TPC Benchmark^{TM} E
Full Disclosure Report
for
Lenovo® System x® 3650 M5
using
Microsoft® SQL Server® 2016
Enterprise Edition
and
Microsoft Windows Server® 2012 R2
Standard Edition

TPC-E^{TM} Version 1.14.0

First Edition
Submitted for Review
March 31, 2016

First Edition – March 2016

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Notes

[1] GHz and MHz only measures microprocessor internal clock speed, not application performance. Many factors affect application performance.

[2] When referring to hard disk capacity, GB, or gigabyte, means one thousand million bytes. Total user-accessible capacity may be less.

Abstract

Lenovo® Corporation conducted the TPC Benchmark^{TM} E on the Lenovo System x®3650 M5 configured as a client/server 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.
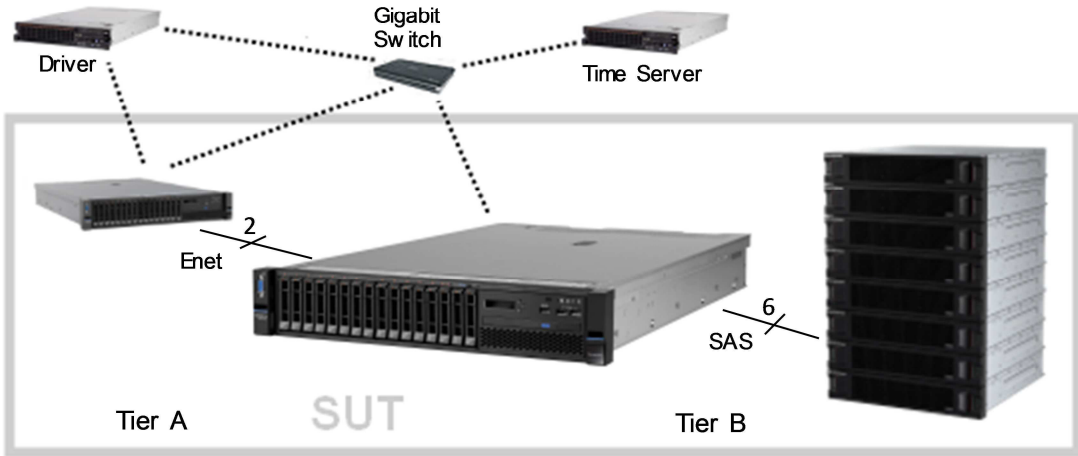
The software used on the Lenovo System x3650 M5 system included Microsoft® Windows Server® 2012 R2 Standard Edition and Microsoft SQL Server® 2016 Enterprise Edition.

Standard metrics, transactions per second-E (tpsE^{TM}), 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	tpsE	$ USD /tpsE	Total Solution Availability Date
Lenovo System x3650 M5	Microsoft SQL Server 2016 Enterprise Edition Microsoft Windows Server 2012 R2 Standard Edition	$582,236 USD	4,938.14	$117.91 USD	July 31, 2016

The benchmark implementation and results were audited by Doug Johnson for InfoSizing (www.sizing.com). The auditor's attestation letter is contained in this report.

	Lenovo® System x® 3650 M5 Microsoft® SQL Server® 2016	TPC-E™ 1.14.0 TPC Pricing 2.0.0
LENOVO		Report Date: March 31, 2016
		Revision Date: March 31, 2016

TPC-E Throughput	Price/Performance	Availability Date	Total System Cost
4,938.14 tpsE	**$117.91 USD per tpsE™**	**July 31, 2016**	**$582,236 USD**

Database Server Configuration

Operating System	Database Manager	Processors/Cores/ Threads	Memory
Microsoft Windows Server® 2012 R2 Standard Edition	**Microsoft SQL Server 2016 Enterprise Edition**	**2/44/88**	**512GB**

System x3650 M5, with:
- 2 x Intel® Xeon® Processor E5-2699 v3 2.30GHz (2 Procs/36 Cores/72 Threads)
- 64GB Memory
- 2 x 300GB SFF SAS (RAID-1)
- 1 x ServeRAID M5210
- Onboard Quad Gb Ethernet
- 1 x Dual 10Gb-T Ethernet

System x3650 M5, with:
- 2 x Intel® Xeon® Processor E5-2699 v4 2.20GHz (2 Procs/44 Cores/88 Threads)
- 512GB Memory
- 2 x 900GB 10K SAS (RAID-1)
- 4 x 800GB SAS SSD (RAID-10)
- 1 x ServeRAID M5210
- 3 x ServeRAID M5225
- Onboard Quad Gb Ethernet
- 1 x Dual 10Gb-T Ethernet

6 x Lenovo E1024 JBOD Enclosures, with:
- 53 x 800GB 2.5" SAS SSD (3 x 17-drive RAID-5) (1 x 2-drive RAID-1)

53 Total External Drives

Initial Database Size 20,518 GB	Redundancy Level: **1** **RAID-10 Log** **RAID-5 Data** **RAID-1 tempdb**	Storage **2 x 900GB 2.5" 10K SAS** **4 x 800GB 2.5" SAS SSD** **53 x 800GB 2.5" SAS SSD**

<table>
<tr><td></td><td>TPC-E 1.14.0</td></tr>
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		TPC-E 1.14.0
Lenovo System x3650 M5 **Microsoft SQL Server 2016**		**TPC Pricing 2.0.0**
		Report Date: March 31, 2016
		Revision Date: March 31, 2016
		Availability Date: July 31, 2016

Description	Part Number	Price Source	Unit Price	Quantity	Extended Price	3-Yr. Maint. Price
Server Hardware						
System x3650 M5 Configure-To-Order, includes:	8871AC1	1	68,588	1	68,588	
x3650 M5 Base + Planar + Power Paddle Card	A5FD, ATE4, A5FT			1		
900W High Efficiency Platinum AC Power Supply	A5EW			2		
Intel Xeon Processor E5-2699 v4 22C 2.2GHz 55MB 145W	ATF2, A2FT			2		
x3650 M5 PCIe Risers 1 & 2 + Thermal Kit	A5FQ, A5R6, ASQD			1		
System x Gen-II Universal Slides Kit	A5FW			1		
900GB 10K 12Gbps SAS 2.5" G3HS HDD	AT8B			2		
800GB 12G SAS 2.5" MLC G3HS Enterprise SSD	AS7G			4		
x3650 M5 8x 2.5" HS HDD Assembly Kit (Single RAID)	A5G6			1		
Power Cable	6400			2		
ServeRAID M5210 SAS/SATA Controller	A3YZ			1		
Intel X540 ML2 Dual Port 10GbaseT Adapter	A40P			1		
x3650 M5 Riser Bracket	A5G5			2		
x3650 M5 Right EIA & EIA Plate	A5V5, A5G1			1		
32GB TruDDR4 Memory PC4-19200 CL17 2400MHz LP RDIMM	ATCB			16		
ServeRAID M5225-2GB SAS/SATA Controller	00AE938	1	899	3	2,697	
ServeRAID M5200 Series Performance Accelerator- FoD	47C8710	1	49	1	49	
Preferred Pro Keyboard USB - US English 103P RoHS v2	00AM600	1	29	1	29	
2-Button Optical Mouse - Black - USB	40K9200	1	19	1	19	
ThinkVision E1922 18.5-inch LED Backlit LCD Monitor	60B8AAR6US	1	100	1	100	
ServicePac for 3-Year 24x7x4 Support (x3650 M5)	67568HG	1	790	1		790
				Subtotal	71,482	790
Server Storage						
S2 42U Standard Rack	93074RX	1	1,565	1	1,565	
Lenovo Storage E1024	64111B4	1	2,999	6	17,994	
1.5m SAS Cable (mSAS HD to mSAS)	00MJ163	1	129	6	774	
Lenovo Storage 2.5" 800GB SSD (SAS)	00MM715	1	4,999	53	264,947	
ServicePac for 3-Year 24x7x4 Support (E1024)	00WX880	1	1,146	6		6,876
ServicePac for 3-Year 24x7x4 Support (Rack)	41L2760	1	315	1		315
				Subtotal	285,280	7,191
Server Software						
SQL Server 2016 Enterprise Edition (2-core licenses)	7JQ-00256	2a	13,472.50	22	296,395	
Windows Server 2012 R2 Standard Edition	P73-06284	2b	882	1	882	
Microsoft Problem Resolution Services	N/A	2a	259	1		259
				Subtotal	297,277	259
Client Hardware						
System x3650 M5 Configure-To-Order, includes:	5462AC1	1	19,352	1	19,352	
x3650 M5 Base + Planar + Power Paddle Card	A5FD, A5EA, A5FT			1		
750W High Efficiency Platinum AC Power Supply	A5EU			2		
Intel Xeon Processor E5-2699 v3 18C 2.3GHz 45MB 145W	ARYJ, ARYT			2		
x3650 M5 PCIe Risers 1 & 2 + Thermal Kit	A5FQ, A5R6, ASQD			1		
System x Gen-II Universal Slides Kit	A5FW			1		
300GB 10K 12Gbps SAS 2.5" G3HS HDD	AT89			2		
x3650 M5 8x 2.5" HS HDD Assembly Kit (Single RAID)	A5G6			1		
8GB TruDDR4 Memory PC4-17000 CL15 2133MHz LP RDIMM	A5B8			8		
Power Cable	6311			2		
ServeRAID M5210 SAS/SATA Controller	A3YZ			1		
Intel X540 ML2 Dual Port 10GbaseT Adapter	A40P			1		
x3650 M5 Riser Bracket	A5G5			2		
x3650 M5 Right EIA & EIA Plate	A5V5, A5G1			1		
ServicePac for 3-Year 24x7x4 Support (x3650 M5)	67568HG	1	790	1		790
				Subtotal	19,352	790
Client Software						
Windows Server 2012 R2 Standard Edition	P73-06284	2b	882	1	882	
				Subtotal	882	0
Infrastructure						
10 ft. Cat 6A Network Cable (2 spares)	CAT6A-10S	3	7	4	28	
				Subtotal	28	0
				Total	674,301	9,030
Dollar Volume Discount (See Note 1)		26.19%	1		100,801	
Microsoft Open Program Discount Schedule		16.67%	2b		294	

Pricing: 1 - Lenovo 1-877-782-7134; 2 - Microsoft; 3 - Newegg	**Three-Year Cost of Ownership USD:** $582,236
Note 1: Discount applies to all line items where Pricing=1; pricing is for these or similar quantities.	**TPC-E Throughput:** 4,938.14
Discounts for similarly sized configurations will be similar to what is quoted here, but may vary based	**$ USD/tpsE:** $117.91
on the specific components priced.	

Benchmark results and test methodology audited by Doug Johnson for InfoSizing, Inc. (www.sizing.com)

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 section of the TPC benchmark specifications. If you find that stated prices are not available according to these terms, please inform the TPC at pricing@tpc.org. Thank you.

	Lenovo System x3650 M5 Microsoft SQL Server 2016	TPC-E 1.14.0
		TPC Pricing 2.0.0
Lenovo.		Report Date: March 31, 2016
		Revision Date: March 31, 2016
		Availability Date: July 31, 2016

Numerical Quantities Summary				
Reported Throughput: 4,938.14 tpsE	**Configured Customers:**		**2,500,000**	
Response Time (in seconds)	**Minimum**	**Average**	**90Th Percentile**	**Maximum**
Broker-Volume	0.01	0.01	0.02	0.71
Customer-Position	0.01	0.01	0.02	0.99
Market-Feed	0.01	0.01	0.04	0.66
Market-Watch	0.01	0.01	0.01	0.32
Security-Detail	0.01	0.01	0.01	0.32
Trade-Lookup	0.01	0.05	0.07	0.38
Trade-Order	0.01	0.04	0.10	1.11
Trade-Result	0.01	0.02	0.04	1.98
Trade-Status	0.01	0.01	0.01	1.01
Trade-Update	0.01	0.06	0.08	0.37
Data-Maintenance	0.01	0.02	N/A	0.09

Transaction Mix	Transaction Count	Mix %
Broker-Volume	17,421,775	4.900%
Customer-Position	46,221,424	13.000%
Market-Feed	3,555,471	1.000%
Market-Watch	63,998,728	18.000%
Security-Detail	49,776,719	14.000%
Trade-Lookup	28,443,874	8.000%
Trade-Order	35,910,234	10.100%
Trade-Result	35,554,652	10.000%
Trade-Status	67,554,039	19.000%
Trade-Update	7,110,833	2.000%
Data-Maintenance	120	N/A

Test Duration and Timings	
Ramp-up Time (hh:mm:ss)	00:28:32
Measurement Interval (hh:mm:ss)	02:00:00
Business Recovery Time (hh:mm:ss)	00:20:40
Total Number of Transactions Completed in Measurement Interval	355,547,749

Table of Contents

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, transactions, 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 anytime, 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.

The 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 interactions 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 on 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.

This benchmark was sponsored by Lenovo Corporation.

Configuration Diagrams

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

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 Report. Original and substituted Components must be clearly identified.

Measured and Priced Configurations

The measured configuration is shown in Figure 1-1. The priced configuration is shown above in the executive summary.

Figure 1-1. Measured Configuration
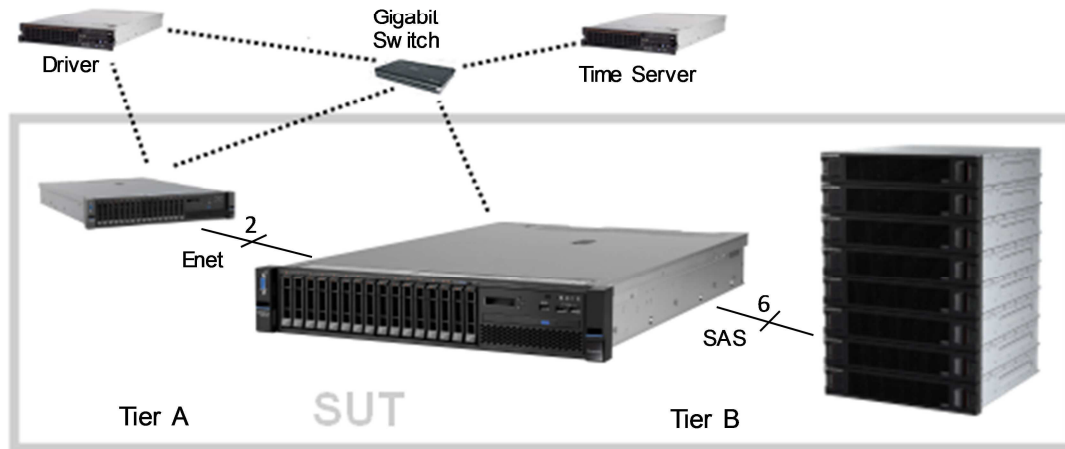
System x3650 M5, with:
 - 2 x Intel® Xeon® Processor
   E5-2699 v3 2.30GHz
   (2 Procs/36 Cores/72 Threads)
 - 64GB Memory
 - 2 x 300GB SFF SAS (RAID-1)
 - 1 x ServeRAID M5210
 - Onboard Quad Gb Ethernet
 - 1 x Dual 10Gb-T Ethernet

System x3650 M5, with:
 - 2 x Intel® Xeon® Processor
   E5-2699 v4 2.20GHz
   (2 Procs/44 Cores/88 Threads)
 - 512GB Memory
 - 2 x 900GB 10K SAS (RAID-1)
 - 4 x 800GB SAS SSD (RAID-10)
 - 1 x ServeRAID M5210
 - 3 x ServeRAID M5225
 - Onboard Quad Gb Ethernet
 - 1 x Dual 10Gb-T Ethernet

12 x E1024 JBOD with:
 - 104 x 800GB 2.5" SAS SSD
   (6 x 17-drive RAID-5)
   (1 x 2-drive RAID-1)

104 Total External Drives

Compared to the priced configuration, the measured configuration contained extra external enclosures and drives used strictly for database backup files and flat file space used during the benchmark database load process. These extra enclosures and drives were not used at all during the benchmark runs.

Hardware and Software Configuration Steps

A description of the steps taken to configure all the hardware must be reported.
A description of the steps taken to configure all the software must be reported.
Any and all configuration scripts or step by step GUI instructions are reported in the Supporting Files (see Clauses 9.4.1.1 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\TierA_x3650M5_Setup.pdf
- Information specific to the Tier B database server and storage can be found in:
  SupportingFiles\Introduction\TierB\TierB_x3650M5_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. 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 Reference.pdf.

Changes and customizations were made to some of the kit files. First, the filegroups the database was loaded onto were changed in number from three filegroups to two. Second, several scripts were modified to customize the load to the specific hardware configuration of this SUT.

The default kit files create the database on three filegroups: fixed_fg, scaling_fg, and growing_fg. That was changed so that only two filegroups were used, fixed_fg and growing_fg. All of the items that would have been loaded onto scaling_fg were loaded instead onto fixed_fg.

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

- Utility\Create_TID_Ranges_Table.sql
- DDL\ Create_Indexes_Scaling_Tables.sql
- DDL\ Create_Tables_Scaling.sql

The files that were customized for this specific SUT hardware are included in the folder SupportingFiles\Clause2\2500000.Cust\Database:

- Tempdb_load.sql specifies temporary database files to use when loading the database
- Tempdb_run.sql specifies temporary database files to use when running the database
- Shrinktempdb.sql removes extra tempdb files
- Backupdev.sql creates devices for SQL Server to back up the database to
- Dropbackupdev.sql removes those devices
- Backup_Database.sql backs up the tpce database to the specified device names
- Restore_Database.sql restores the tpce database from the specified device names
- Create_Database.sql maps the database filegroups and log to physical storage
- Flatfile.txt tells the database loader where to store the database flatfiles during the load
- Remove_Database.sql drops the current tpce database

Database Physical Organization

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

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 related 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.

Partitioning was not used for this benchmark.

Replication

Replication of tables, if used, must be reported.

Replication was not used for this benchmark.

Table Attributes

Additional and/or duplicated columns in any table must be reported 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 the database load (see Clause 2.6), must be reported.

The database was built with 2,500,000 customers. The cardinality is shown in Table 2-1.

Table 2-1. Initial Cardinality of Tables

Table Name	Rows
ACCOUNT_PERMISSION	17,750,259
ADDRESS	3,750,004
BROKER	25,000
CASH_TRANSACTION	39,743,879,263
CHARGE	15
COMMISSION_RATE	240
COMPANY	1,250,000
COMPANY_COMPETITOR	3,750,000
CUSTOMER	2,500,000
CUSTOMER_ACCOUNT	12,500,000
CUSTOMER_TAXRATE	5,000,000
DAILY_MARKET	2,234,812,500
EXCHANGE	4
FINANCIAL	25,000,000
HOLDING	2,211,783,746
HOLDING_HISTORY	57,895,302,576
HOLDING_SUMMARY	124,334,325
INDUSTRY	102
LAST_TRADE	1,712,500
NEWS_ITEM	2,500,000
NEWS_XREF	2,500,000
SECTOR	12
SECURITY	1,712,500
SETTLEMENT	43,200,000,000
STATUS_TYPE	5
TAXRATE	320
TRADE	43,200,000,000
TRADE_HISTORY	103,679,930,411
TRADE_REQUEST	0
TRADE_TYPE	5
WATCH_ITEM	250,080,772
WATCH_LIST	2,500,000
ZIP_CODE	14,741

Distribution of Tables and Logs

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

There were two 900GB 2.5" 10K SAS drives in the server accessed by the internal ServeRAID M5210 SAS/SATA controller. The OS was loaded onto a RAID-1 array located on these two drives.

The database log was stored on four 800GB 2.5" SAS SSDs in the server accessed by the internal ServeRAID M5210 SAS/SATA controller. These drives were used to create a RAID-10 array.

The database data was stored on external SAS SSD storage. This storage was accessed by three ServeRAID M5225 SAS/SATA controllers. Each of these controllers was connected to two Lenovo E1024 enclosures, one holding eight 800GB 2.5" SAS SSDs and the other holding nine 800GB 2.5" SAS SSDs. These 17 total SSDs per RAID adapter were used to create a RAID-5 array. Additionally, for one of these RAID adapters, each of the two attached enclosures held one additional 800GB 2.5" SAS SSD. These two SSDs were used to create a RAID-1 array to hold the run-time tempdb database.

In total, for database data, six Lenovo E1024 enclosures and 51 external SSDs were connected to the database server and were used to create three RAID-5 data arrays. Each data array was broken into three partitions: one for fixed_fg (RAW), one for growing_fg (RAW), and one for extra space (NTFS). One partition was created on the run-time tempdb array and formatted NTFS.

In addition to the priced configuration described above, the measured configuration included six additional external E1024 enclosures. Each one of these was daisy-chained to one of the priced enclosures above, creating six total enclosure chains with 2 enclosures each. So each ServeRAID M5225 adapter had two chains and four total E1024 enclosures attached, two of which are priced. The extra two enclosures per M5225 adapter held 17 800GB 2.5" SAS SSDs. These 17 SSDs per RAID adapter were used to create a RAID-5 array. There were three of these backup arrays in total. This additional space was used during the database load process to hold load-time tempdb, flat files, and database backups. This hardware- all six of these enclosures and the drives contained in them- performed no function during benchmark runs.

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\Introduction\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 Enclosure RAID Level (Pricing)	Partition (File System)	Size	Use
0	M5225 #1	17 x 800GB SAS SSD Lenovo E1024 RAID-5	c:\mp\fx1 (RAW) c:\mp\gw1 (RAW) c:\mp\xt1 (NTFS)	179.20GB 8545.12GB 3181.57GB	fixed_fg growing_fg tempdb
1	M5225 #1	17 x 800GB SAS SSD Lenovo E1024 RAID-5 (Measured)	c:\mp\bk1 (NTFS)	11905.89GB	backup & flatfiles
2	M5225 #2	17 x 800GB SAS SSD Lenovo E1024 RAID-5	c:\mp\fx2 (RAW) c:\mp\gw2 (RAW) c:\mp\xt2 (NTFS)	179.20GB 8545.12GB 3181.57GB	fixed_fg growing_fg tempdb
3	M5225 #2	2 x 800GB SAS SSD Lenovo E1024 RAID-1	T: (NTFS)	744.00GB	run-time tempdb

Disk #	Controller	Drives Enclosure RAID Level (Pricing)	Partition (File System)	Size	Use
4	M5225 #2	17 x 800GB SAS SSD Lenovo E1024 RAID-5 (Measured)	c:\mp\bk2 (NTFS)	11905.89GB	backup & flatfiles
5	Internal M5210	2 x 900GB SAS HDD internal RAID-1	C: (NTFS)	836.74GB	OS
6	Internal M5210	4 x 800GB SAS SSD internal RAID-10	E: (RAW) F: (NTFS)	1074.22GB 413.91GB	tpce log MDF
7	M5225 #3	17 x 800GB SAS SSD Lenovo E1024 RAID-5	c:\mp\fx3 (RAW) c:\mp\gw3 (RAW) c:\mp\xt3 (NTFS)	179.20GB 8545.12GB 3181.57GB	fixed_fg growing_fg tempdb
8	M5225 #3	17 x 800GB SAS SSD Lenovo E1024 RAID-5 (Measured)	c:\mp\bk3 (NTFS)	11905.89GB	backup & flatfiles

Database Interface and 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 2016 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.

The database was loaded using the flat files option on the EGenLoader command line. This will generate flat files first, then bulk insert the data into the tables. A further description is provided in 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.

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

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

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

Database Footprint of Transactions

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

The database footprint requirements were met.

Clause 4 – SUT, Driver, and Network

Network Configuration

The Network configurations of both the Measured and Priced Configurations must be described and reported. This includes the mandatory Network between the Driver and Tier A (see Clause 4.2.2) and any optional Database Server interface networks (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 had six Ethernet ports. Four of these were provided by the onboard Gb Ethernet solution and the remaining two were provided by one dual-port 10Gb Ethernet adapter.

The Tier B database server had six Ethernet ports. Four of these were provided by the onboard Gb Ethernet solution and the remaining two were provided by one dual-port 10Gb Ethernet adapter.

The Tier A client and Tier B database server were connected by two Ethernet crossover connections. These cables were plugged into both ports of the 10Gb adapters in each server. These crossover networks, all running at 10Gb, handled all of the network traffic between Tier A and Tier B while a measurement was underway.

An additional crossover connection was setup between the Tier A client and the driver. This network, which fulfills the mandatory network between the driver and Tier A, was used by the client to report its results to the driver as a benchmark run was underway.

Another network connected the driver, the database server, the client, and a time server. This network, which was connected via a Gb Ethernet switch, used one of the onboard Ethernet ports on the client and one of the onboard Ethernet ports on the database server. It was used for miscellaneous file sharing and time syncing. It was not used during a benchmark run.

Clause 5 – EGen

EGen Version

The version of EGen used in the benchmark must be reported (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. If the Test Sponsor modified EGen, a statement EGen has been modified must be reported. All formal waivers from the TPC documenting the allowed changes to EGen must also be reported (see Clause 5.3.7.1). If any of the changes to EGen do not have a formal waiver, that must also be reported. 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 an Auditor must be reported (see Clause 5.7.4).

All required TPC-provided EGen code was used in the 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 Instances

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

There were 16 EGenDriverCEs with a total of 672 EGenDriverCE instances used in the benchmark.

There were 16 EGenDriverMEEs with a dynamic number of instances used in the benchmark.

Reported Throughput

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

The Reported Throughput was 4,938.14 tpsE.

Throughput vs. Elapsed Time for Trade-Result Transaction

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

Figure 6-1. Test Run Graph
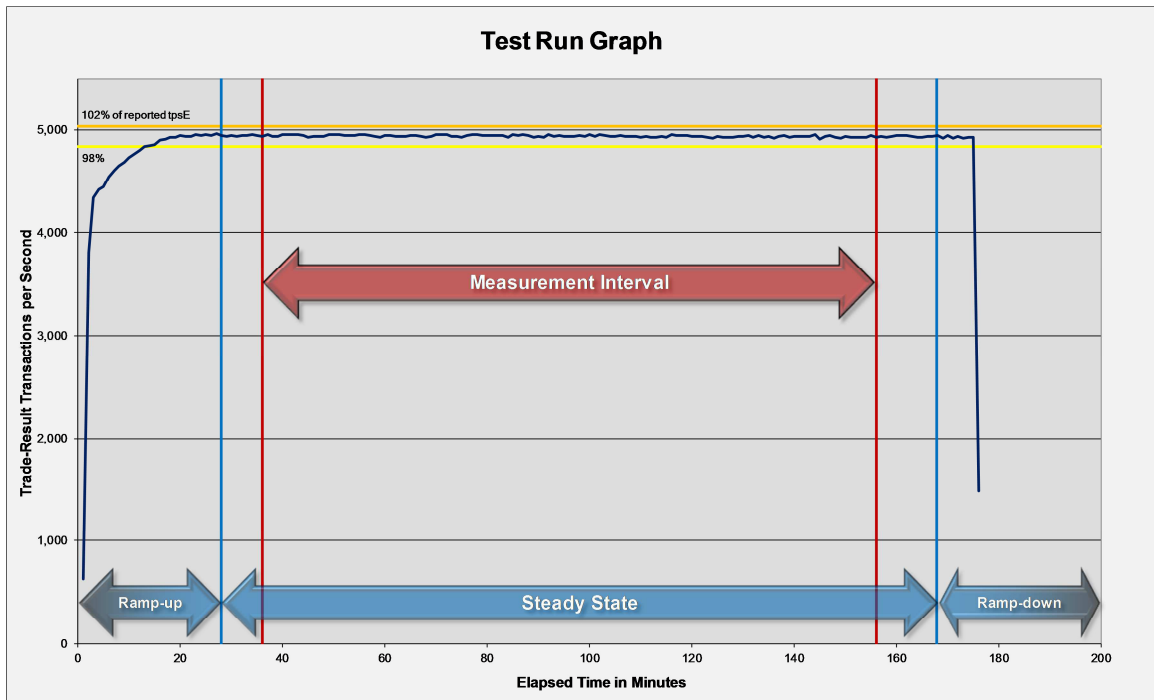
Steady State Methodology

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

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 (e.g., checkpointing, writing Undo/Redo Log records, etc.).

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

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 clause 6.4.1 must be reported.

Table 6-1 contains the transaction statistics.

Table 6-1. Transaction Statistics

Input Parameter	Value	Actual Percentage	Required Range
Customer-Position			
By Tax ID	1	50.00%	48% to 52%
Get History	1	50.00%	48% to 52%
Market-Watch			
Securities chosen by	Watch List	60.00%	57% to 63%
	Account ID	35.00%	33% to 37%
	Industry	5.00%	4.5% to 5.5%
Security-Detail			
Access LOB	1	1.00%	0.9% to 1.1%
Trade-Lookup			
Frame to execute	1	29.98%	28.5% to 31.5%
	2	30.00%	28.5% to 31.5%
	3	30.00%	28.5% to 31.5%
	4	10.01%	9.5% to 10.5%
Trade-Order			
Transactions requested by a third party		10.01%	9.5% to 10.5%
By Company Name		39.99%	38% to 42%
Buy On Margin	1	8.00%	7.5% to 8.5%
Rollback	1	0.99%	0.94% to 1.04%
LIFO	1	35.01%	33% to 37%
Trade Quantity	100	25.00%	24% to 26%
	200	25.01%	24% to 26%
	400	24.98%	24% to 26%
	800	25.00%	24% to 26%
Trade Type	Market Buy	30.00%	29.7% to 30.3%
	Market Sell	29.99%	29.7% to 30.3%
	Limit Buy	20.00%	19.8% to 20.2%
	Limit Sell	10.00%	9.9% to 10.1%
	Stop Loss	10.00%	9.9% to 10.1%
Trade-Update			
Frame to execute	1	32.98%	31% to 35%
	2	32.98%	31% to 35%
	3	34.04%	32% to 36%

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 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 zero. 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 one. 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 file SupportingFiles\Clause7\MSTPCE ACID Procedures.pdf.

The atomicity scripts and outputs are located in the directory 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 file SupportingFiles\Clause7\MSTPCE ACID Procedures.pdf.

The consistency scripts and outputs are located in the directory 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.

Isolation tests 1 through 4 were successfully done following the procedure documented in the file SupportingFiles\Clause7\MSTPCE ACID Procedures.pdf.

The isolation scripts and outputs are located in the directory 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.

Durability Test for Data Accessibility

The Test Sponsor must 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.

A Data Accessibility Graph for each run demonstrating a Redundancy Level must be reported (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	Bus Type	Array Redundancy	Controller
Database Data	SSD	SAS	RAID-5	ServeRAID M5225
Database Log	SSD	SAS	RAID-10	ServeRAID M5210
Database tempdb	SSD	SAS	RAID-1	ServeRAID M5225

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

1. Performed Trade-Cleanup to remove remnants of previous benchmark runs from the database.

2. Determined the current number of completed trades in the database, *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, which in this case was failing a drive in the database log array by physically removing it from its enclosure. Since the database log array is RAID protected, transaction processing continued.

5. Waited until the Data Accessibility Throughput Requirements were met again for at least 5 minutes.

6. Induced the second failure, which in this case was failing a drive in the tempdb array by physically removing it from its enclosure. Since the tempdb array is RAID protected, transaction processing continued.

7. Waited until the Data Accessibility Throughput Requirements were met again for at least 5 minutes.

8. Induced the third failure, which in this case was failing a drive in a database data array by physically removing it from its enclosure. Since the database data arrays are RAID protected, transaction processing continued.

9. After a few minutes passed, a new drive was inserted into the data enclosure to replace the failed data drive. The data array rebuilding process was started.

10. After a few minutes passed, a new drive was inserted into the tempdb enclosure to replace the failed tempdb drive. The tempdb array rebuilding process was started.

11. After a few minutes passed, a new drive was inserted into the log enclosure to replace the failed log drive. The log array rebuilding process was started.

12. Continued running the benchmark for at least 20 minutes.

13. Terminated the run gracefully.

14. Retrieved the new number of completed trades in the database by running *select count(*) as count2 from SETTLEMENT*.

15. 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.

16. 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
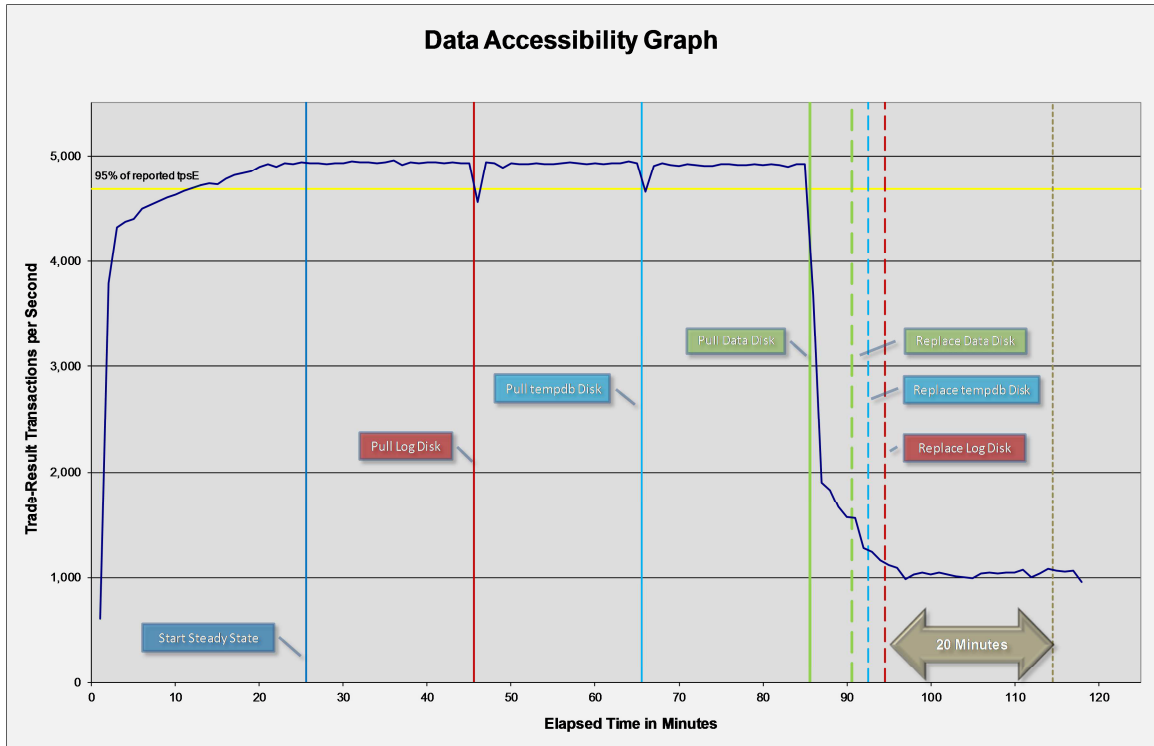
The files related to this data accessibility test are located in
SupportingFiles\Clause7\Durability\DataAccessibility.

Durability Test for Business Recovery

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

The Business Recovery Time must be reported. 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 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. Performed Trade-Cleanup to remove remnants of previous benchmark runs from the database.

2. Determined the current number of completed trades in the database, *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 their batteries were present, 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 the data file and log file 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(*) as count2 from SETTLEMENT.*

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 00:08:33. The Application Recovery Time was 00:12:07. The Business Recovery Time, which is the sum of the Database Recovery Time and the Application Recovery Time, was 00:20:40.

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

Figure 7-2. Business Recovery Time Graph
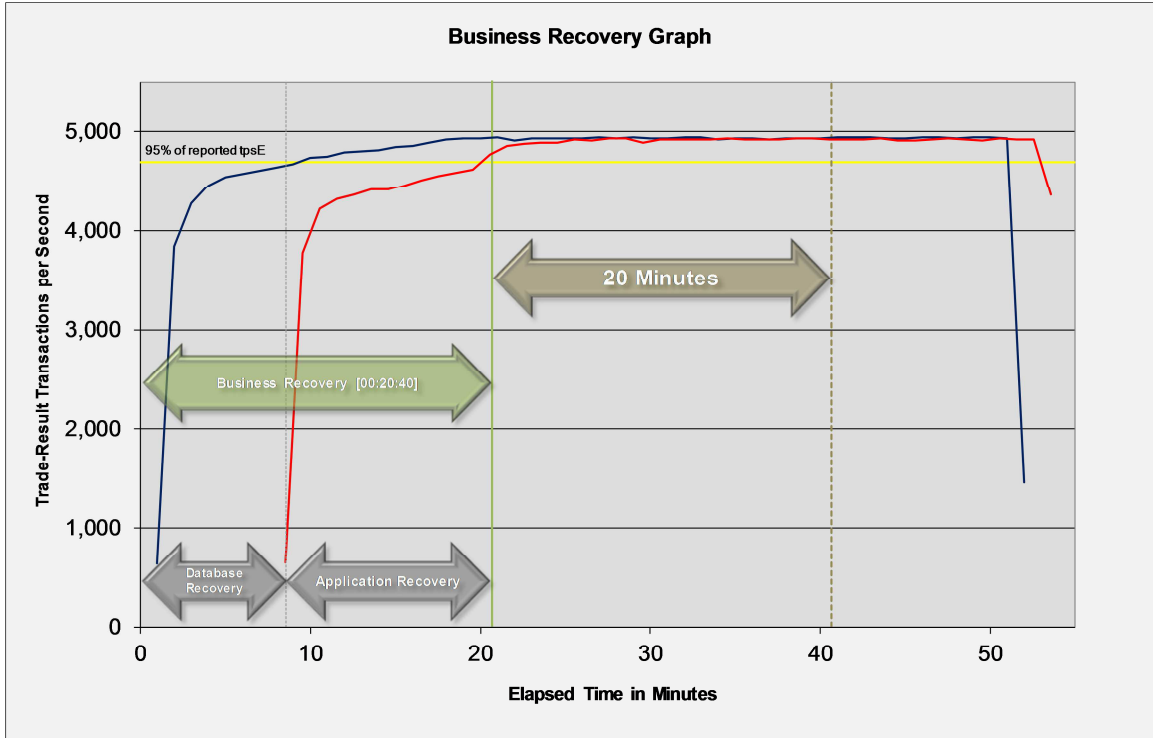
The files related to this business recovery test are located in
SupportingFiles\Clause7\Durability\BusinessRecovery.

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.

The 60-day space calculations shown in Table 8-1 are included in SupportingFiles\Clause8\ tpce_space.xls.

Table 8-1. Disk Space Requirements

Customers	2,500,000		Measured Throughput	4,938.14	Trade-Results/s		Reported Throughput	4,938.14	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	25,000	1,824	1,808	182	3,814	25,000	3,632	-	-	182
CASH_TRANSACTION	39,743,879,263	4,129,342,912	8,710,008	206,902,646	4,344,955,566	39,826,343,908	4,153,696,568	15,643,648	24,821,020	24,821,020
CHARGE	15	8	8	1	17	15	16	-	-	1
COMMISSION_RATE	240	16	16	2	34	240	32	-	-	2
SETTLEMENT	43,200,000,000	2,059,941,904	4,344,144	103,214,302	2,167,500,350	43,289,634,315	2,073,022,280	8,736,232	13,861,357	13,861,357
TRADE	43,200,000,000	5,157,281,056	2,871,753,048	401,451,705	8,430,485,809	43,291,306,428	8,064,363,016	35,328,912	56,054,676	56,054,676
TRADE_HISTORY	103,679,930,411	3,118,193,744	8,128,384	156,316,106	3,282,638,234	103,898,469,946	3,141,901,824	15,579,696	24,719,551	24,719,551
TRADE_REQUEST	-	-	-	-	-	295,972	822,368	822,368	1,304,812	1,304,812
TRADE_TYPE	5	8	1,032	52	1,092	5	1,040	-	-	52
ACCOUNT_PERMISSION	17,750,259	977,392	5,088	49,124	1,031,604	17,750,259	982,656	176	280	49,124
CUSTOMER	2,500,000	409,672	119,664	26,467	555,803	2,500,000	529,384	48	77	26,467
CUSTOMER_ACCOUNT	12,500,000	1,132,728	276,104	70,442	1,479,274	12,500,000	1,408,832	-	-	70,442
CUSTOMER_TAXRATE	5,000,000	104,280	736	5,251	110,267	5,000,000	105,256	240	381	5,251
HOLDING	2,211,783,746	147,864,440	101,083,816	12,447,413	261,395,669	2,214,062,607	254,352,264	5,404,008	8,574,279	8,574,279
HOLDING_HISTORY	57,895,302,576	2,105,284,056	1,406,411,096	175,584,758	3,687,279,910	58,016,166,325	3,530,610,720	18,915,568	30,012,417	30,012,417
HOLDING_SUMMARY	124,334,325	5,449,992	20,224	273,511	5,743,727	124,334,179	5,470,232	16	26	26
WATCH_ITEM	250,080,772	7,018,204	25,760	352,200	7,396,200	250,080,772	7,044,392	392	622	352,200
WATCH_LIST	2,500,000	62,280	56,144	5,921	124,345	2,500,000	118,424	-	-	5,921
COMPANY	1,250,000	266,664	79,040	17,285	362,989	1,250,000	345,744	40	64	17,285
COMPANY_COMPETITOR	3,750,000	100,688	90,568	9,563	200,819	3,750,000	191,256	-	-	9,563
DAILY_MARKET	2,234,812,500	104,782,872	305,480	5,254,418	110,342,770	2,234,812,500	105,090,608	2,256	3,580	5,254,418
EXCHANGE	4	8	8	1	17	4	16	-	-	1
FINANCIAL	25,000,000	2,817,224	7,760	141,249	2,966,233	25,000,000	2,825,520	536	851	141,249
INDUSTRY	102	8	24	2	34	102	32	-	-	2
LAST_TRADE	1,712,500	106,768	752	5,376	112,896	1,712,500	107,520	-	-	5,376
NEWS_ITEM	2,500,000	271,045,560	2,576	13,552,407	284,600,543	2,500,000	271,048,216	80	127	13,552,407
NEWS_XREF	2,500,000	62,288	728	3,151	66,167	2,500,000	63,016	-	-	3,151
SECTOR	12	8	24	2	34	12	32	-	-	2
SECURITY	1,712,500	237,288	65,272	15,128	317,688	1,712,500	302,576	16	26	15,128
STATUS_TYPE	5	8	8	1	17	5	16	-	-	1
ADDRESS	3,750,004	216,280	776	10,853	227,909	3,750,004	217,168	112	178	10,853
TAXRATE	320	24	16	2	42	320	56	16	26	26
ZIP_CODE	14,741	488	32	26	546	14,741	520	-	-	26
TOTALS (KB)		17,112,700,728	4,401,490,144	1,075,709,544	22,589,900,416		21,614,625,232	100,434,360	159,354,350	178,867,264

Initial Database Size (MB)		21,009,952	20,518 GB	

Database Filegroups	LUN Count	Partition Size (MB)	MB Allocated	MB Loaded	MB Required	
	0	-	-	-	-	OK
growing_fg	3	8,750,100	26,250,300	20,628,720	20,784,333	OK
	0	-	-	-	-	OK
fixed_fg	3	183,400	550,200	381,232	400,294	OK

Settlements	89,634,315

Data Space Required (MB)		Data Space Configured (MB)					Log Space Required (MB)		Log Space Configured (MB)	
Initial Growing Space	20,628,720						Initial Log Size	33,837	Log LUNS	1
Final Growing Space	20,726,796	Data LUNS	3	-	-	-	Final Log Size	651,054	Log Disks	4
Delta	98,077	Disks per LUN	17	-	-	-	Log Growth	617,216	Disk Capacity	761,985
Data Space per Trade	0.001094186	Disk Capacity	761,985	-	-	-	Log Growth/Trade	0.006885935	RAID Overhead	50%
1 Day Data Growth	155,613	RAID Overhead	94%	0%	0%	0%	Log Growth/Trade			
60 Day Space	30,346,757	Total Space				36,575,281	1 Day Log Space	1,013,144	Log Space	1,523,970
						OK				OK

Availability Date

The committed Availability Date of Components used in the price calculations must be reported with a precision of one day. All hardware, software and support used in the calculations must be Orderable by Any Customer on the Availability 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 the order date arrives*
- *The method for verifying the price*

The total solution as priced will be generally available July 31, 2016.

Supporting Files Index

An index for all files required by Clause 9.4 Supporting Files must be provided.

An index of the files contained in the supporting files is here: 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 on the next two pages.

Marc Baker, Manager
System x Server Performance
Lenovo Enterprise Business Group
8001 Development Drive
Morrisville, NC 27560

March 15, 2016

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

Platform: System x3650 M5
Operating System: Microsoft Windows Server 2012 R2 Standard Edition
Database Manager: Microsoft SQL Server 2016 Enterprise Edition

The results were:

Performance Metric   **4,938.14 tpsE**
Trade-Result 90th %-tile   0.04 Seconds

Tier B (Server)	**System x3650 M5**		
CPUs	2 x Intel Xeon Processor E5-2699 v4 (2.20 GHz, 22-core, 55 MB L3)		
Memory	512 GB		
Storage	*Qty*	*Size*	*Type*
	2	900 GB	10K rpm SAS HDD
	4	800 GB	SAS SSD
	53	800 GB	SAS SSD

Tier A (Client)	**System x3650 M5**
CPUs	2 x Intel Xeon Processor E5-2699 v3 (2.30 GHz, 18-core, 45 MB L3)
Memory	64 GB
Storage	2 x 300 GB 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:

- All EGen components were verified to be v1.14.0
- The transactions were correctly implemented
- The database was properly scaled and populated for 2,500,000 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 00:20:40 was correctly measured
- The 60-day storage requirement was correctly computed
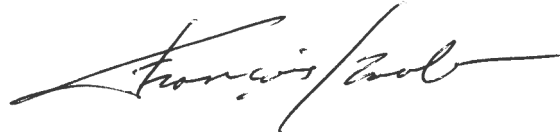- The system pricing was verified for major components and maintenance

Additional Audit Notes:

    None.

Respectfully Yours,

Doug Johnson, Auditor   François Raab, President

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

March 9, 2016

Lenovo
Ray Engler
8001 Development Drive
Morrisville, NC 27560

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

All pricing shown is in US Dollars ($).

Part Number	Description	Unit Price	Quantity	Price
Database Management System				
7JQ-00256	**SQL Server 2016 Enterprise Edition** *2 Core License* *Open Program - Level C*	$13,472.50	22	$296,395.00
Database Server Operating System				
P73-06284	**Windows Server 2012 R2 Standard Edition** *2 Processor License* *Open Program - Level C* *Unit Price reflects a 17% discount from the retail unit price of $882.*	$735.00	1	$735.00
Tier-A Operating System(s)				
P73-06284	**Windows Server 2012 R2 Standard Edition** *2 Processor License* *Open Program - Level C* *Unit Price reflects a 17% discount from the retail unit price of $882.*	$735.00	1	$735.00
Support				
N/A	**Microsoft Problem Resolution Services** *Professional Support* *(1 Incident).*	$259.00	1	$259.00

Windows Server 2012 R2 Standard Edition are currently orderable and available through Microsoft's normal distribution channels. 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**

SQL Server 2016 Enterprise Edition will be orderable on March 10, 2016 and generally available by July 31, 2016.

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

This quote is valid for the next 90 days.
Reference ID: TPCE_qhtplylGYLKTVUKf37289rhru_2016_lre.

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Move Selected To...

Newegg Standard Shipping Service   Important Shipping Information

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○ Newegg 3 Business Days   are ready for pick-up.
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