2) must be reported in the Report for all Business Recovery tests.*

The tests for "Loss of Processing," "Loss of Vulnerable Storage Component," and "Loss of all External Power to the SUT" were combined.

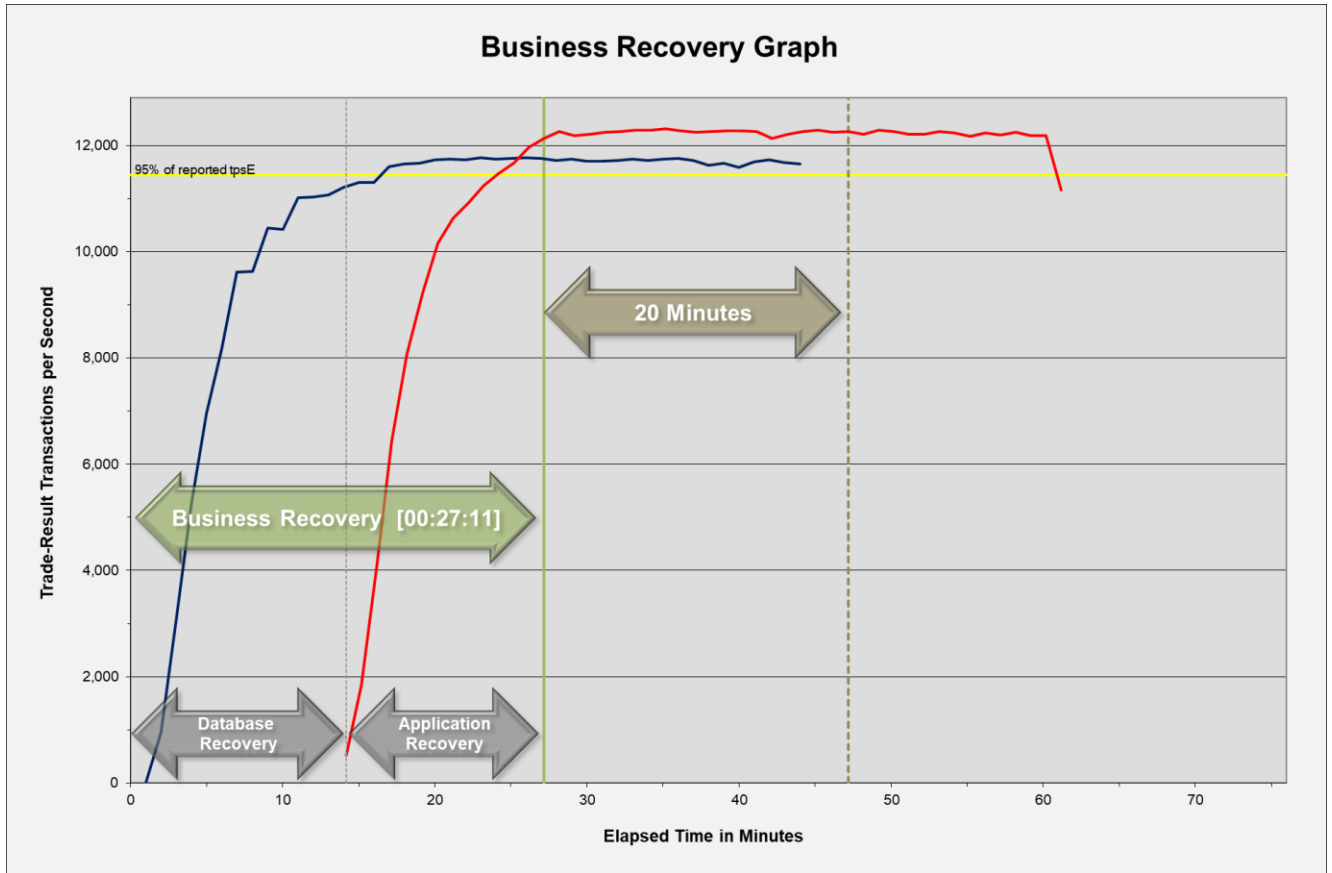
The following steps were successfully performed to test Business Recovery:

1. Restored the database to its freshly loaded, proven consistent state.
2. Determined the current number of completed trades in the database by running `select count(*) from SETTLEMENT (settlement count1)`.
3. Started a run, using the profile from the measured run, with checkpoints, and met the Durability Throughput Requirements for at least 20 minutes.
4. Pulled the power cords from the database server, causing it to immediately cease functioning. All the contents of the server's main memory and caches were lost. All the disk controllers were inside the server, and none of them had batteries or energy packs present to preserve their caches, so all disk controller cache contents were lost.
5. Stopped submitting transactions.
6. Plugged in and restarted the database server. It booted a fresh copy of the OS from the OS array.
7. Deleted all of the data and log files for tempdb.
8. Started SQL Server on the database server. It automatically began recovery of the tpce database. The timestamp in the SQL Server ERRORLOG of the first message related to database tpce is considered the start of Database Recovery.
9. Waited for SQL Server to finish recovering the database. The timestamp in the SQL Server ERRORLOG of the message indicating "Recovery is complete" is considered the end of Database Recovery.
10. Since there was a time gap between the end of Database Recovery and the start of Application Recovery, and the Drivers and Transactions needed to be started again (not just continued), the TRADE\_CLEANUP Transaction was executed during this time gap.
11. Started a run, using the profile from the measured run, with checkpoints. The time when the first transaction is submitted to the database is considered the start of Application Recovery.
12. Let the run proceed until a 20 minute window existed such that the first minute of the window and the entire window both scored at least 95% of the Reported Throughput. The time of the beginning of that 20-minute window is considered the end of Application Recovery.
13. Terminated the run gracefully.
14. Verified that no errors were reported during steps 8 through 13.
15. Retrieved the new number of completed trades in the database by running `select count(*) from SETTLEMENT (settlement count2)`.
16. Verified that  $(count2 - count1)$ , which is the number of actual completed Trade-Result Transactions done during the two runs, was greater than or equal to the combined number of successful Trade-Result Transactions reported by the Driver for both runs. In the case of an inequality, verified that the difference was less than or equal to the maximum number of transactions that could be simultaneously in-flight from the Driver to the SUT.
17. Verified database consistency.

The Database Recovery Time was 00:14:11. The Application Recovery Time was 00:13:00. The Business Recovery Time, which is the sum of the Database Recovery Time, and the Application Recovery Time was 00:27:11.

Figure 7-2 is a graph of the measured throughput versus elapsed time for Business Recovery.

Figure 7-2. Business Recovery Time Graph



The files related to this business recovery test are in the Supporting Files (SupportingFiles\Clause7\Durability\BusinessRecovery).

## Clause 8 – Pricing

### 60-Day Space

*Details of the 60-Day Space computations (see Clause 6.6.6.6) along with proof that the database is configured to sustain a Business Day of growth (see Clause 6.6.6.1) must be reported in the Report.*

The 60-day space calculations shown in Table 8-1 are included in the Supporting Files (SupportingFiles\Clause8\tpce\_space.xls).

Table 8-1. Disk Space Requirements

Customers	6,050,000	Measured Throughput			12,054.79	Trade-Results/s	Reported Throughput		12,054.79	tpsE	
Table	Initial Rows	Data Size (KB)	Index Size (KB)	Extra 5% (KB)	Total + 5% (KB)	Rows After	After Run (KB)	Growth (KB)	Bus. Day Growth (KB)	Req. Add. (KB)	
BROKER	60,500	4,616	5,168	489	10,273	60,500	9,784	-	-	489	
CASH_TRANSACTION	96,180,381,553	10,019,121,560	21,114,248	502,011,790	10,542,247,598	96,294,876,033	10,061,107,536	20,871,728	58,225,255	58,225,255	
CHARGE	15	8	8	1	17	15	16	-	-	1	
COMMISSION_RATE	240	16	40	3	59	240	56	-	-	3	
SETTLEMENT	104,544,000,000	4,985,061,288	10,506,032	249,778,366	5,245,345,686	104,668,451,216	5,007,315,088	11,747,768	32,772,409	32,772,409	
TRADE	104,544,000,000	12,482,174,584	6,956,938,072	971,955,633	20,411,068,289	104,669,169,162	19,504,591,536	65,478,880	182,664,535	182,664,535	
TRADE_HISTORY	250,905,666,560	7,546,035,464	19,667,432	378,285,145	7,943,988,041	251,204,635,707	7,586,502,168	20,799,272	58,023,127	58,023,127	
TRADE_REQUEST	-	8	8	1	17	717,946	2,175,792	2,175,776	6,069,700	6,069,700	
TRADE_TYPE	5	8	1,032	52	1,092	5	1,040	-	-	52	
ACCOUNT_PERMISSION	42,952,600	2,364,632	11,336	118,798	2,494,766	42,952,600	2,376,104	136	380	118,798	
CUSTOMER	6,050,000	990,992	286,136	63,856	1,340,984	6,050,000	1,277,184	56	157	63,856	
CUSTOMER_ACCOUNT	30,250,000	2,740,672	667,008	170,384	3,578,064	30,250,000	3,407,680	-	-	170,384	
CUSTOMER_TAXRATE	12,100,000	251,800	960	12,638	265,398	12,100,000	252,920	160	447	12,638	
HOLDING	5,352,289,951	358,405,624	245,016,216	30,171,092	633,592,932	5,355,466,412	610,634,088	7,212,248	20,119,800	20,119,800	
HOLDING_HISTORY	140,106,646,527	5,094,787,536	3,403,507,584	424,914,756	8,923,209,876	140,274,462,035	8,522,695,160	24,400,040	68,068,085	68,068,085	
HOLDING_SUMMARY	300,875,731	13,214,896	47,712	663,130	13,925,738	300,877,451	13,262,608	-	-	-	
WATCH_ITEM	605,004,786	17,019,016	61,328	854,017	17,934,361	605,004,786	17,080,592	248	692	854,017	
WATCH_LIST	6,050,000	150,232	133,520	14,188	297,940	6,050,000	283,752	-	-	14,188	
COMPANY	3,025,000	645,696	189,520	41,761	876,977	3,025,000	835,240	24	67	41,761	
COMPANY_COMPETITOR	9,075,000	243,184	217,832	23,051	484,067	9,075,000	461,016	-	-	23,051	
DAILY_MARKET	5,408,246,250	253,945,432	741,312	12,734,337	267,421,081	5,408,246,250	254,687,968	1,224	3,415	12,734,337	
EXCHANGE	4	8	8	1	17	4	16	-	-	1	
FINANCIAL	60,500,000	6,817,248	17,944	341,760	7,176,952	60,500,000	6,835,488	296	826	341,760	
INDUSTRY	102	8	24	2	34	102	32	-	-	2	
LAST_TRADE	4,144,250	258,136	1,032	12,958	272,126	4,144,250	259,168	-	-	12,958	
NEWS_ITEM	6,050,000	655,929,856	6,000	32,796,793	688,732,649	6,050,000	655,935,896	40	112	32,796,793	
NEWS_XREF	6,050,000	150,216	808	7,551	158,575	6,050,000	151,024	-	-	7,551	
SECTOR	12	8	24	2	34	12	32	-	-	2	
SECURITY	4,144,250	575,048	157,024	36,604	768,676	4,144,250	732,112	40	112	36,604	
STATUS_TYPE	5	8	8	1	17	5	16	-	-	1	
ADDRESS	9,075,004	522,944	1,568	26,226	550,738	9,075,004	524,624	112	313	26,226	
TAXRATE	320	24	40	3	67	320	80	16	45	45	
ZIP_CODE	14,741	488	40	26	554	14,741	528	-	-	26	
TOTALS (KB)		41,441,411,256	10,659,297,024	2,605,035,414	54,705,743,694		52,253,396,344	152,688,064	425,949,477	473,198,454	
Initial Database Size (MB)		50,879,598	49,687 GB								
Database Filegroups	LUN Count	Partition Size (MB)	MB Allocated	MB Loaded	MB Required						
	0	-	-	-	-					OK	
growing_fg	8	12,300,000	98,400,000	49,956,639	50,372,599					OK	
	0	-	-	-	-					OK	
fixed_fg	4	500,000	2,000,000	922,959	969,107					OK	
Settlements	124,451,216										
Data Space Required (MB)	Data Space Configured (MB)	Log Space Required (MB)	Log Space Configured (MB)								
Initial Growing Space	49,956,639										
Final Growing Space	50,105,746	Data LUNS	2	-	-	-	Initial Log Size	15,944	Log LUNS	1	
Delta	149,107	Disks per LUN	8	-	-	-	Final Log Size	857,195	Log Disks	4	
Data Space per Trade	0.001198117	Disk Capacity	7,247,925	-	-	-	Log Growth	841,251	Disk Capacity	3,051,758	
1 Day Data Growth	415,960	RAID Overhead	88%	0%	0%	0%	Log Growth/Trade	0.006759689	RAID Overhead	50%	
60 Day Space	75,837,190	Total Space				101,470,950	1 Day Log Space	2,362,759	Log Space	6,103,516	
						OK				OK	

### Configuration Components

A detailed list of hardware, software, and/or Licensed Compute Services used in the Priced configuration must be reported. The listing for each separately Orderable item must have vendor Part Number, description and applicable

*release/revision level, Pricing Source, List Price including the ISO Currency Code, quantity, extended price including the ISO Currency Code, applicable Discounted price including the ISO Currency Code, 3-year maintenance prices including the ISO Currency Code. If package-pricing is use, the vendor Part Number of the package and a description uniquely identifying each of the Components of the package must be disclosed to a sufficient level of detail to meet the requirements of Clause 5.2.*

A detailed list of all hardware, software, and maintenance is provided in the Executive Summary Statement at the front of this report. Price quotations are included in Appendix A.

## Pricing Methodology

*If the Benchmark Standard does not specify the allowed Pricing Methodology, then the Default Pricing Methodology will apply. The price of the entire Priced configuration must be used, including all hardware (purchase price), software (license charges), Licensed Compute Services, and hardware maintenance/Software Maintenance Update charges over a period of 3 years (36 months).*

The default 3-year Pricing Methodology was used.

## Pricing Locale

*The Priced Locale and Priced Currency of the Priced Configuration must be disclosed. All Line Items of the system must be Generally Available in the Priced Locale by the Availability Date.*

The configuration was priced in \$USD for the United States of America.

## Currency Conversions

*The date, rate(s), and source of any Currency Conversions must be reported. Documentation of all Currency Conversions from the Currency Conversion Source, including the date of the conversion, must be included in the FDR.*

No currency conversions were done.

## Pricing Calculations

*The following items must be included in the Full Disclosure Report and Executive Summary:*

- *The benchmark performance metric*
- *Respective calculations for the Pricing Methodology pricing time period (See Clauses 1.7 through 1.10)*
- *price/performance*
- *Availability Date*

*Pricing may use packages and Discounts that are Generally Available (see Clause 1.5). The priced items over which a Discount applies must be specified (see Clause 5.1.2). The percentage, amount, and basis (including type and justification) of all allowed Discounts listed must be disclosed (see Clause 5.1.2).*

The benchmark performance metric, pricing calculations, discount information, price/performance, and Availability Date are all included in the Executive Summary Statement at the front of this report.

## Total Price

*The Total Price, including the ISO Currency Code, of the entire Priced Configuration and the Price/Performance metric must be reported.*



The Total Price and Price/Performance are both included in the Executive Summary Statement at the front of this report.

## Availability Date

*The committed Availability Date of Line Items used in the price calculations must be reported. The Availability Date must be reported on the first page of the Executive Summary and with a precision of one day. When the priced system includes products and/or Licensed Compute Services with different Availability Dates, the reported Availability Date for the priced system must be a date at which all Line Items are committed to being Generally Available. Each Line Item used in the Priced Configuration is considered to be Available on the Availability Date unless an earlier date is specified.*

*For each of the Line Items 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 Line Item 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 the order date arrives*
- *The method for verifying the price*

The total solution as priced will be Generally Available May 8, 2023.

## Supporting Files Index

*An index for all files required by Clause 9.4 Supporting Files must be provided in the Report.*

An index of the files contained in the supporting files is found in the Supporting Files (SupportingFiles\SupportingFilesIndex.pdf).

## Auditor's Attestation Letter

*The Auditor's Attestation Letter, which indicates compliance, must be included in the Report.*

The auditor's Attestation Letter is found on the next few pages.

Ankit Chouksey  
Hewlett-Packard Enterprise  
192 Mahadevapura,  
Whitefield Road  
Bangalore, India 560048

May 5, 2023

I verified the TPC Benchmark™ E v1.14.0 performance of the following configuration:

Platform: HPE ProLiant DL345 Gen11  
Operating System: Microsoft® Windows Server® 2022 Standard Edition  
Database Manager: Microsoft SQL Server® 2022 Enterprise Edition

The results were:

**Performance Metric** **12,054.79 tpsE**  
Trade-Result 90<sup>th</sup> %-tile 0.02 Seconds

**Tier B (Server)** **HPE ProLiant DL345 Gen11**

CPU	1x AMD EPYC 9654P 96-Core Processor (2.40 GHz, 32 MB L3)		
Memory	1,536 GB		
Storage	<b>Qty</b>	<b>Size</b>	<b>Type</b>
	2	3.2 TB	NVMe (RAID-1)
	4	3.2 TB	NVMe (RAID-1)
	16	7.6 TB	NVMe (2x 8-drive RAID-5)

**Tier A (Client)** **HPE ProLiant DL325 Gen10 Plus v2**

CPU	1x AMD EPYC 7543P 32-Core Processor (2.80 GHz, 256 MB L3)
Memory	256 GB
Storage	2 x 240 GB M.2 (RAID-1)

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:

- All EGen components were verified to be v1.14.0.
- The transactions were correctly implemented.
- The database was properly scaled and populated for 6,050,000 customers.

- The mandatory network between the driver and the SUT was configured.
- The ACID properties were met.
- Input data was generated according to the specified percentages.
- The reported response times were correctly measured.
- All 90% response times were under the specified maximums.
- The measurement interval was 120 minutes.
- The implementation used Redundancy Level 1.
- The Business Recovery Time of 00:27:11 was correctly measured.
- The 60-day storage requirement was correctly computed.
- The system pricing was verified for major components and maintenance.

Additional Audit Notes:

None.

Respectfully Yours,

A handwritten signature in black ink that reads "Doug Johnson". The signature is fluid and cursive, with a long horizontal flourish extending to the right.

Doug Johnson, Certified TPC Auditor

## Appendix A – Price Quotes

Microsoft Corporation  
One Microsoft Way  
Redmond, WA 98052-6399

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

**Microsoft**

May 2, 2023

Ankit Chouksey  
Hewlett Packard Enterprise  
192, Mahadevapura  
Whitefield Road  
Bangalore, India 560048

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

All pricing shown is in US Dollars (\$).

Description	Unit Price	Quantity	Price
<b>Database Management System</b>			
<b>SQL Server 2022 Enterprise Edition</b> <i>2 Core License</i> <i>Open Program – No Level - ERP</i>	\$15,123.00	48	\$725,904.00
<b>Database Server Operating System</b>			
<b>Windows Server 2022 Standard</b> <i>16 Core License</i> <i>Open Program – No Level - ERP</i>	\$1,069.00	6	\$6,414.00
<b>Tier-A Operating System(s)</b>			
<b>Windows Server 2022 Standard</b> <i>16 Core License</i> <i>Open Program – No Level -ERP</i>	\$1,069.00	2	\$2,138.00
<b>Support</b>			
<b>Microsoft Problem Resolution Services</b> <i>Professional Support</i> <i>(1 Incident).</i>	\$259.00	1	\$259.00

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

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

This quote is valid for the next 120 days.

Reference ID: TPCE\_uzqfspwe27309072\_2022

Written price quotations from all Third-Party Pricing Sources must be included as the final appendix in the FDR.

HP US Store - Shopping Cart

Expert Sales Help: 1-888-897-8561 | Need help? | Customer Service | My HP Rewards | Discount Programs | Sign in/Register

hp Explore Shop Support What are you looking for?

< Back to shopping

## YOUR CART

SHARE CART | PRINT CART

	HP 225 Wired Mouse and Keyboard Combo 286J4UT#ABA Return policy Estimated delivery date: May 04 - May 09	1	\$21.00 Earn 1X HP Rewards Points
	HP V22v G5 FHD Monitor 65PS6AA#ABA Return policy Estimated delivery date: May 04 - May 09	1	\$129.99 Earn 1X HP Rewards Points

**Don't miss out!**  
Your purchase is eligible for **HP Rewards Points\***.  
Create an account or Sign in to join the program.  
\*Restrictions apply. HP Rewards Terms and Conditions

Estimated shipping based on zip code: 10036		Estimated Delivery Dates	Pricing
<b>STANDARD</b>		Delivery in 3 - 5 business days for orders placed M-F prior to 2:30pm EST.	Free <input checked="" type="radio"/>
<b>EXPRESS</b>		Delivery in 2 - 3 business days for orders placed M-F prior to 2:30pm EST.	\$17.70 <input type="radio"/>

**ORDER SUMMARY**

Sub-total **\$150.99**

Shipping **Free**

Estimated Tax **\$13.40**  
Based on: 10036 - Change

---

**Total \$164.39**

Coupon code

**HP CHECKOUT**

Email

You may create an account after submitting your order.

or