Hewlett-Packard Company

TPC Benchmark™ C
Full Disclosure Report
for
ProLiant DL380-G3-1M-1P
using
Microsoft SQL Server 2000 Enterprise Edition
and
Microsoft Windows Server 2003, Enterprise Edition

First Edition
December 2003

First Edition − December 2003

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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 C 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 were obtained in a rigorously controlled environment. Results obtained in other operating environments may vary significantly. HP does not warrant or represent that a user can or will achieve similar performance expressed in transactions per minute (tpmC) or normalized price/performance ($/tpmC). No warranty of system performance or price/performance is expressed or implied in this report.

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Preface

The TPC Benchmark C was developed by the Transaction Processing Performance Council (TPC). The TPC was founded to define transaction processing benchmarks and to disseminate objective, verifiable performance data to the industry. This full disclosure report is based on the TPC Benchmark C Standard Specifications Version 5.1, released December 2002.

TPC Benchmark C Overview

The TPC describes this benchmark in Clause 0.1 of the specifications as follows:

TPC Benchmark™ C (TPC-C) is an OLTP workload. It is a mixture of read-only and update intensive transactions that simulate the activities found in complex OLTP application environments. It does so by exercising 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
- On-line and deferred transaction execution modes
- Multiple on-line terminal sessions
- Moderate system and application execution time
- Significant disk input/output
- Transaction integrity (ACID properties)
- Non-uniform distribution of data access through primary and secondary keys
- Databases consisting of many tables with a wide variety of sizes, attributes, and relationships
- Contention on data access and update

The performance metric reported by TPC-C is a "business throughput" measuring the number of orders processed per minute. Multiple transactions are used to simulate the business activity of processing an order, and each transaction is subject to a response time constraint. The performance metric for this benchmark is expressed in transactions-per-minute-C (tpmC). To be compliant with the TPC-C standard, all references to tpmC results must include the tpmC rate, the associated price-per-tpmC, and the availability date of the priced configuration.

Although these specifications express implementation in terms of a relational data model with conventional locking scheme, the database may be implemented using any commercially available database management system (DBMS), database server, file system, or other data repository that provides a functionally equivalent implementation. The terms "table", "row", and "column" are used in this document only as examples of logical data structures.

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

Despite the fact that this benchmark offers a rich environment that emulates 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-C 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 as a result of these and other factors. Therefore, TPC-C should not be used as a substitute for a specific customer application benchmarking when critical capacity planning and/or product evaluation decisions are contemplated.

Abstract

Overview

This report documents the methodology and results of the TPC Benchmark C test conducted on the HP ProLiant DL380G3R. The operating system used for the benchmark was Microsoft Windows Server 2003, Enterprise Edition. The DBMS used was Microsoft SQL Server 2000 Enterprise Edition.

TPC Benchmark C Metrics

The standard TPC Benchmark C metrics, tpmC (transactions per minute), price per tpmC (three year capital cost per measured tpmC), and the availability date are reported as:

33,873.83 tpmC
$2.40 per tpmC

The availability date is December 17, 2003.

Standard and Executive Summary Statements

The following pages contain executive summary of results for this benchmark.

Auditor

The benchmark configuration, environment and methodology were audited by Tom Sawyer of Performance Metrics, Inc. to verify compliance with the relevant TPC specifications.

Hewlett Packard Company	ProLiant DL380-G3-1M 2P C/S with ProLiant DL360R02	TPC-C Rev. 5.1
		Report Date: Dec. 17, 2003

Total System Cost	TPC-C Throughput	Price/Performance	Availability Date
$81,177	**33,873.83**	**$2.40**	**Dec. 17, 2003**

Processors	Database Manager	Operating System	Other Software	Number of Users
1 Intel Xeon 3.20 GHz – 1M L3 cache – Server 1 Intel Xeon 2.8 GHz – Clients	Microsoft SQL Server 2000 Enterprise Edition SP3	Microsoft Windows Server 2003, Enterprise Edition	Microsoft Visual C++ Microsoft COM+	**27000**

HP ProLiant DL380G3 w/ 12 GB RAM, 3 SMART 5302 RAID Controllers with 4X 72GB 10K Drives in the internal bays

1 RTE simulating 27000 PCs

5 HP Storage Works 4414R disk enclosures with 70X 18.2 GB 15K drives

1 HP ProLiant DL360R03 each with 1x2.8 GHz processor, 1X 18.2 GB 15K drive
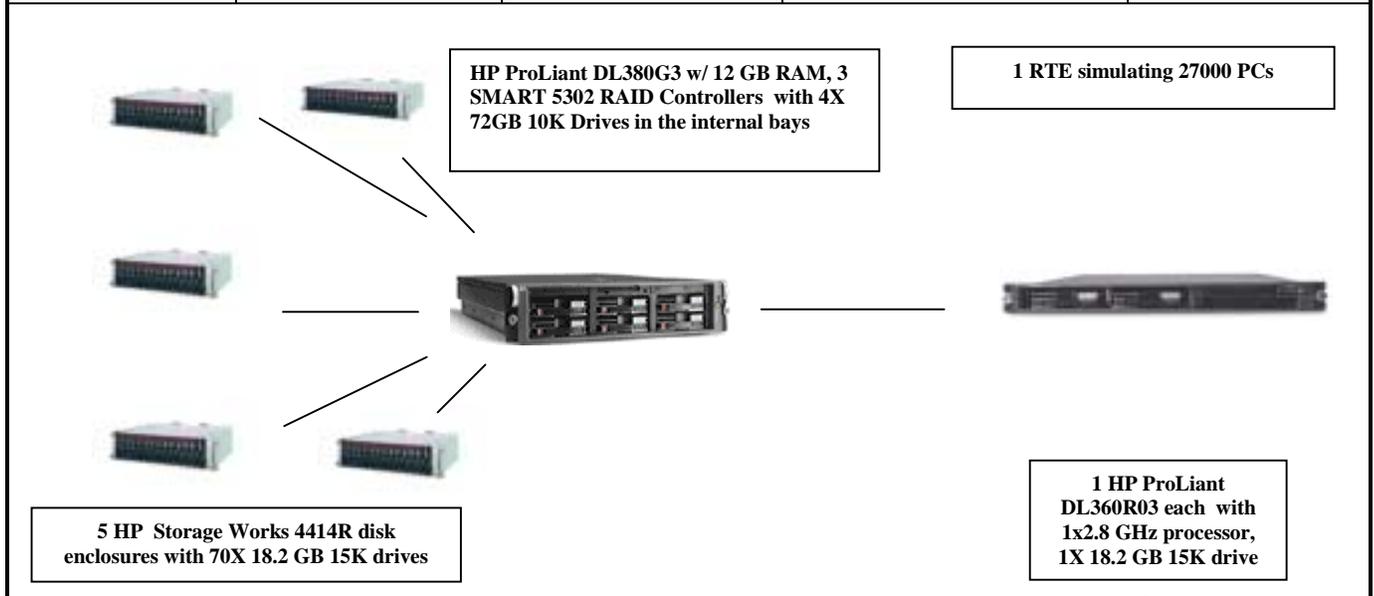
System Components	Server Quantity	Server Description	Each Client Quantity	Each Client Description
Processor	1	3.20 GHz Intel Xeon w/ 1M Cache	1	2.8 GHz Pentium III Xeon w/ 256K cache
Memory	6	2048 MB DDR	1	1 GB (4x 256 MB)
Disk Controllers	1	Integrated SMART 5i Array Controller	1	Integrated SMART Array Controller
	5	SMART 5302 Array Controller		
Disk Drives	4	72.8 GB SCSI Drives	1	18 GB SCSI Drive
	70	18.2 GB SCSI Drives		
Total Storage		1565.2 GB		18 GB
Backup Storage	1	DVD+R/DVD+RW drive		

Hewlett-Packard Company	HP ProLiant DL380 G3 1P		TPC-C Rev. 5.1	
	Client/Server		Report Date:	17-Dec-03

Description	Part Number	Third Party Brand Pricing	Unit Price	Qty	Extended Price	3 yr. Maint. Price
Server Hardware						
DL380G3 X3.2GHz/533 1MB 1GB 1P Rck US	333705-001	1	3,899	1	3,899	
4GB PC2100 DDR SDRAM DIMM 2x2048	300682-B21	1	3,499	3	10,497	
StorageWorks MSA30 Storage Enclosure - Rack-mountable	302969-B21	1	2,978	5	14,890	
Smart Array 5302/128 Controller	283552-B21	1	1,299	3	3,897	
S5500 15 carbon / silver monitor	261602-001	1	129	1	129	
Standard 2 button mouse	402366-B22	1	5	1	5	
PS/2 Easy Access Keyboard	304788-001	1	10	1	10	
Pro UPS 500 (500VA/300 Watts; 110-127 VAC, 60Hz)	136386-001	1	146	1	146	
18GB 15K U320 Pluggable Hard Drive	286775-B22	1	299	70	20,930	
18GB 15K U320 Pluggable Hard Drive (10% spares)	286775-B22	1	299	7		2,093
72.8GB 10Krpm U320 UNI HDD (OS, internal log)	286714-B22	1	429	4	1,716	
HP CP 3Y 4H 24x7 HW 300 Srs 4-Hour 24 Hour x 7 Day Coverage 3 Year	162657-002	1	949	1		949
FM-4E724-36 3YR 24X7/4HR EMPTY DISK ENCL	171242-002	1	157	5		785
				Subtotal	**56,119**	**3,827**
Server Software						
Database Server Support Package	-PRORS-16U-01	Microsoft 2	1,950	3		5,850
SQL Server 2000 Enterprise Edition 32-bit	810-00845	Microsoft 2	17,279	1	17,279	Incl Above
Visual C++ .Net Standard	254-00170	Microsoft 2	109	1	109	Incl Above
Windows Server 2003 Enterprise Edition	P72-00264	Microsoft 2	2,399	1	2,399	Incl Above
				Subtotal	**19,787**	**5,850**
Client Hardware						
ProLiant DL360 G3 1x2.8GHz, 512MB (2x256MB) , Two integrated Gigabit NIC, Integrated Smart Array Controller	292889-001	1	2,299	1	2,299	
512MB PC2100 DDR SDRAM DIMM 2x256	300678-B21		298	1	298	
18.2GB 15Krpm U320 UNI HDD	286775-B22	1	299	1	299	
HP Carepaq 3YR 24X7/4HR ENTRY 300 SVR	162675-002	1	599	1		599
				Subtotal	**2,896**	**599**
Client Software						
Windows 2000 Server 32-bit	C11-00821	Microsoft 2	738	1	738	Incl. Above
				Subtotal	**738**	**0**
User Connectivity and Server Backup Device						
7 ft. CAT5e Patch cable	CBLC57	LanAdapters 3	1	3	3	
HP DVD Writer dvd300xe (external, USB)	460898	4	240	1	240	
				Subtotal	**243**	**0**
Large Purchase and Net 30 discount (See Note 1)	14.0%		1		**($8,262)**	**($620)**
				Total	**$71,520**	**$9,656**

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

Three-Year Cost of Ownership: **$81,177**

tpmC Rating: **33873.83**

$ / tpmC: **$2.40**

Pricing: 1=HP 2= Microsoft 3=LanAdapters.com 4=CDW.com

Note 1 = Discount based on HP Direct guidance with large purchase and Net 30 discount.

Note:The benchmark results and test methodology were audited by Tom Sawyer of Performance Metrics, Inc.

Numerical Quantities Summary

MQTH, Computed Maximum Qualified Throughput   **33,873.83 tpmC**

Response Times (in seconds)	Average	90%	Maximum
New-Order	0.30	0.44	5.44
Payment	0.20	0.30	4.98
Order-Status	0.22	0.33	5.50
Delivery (interactive portion)	0.10	0.11	0.17
Delivery (deferred portion)	0.24	0.36	1.00
Stock-Level	1.00	1.41	3.63
Menu	0.10	0.11	0.34

Transaction Mix, in percent of total transaction

New-Order			44.89%
Payment			43.04%
Order-Status			4.02%
Delivery			4.01%
Stock-Level			4.03%

Emulation Delay (in seconds)		Resp.Time	Menu
New-Order		0.10	0.10
Payment		0.10	0.10
Order-Status		0.10	0.10
Delivery (interactive)		0.10	0.10
Stock-Level		0.10	0.10

Keying/Think Times (in seconds)	Min.	Average	Max.
New-Order	18.00/0.00	18.01/12.11	18.05/121.12
Payment	3.00/0.00	3.02/12.10	3.05/121.12
Order-Status	2.00/0.00	2.01/10.07	2.04/101.00
Delivery (interactive)	2.00/0.00	2.01/5.09	2.04/50.82
Stock-Level	2.00/0.00	2.01/5.08	2.04/50.81

Test Duration

Ramp-up time	35 minutes
Measurement interval	120 minutes
Transactions (all types) completed during measurement interval	9,377,599
Ramp down time	31 minutes

Checkpointing

Number of checkpoints	4
Checkpoint interval	30 minutes

General Items

Test Sponsor

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

This benchmark was sponsored by Hewlett-Packard Company. The benchmark was developed and engineered by Hewlett-Packard Company. Testing took place at HP benchmarking laboratories in Houston, Texas.

Application Code and Definition Statements

The application program (as defined in clause 2.1.7) must be disclosed. This includes, but is not limited to, the code implementing the five transactions and the terminal input output functions.

Appendix A contains all source code implemented in this benchmark.

Parameter Settings

Settings must be provided for all customer-tunable parameters and options which have been changed from the defaults found in actual products, including by not limited to:

- *Database options*
- *Recover/commit options*
- *Consistency locking options*
- *Operating system and application configuration parameters*

This requirement can be satisfied by providing a full list of all parameters.

Appendix C contains the tunable parameters to for the database, the operating system, and the transaction monitor.

Configuration Items

Diagrams of both measured and priced configurations must be provided, accompanied by a description of the differences.

The configuration diagrams for both the tested and priced systems are included on the following pages.

Figure 1. Benchmarked and Priced Configuration

HP ProLiant DL380G3 w/ 12 GB RAM, 3 SMART 5302 RAID Controllers with 4X 72GB 10K Drives in the internal bays

1 RTE simulating 27000 PCs

1 HP ProLiant DL360R03 each with 1x2.8 GHz processor, 1X 18.2 GB 15K drive

5 HP Storage Works 4414R disk enclosures with 70X 18.2 GB 15K drives
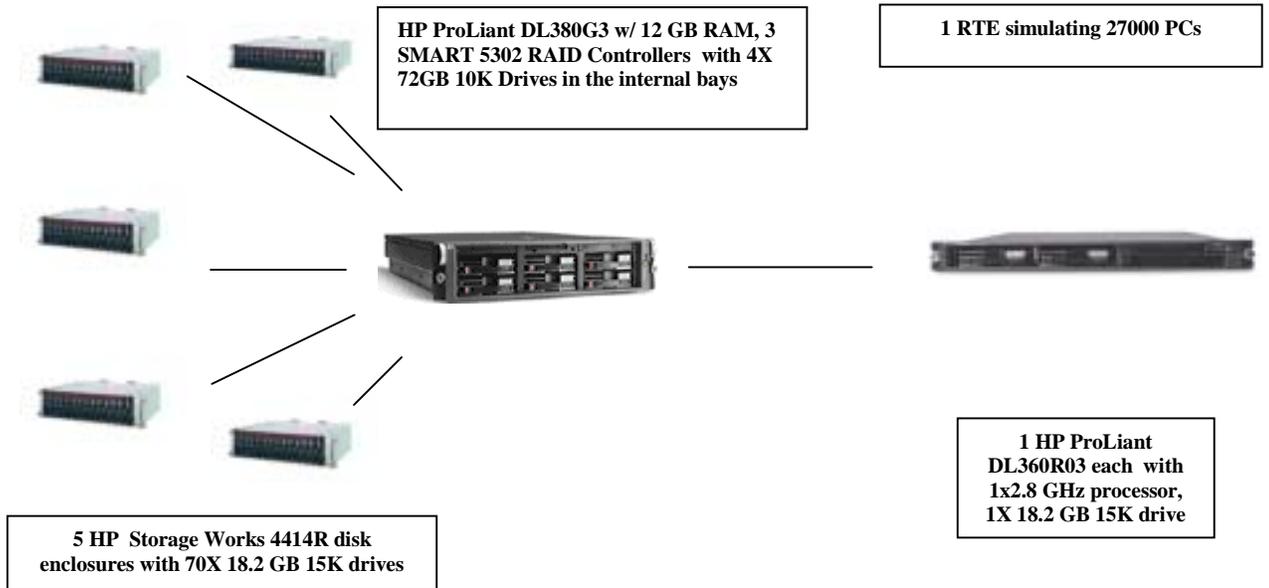
Clause 1 Related Items

Table Definitions
Listing must be provided for all table definition statements and all other statements used to set up the database.

Appendix B contains the code used to define and load the database tables.

Physical Organization of Database
The physical organization of tables and indices within the database must be disclosed.
The tested configuration consisted of: 70 18.2 GB 15K drives for the database data connected to 3 SMART 5302 RAID controllers and 4 72.8 GB 10K drives for the operating system and the transaction log connected to the embedded SMART array controller..

Benchmarked Configuration:

Integrated SMART 5i Controller
LOGICAL DRIVE C: Total Capacity = 8.00 GB   RAID 0+1
     Microsoft Windows Server 2003 Enterprise Edition, MSSQL_tpcc_root.mdf
Integrated SMART 5i Controller
LOGICAL DRIVE E: Total Capacity = 127.66 GB   RAID 0+1
     MSSQL_tpcc_log

SMART-5302 Controller, Slot 1, Array A
LOGICAL DRIVE F: Total Capacity = 33.54 GB   RAID 0
     MSSQL_cust1

SMART-5302 Controller, Slot 1, Array A
LOGICAL DRIVE H: Total Capacity = 46.24 GB   RAID 0
     MSSQL_stock1

SMART-5302 Controller, Slot 1, Array A
LOGICAL DRIVE X: Total Capacity = 147.51 GB   RAID 0+1
     Backup1

SMART-5302 Controller, Slot 2, Array A
LOGICAL DRIVE G: Total Capacity = 33.54 GB   RAID 0
     MSSQL_cust2

SMART-5302 Controller, Slot 2, Array A
LOGICAL DRIVE I: Total Capacity = 46.24 GB   RAID 0
     MSSQL_stock2

SMART-5302 Controller, Slot 2, Array A
LOGICAL DRIVE Y: Total Capacity = 147.51 GB   RAID 0+1
     Backup2

SMART-5302 Controller, Slot 3, Array A
LOGICAL DRIVE J: Total Capacity = 63.47 GB   RAID 0
     MSSQL_ordln1

SMART-5302 Controller, Slot 3, Array A

LOGICAL DRIVE K:	Total Capacity = 14.94 GB	RAID 0
MSSQL_misc1		

SMART-5302 Controller, Slot 3, Array A

LOGICAL DRIVE Z:	Total Capacity = 79.49 GB	RAID 0+1
Backup3		

Priced Configuration vs. Measured Configuration:

The measured and priced configuration differ in that the measured configuration used disk drives for database backup and the priced configuration used a DVD recorder drive for backup.

Insert and Delete Operations

It must be ascertained that insert and/or delete operations to any of the tables can occur concurrently with the TPC-C transaction mix. Furthermore, any restrictions in the SUT database implementation that precludes inserts beyond the limits defined in Clause 1.4.11 must be disclosed. This includes the maximum number of rows that can be inserted and the minimum key value for these new rows.

All insert and delete functions were fully operational during the entire benchmark.

Partitioning

While there are a few restrictions placed upon horizontal or vertical partitioning of tables and rows in the TPC-C benchmark, any such partitioning must be disclosed.

No partitioning was used in this benchmark.

Replication, Duplication or Additions

Replication of tables, if used, must be disclosed. Additional and/or duplicated attributes in any table must be disclosed along with a statement on the impact on performance.

No replications, duplications or additional attributes were used in this benchmark.

Clause 2 Related Items

Random Number Generation
The method of verification for the random number generation must be described.

In the Benchcraft RTE from Microsoft, each driver engine uses an independent random number sequence. All of the users within a given driver draw from the same sequence.

The Benchcraft RTE computes random integers as described in "Random Numbers Generators: Good Ones Are Hard to Find." Communications of the ACM - October 1988 Volume 31 Number 10.

The seeds for each user were captured and verified by the auditor to be unique. In addition, the contents of the database were systematically searched, and randomly sampled by the auditor for patterns that would indicate the random number generator had affected any kind of a discernible pattern; none were found.

Input/Output Screen Layout
The actual layout of the terminal input/output screens must be disclosed.

All screen layouts followed the specifications exactly.

Priced Terminal Feature Verification
The method used to verify that the emulated terminals provide all the features described in Clause 2.2.2.4 must be explained. Although not specifically priced, the type and model of the terminals used for the demonstration in 8.1.3.3 must be disclosed and commercially available (including supporting software and maintenance).

The terminal attributes were verified by the auditor. The auditor manually exercised each specification on a representative HP ProLiant web server.

Presentation Manager or Intelligent Terminal
Any usage of presentation managers or intelligent terminals must be explained.

Application code running on the client machines implemented the TPC-C user interface. No presentation manager software or intelligent terminal features were used. The source code for the forms applications is listed in Appendix A.

Transaction Statistics
Table 2.1 lists the numerical quantities that Clauses 8.1.3.5 to 8.1.3.11 require.

Table 2.1 Transaction Statistics

Statistic		Value
New Order	Home warehouse order lines	99.00%
	Remote warehouse order lines	1.00%
	Rolled back transactions	1.00%
	Average items per order	10.00
Payment	Home warehouse payments	85.00%
	Remote warehouse payments	15.00%

Statistic		Value
	Accessed by last name	59.99%
Order Status	Accessed by last name	60.04%
Transaction Mix	New Order	44.89%
	Payment	43.04%
	Order status	4.02%
	Delivery	4.01%
	Stock level	4.03%

Queuing Mechanism

The queuing mechanism used to defer the execution of the Delivery transaction must be disclosed.

Microsoft COM+ on each client machine served as the queuing mechanism to the database. Each delivery request was submitted to Microsoft COM+ asynchronously with control being returned to the client process immediately and the deferred delivery part completing asynchronously.

The source code is listed in Appendix A.

Clause 3 Related Items

Transaction System Properties (ACID)
The results of the ACID tests must be disclosed along with a description of how the ACID requirements were met. This includes disclosing which case was followed for the execution of Isolation Test 7.

All ACID property tests were successful. The executions are described below.

Atomicity
The system under test must guarantee that the database transactions are atomic; the system will either perform all individual operations on the data or will assure that no partially completed operations leave any effects on the data.

Completed Transactions
A row was selected in a script from the warehouse, district and customer tables, and the balances noted. A payment transaction was started with the same warehouse, district and customer identifiers and a known amount. The payment transaction was committed and the rows were verified to contain correctly updated balances.

Aborted Transactions
A row was selected in a script from the warehouse, district and customer tables, and the balances noted. A payment transaction was started with the same warehouse, district and customer identifiers and a known amount. The payment transaction was rolled back and the rows were verified to contain the original balances.

Consistency
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, assuming that the database is initially in a consistent state.

Consistency conditions one through four were tested using a script to issue queries to the database. The results of the queries verified that the database was consistent for all four tests.

A run was executed under full load lasting over two hours and included a checkpoint.

The script was executed again. The result of the same queries verified that the database remained consistent after the run.

Isolation
Sufficient conditions must be enabled at either the system or application level to ensure the required isolation defined above (clause 3.4.1) is obtained.

Isolation tests one through nine were executed using shell scripts to issue queries to the database. Each script included timestamps to demonstrate the concurrency of operations. The results of the queries were captured to files. The captured files were verified by the auditor to demonstrate that the required isolation had been met.

In addition, the phantom tests and the stock level tests were executed and verified.

For Isolation test seven, case A was followed.

Durability

The tested system must guarantee durability: the ability to preserve the effects of committed transaction and insure database consistency after recovery from any one of the failures listed in Clause 3.5.3.

Durable Media Failure

<u>Loss of Data and Log</u>
To demonstrate recovery from a permanent failure of durable medium containing DBMS logs and TPC-C tables, the following steps were executed on a fully scaled database of 270 warehouses under a full load of 2700 users:

- The full database (270 warehouses) was started.
- The total number of New Orders was determined by the sum of D_NEXT_O_ID of all rows in the DISTRICT table giving the beginning count.
- The RTE was started with 2700 users.
- The test was allowed to run for a minimum of 5 minutes.
- One log disk was removed from the server.
- Since the disk was mirrored, processing was not interrupted. This was verified by checking the users status on the RTE.
- One of the data disks was removed from a drive cabinet.
- When Microsoft SQL Server recorded errors about not being able to access the database, the RTE and SQL Server was shut down.
- A new log disk was inserted into the server. A new data disk was inserted into the data drive cabinet. After the RAID recovery process finished, the system was rebooted and Microsoft SQL Server was started.
- A dump of the transaction log was taken and the Microsoft SQL Server was shutdown.
- The database was restored from backup and the transaction log dump was applied.
- Consistency condition #3 was executed and verified.
- Step 2 was repeated and the difference between the first and second counts was noted.
- An RTE report was generated for the entire run time giving the number of NEW-ORDERS successfully returned to the RTE.
- The counts in step 13 and 14 were compared and the results verified that all committed transactions had been successfully recovered.
- Samples were taken from the RTE files and used to query the database to demonstrate successful transactions had corresponding rows in the ORDER table.

Instantaneous Interruption and Loss of Memory :

Because loss of power erases the contents of memory, the instantaneous interruption and the loss of memory tests were combined into a single test. This test was executed on a fully scaled database of 2700 warehouses under a full load of 27000 users. The following steps were executed:

- The full database was started.
- The total number of New Orders was determined by the sum of D_NEXT_O_ID of all rows in the DISTRICT table giving the beginning count.
- The RTE was started with 27000 users.
- The test was allowed to run for a minimum of 5 minutes.
- A checkpoint was performed.
- The system crash and loss of memory were induced by physically removing the power cord from the SUT. No battery backup or Uninterruptible Power Supply (UPS) were used to preserve the contents of memory.
- The RTE was shutdown.
- Power was restored and the system restarted.
- Microsoft SQL Server was restarted and performed an automatic recovery.
- Consistency condition #3 was executed and verified.

- Step 2 was repeated and the difference between the first and second counts was noted.
- An RTE report was generated for the entire run time giving the number of NEW-ORDERS successfully returned to the RTE.
- The counts in step 10 and 11 were compared and the results verified that all committed transactions had been successfully recovered.
- Samples were taken from the RTE files and used to query the database to demonstrate successful transactions had corresponding rows in the ORDER table.

Clause 4 Related Items

Initial Cardinality of Tables

The cardinality (e.g. number of rows) of each table, as it existed at the start of the benchmark run, must be disclosed. If the database was over-scaled and inactive rows of the WAREHOUSE table were deleted, the cardinality of the WAREHOUSE table as initially configured and the number of rows deleted must be disclosed.

Table 4.1 Number of Rows for Server

Table	Cardinality as built
Warehouse	2,700
District	27,000
Customer	81,000,000
History	81,000,000
Orders	81,000,000
New Order	24,300,000
Order Line	810,001,666
Stock	270,000,000
Item	100,000
Deleted Warehouses	0

Database Layout

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

The benchmarked configuration used 3 SMART-5302 Array controllers with 2 SCSI channels. Each controller is capable of accessing up to 14 disk drives per channel, and supports RAID 0, RAID 0+1,and RAID 5 per each logical volume configured. The data tables were stored on 2 RAID arrays of (28) 18.2GB 15K drives each and 1 RAID array of (14) 18.2 GB 15K drives. There was only one RAID array configured for each controller that consisted of all of the drives attached to that controller. Each of the controllers had 2 RAID 0 logical drives for storing data tables and a RAID 0+1 logical drive used for backup of the database. The integrated SMART Array 5i controller had one array consisting of (4) 72.8 GB 10K drives with a RAID 0+1 logical volume for the operating system and a RAID 0+1 logical volume for the database log. The Array Accelerators on the data controllers were configured as 100% write cache and were enabled for all logical drives on these controllers. The logical drive for the transaction log had the cache disabled. All RAID volumes used hardware RAID.

Section 1.2 of this report details the distribution of database tables across all disks. The code that creates the filegroups and tables is included in Appendix B.

Type of Database

A statement must be provided that describes:

- *The data model implemented by DBMS used (e.g. relational, network, hierarchical).*
- *The database interface (e.g. embedded, call level) and access language (e.g. SQL, DL/1, COBOL read/write used to implement the TPC-C transaction. If more than one interface/access language is used to implement TPC-C, each interface/access language must be described and a list of which interface/access language is used with which transaction type must be disclosed.*

Microsoft SQL Server 2000 Enterprise Edition is a relational DBMS.

The interface used was Microsoft SQL Server stored procedures accessed with Remote Procedure Calls embedded in C code.

Database Mapping

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

The database was not replicated.

60 Day Space

Details of the 60 day space computations along with proof that the database is configured to sustain 8 hours of growth for the dynamic tables (Order, Order-Line, and History) must be disclosed.

To calculate the space required to sustain the database log for 8 hours of growth at steady state, the following steps were followed:

- The free space on the log file was queried using *dbcc sqlperf(logspace)*.
- Transactions were run against the database with a full load of users.
- The free space was again queried using *dbcc sqlperf(logspace)*.
- The space used was calculated as the difference between the first and second query.
- The number of NEW-ORDERS was verified from the difference in the sum(d_next_o_id) taken from before and after the run.
- The space used was divided by the number of NEW-ORDERS giving a space used per NEW-ORDER transaction.
- The space used per transaction was multiplied by the measured tpmC rate times 480 minutes.

The same methodology was used to compute growth requirements for dynamic tables Order, Order-Line and History.

The details of both the 8-hour transaction log space requirement and the 60-day space requirement is shown in Appendix D.

Clause 5 Related Items

Throughput

Measured tpmC must be reported

Measured tpmC	33,873.83 tpmC
Price per tpmC	$2.40 per tpmC

Response Times

Ninetieth percentile, maximum and average response times must be reported for all transaction types as well as for the menu response time.

Table 5.2: Response Times

Type	Average	90th %	Maximum
New-Order	0.30	0.44	5.44
Payment	0.20	0.30	4.98
Order-Status	0.22	0.33	5.50
Interactive Delivery	0.10	0.11	0.17
Deferred Delivery	0.24	0.36	1.00
Stock-Level	1.00	1.41	3.63
Menu	0.10	0.11	0.34

Keying and Think Times

The minimum, the average, and the maximum keying and think times must be reported for each transaction type.

Table 5.3: Keying Times

Type	Minimum	Average	Maximum
New-Order	18.00	18.01	18.05
Payment	3.00	3.02	3.05
Order-Status	2.00	2.01	2.04
Interactive Delivery	2.00	2.01	2.04
Stock-Level	2.00	2.01	2.04

Table 5.4: Think Times

Type	Minimum	Average	Maximum
New-Order	0.00	12.11	121.12
Payment	0.00	12.10	121.12
Order-Status	0.00	10.07	101.00
Interactive Delivery	0.00	5.09	50.82
Stock-Level	0.00	5.08	50.81

Response Time Frequency Distribution Curves and Other Graphs

Response Time frequency distribution curves (see Clause 5.6.1) must be reported for each transaction type.

The performance curve for response times versus throughput (see Clause 5.6.2) must be reported for the New-Order transaction.

Think Time frequency distribution curves (see Clause 5.6.3) must be reported for each transaction type.

Keying Time frequency distribution curves (see Clause 5.6.4) must be reported for each transaction type.

A graph of throughput versus elapsed time (see Clause 5.6.5) must be reported for the New-Order transaction.

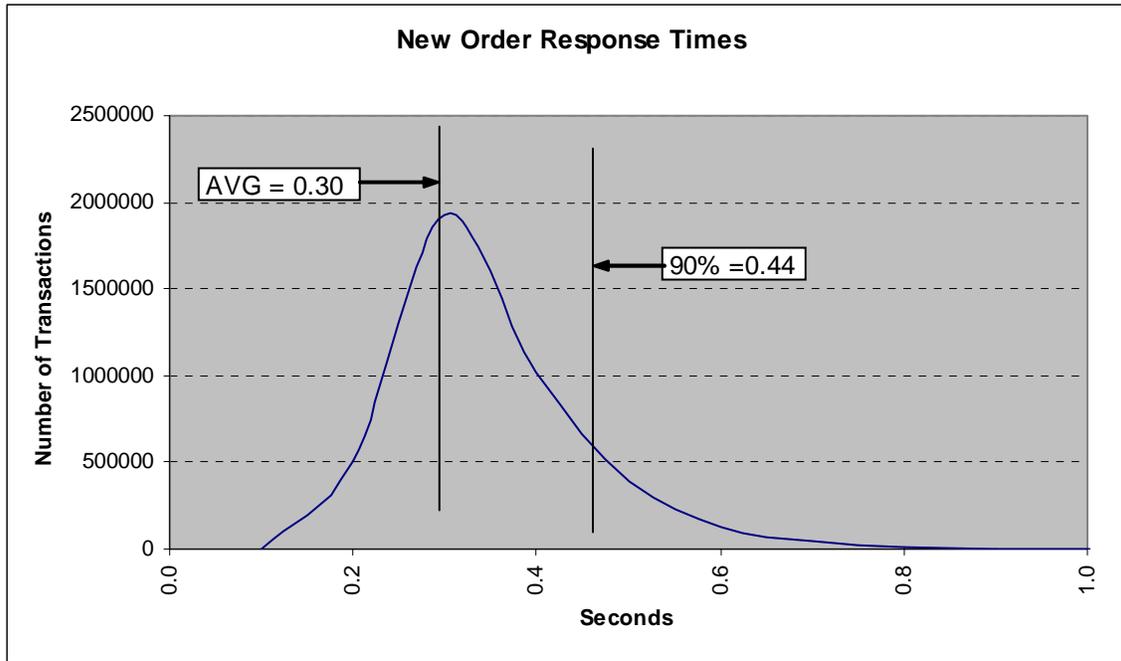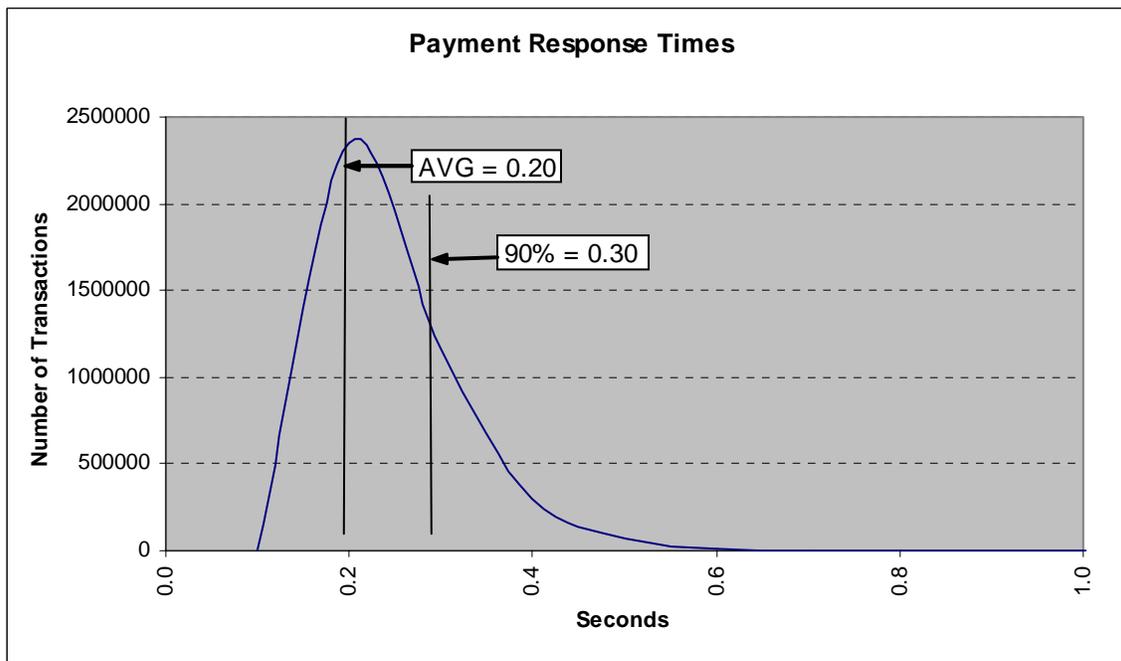**Figure 3. New Order Response Time Distribution**

New Order Response Times

AVG = 0.30

90% =0.44

Number of Transactions

Seconds

Figure 4. Payment Response Time Distribution

Payment Response Times

AVG = 0.20

90% = 0.30

Number of Transactions

Seconds

Figure 5. Order Status Response Time Distribution

Order Status Response Times

Number of Transactions vs Seconds chart. Peak near 180000 transactions at approximately 0.22 seconds.

AVG = 0.22

90% = 0.33
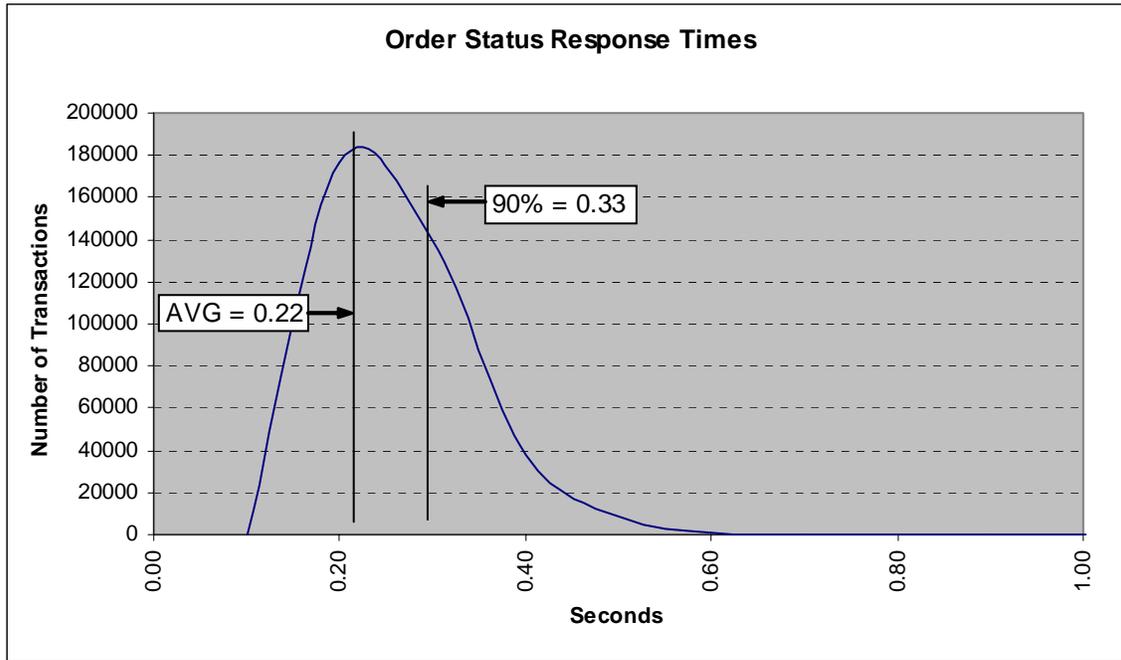
Figure 6. Delivery Response Time Distribution

Delivery Response Times

Number of Transactions vs Seconds chart. Peak near 360000 transactions at approximately 0.20 seconds.

AVG = 0.10

90% = 0.11

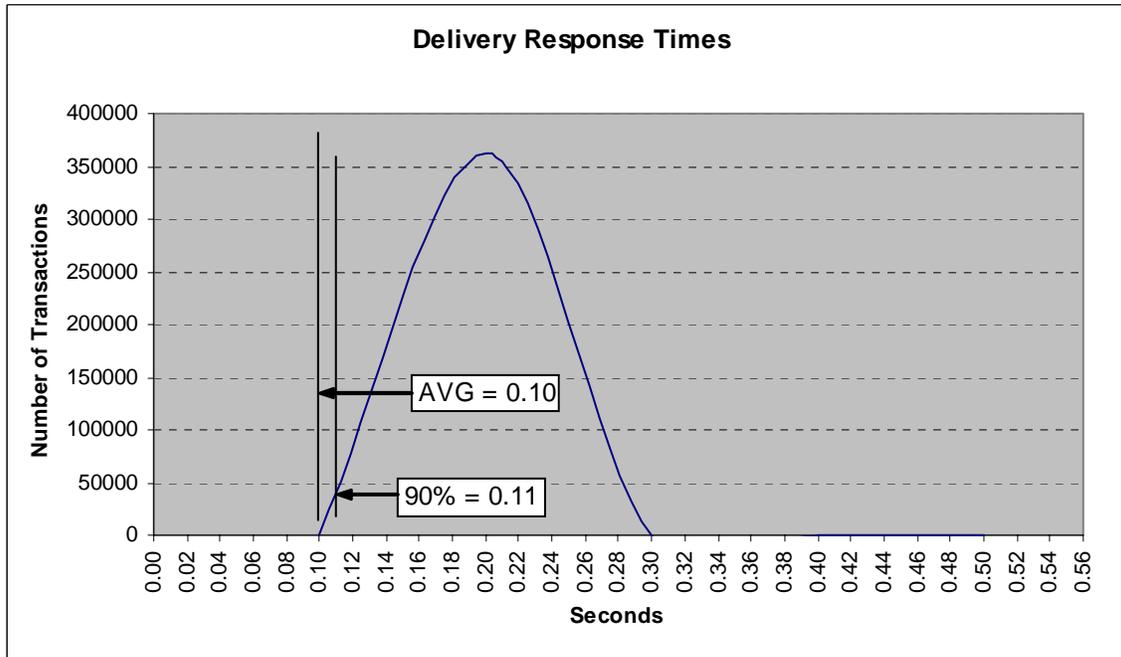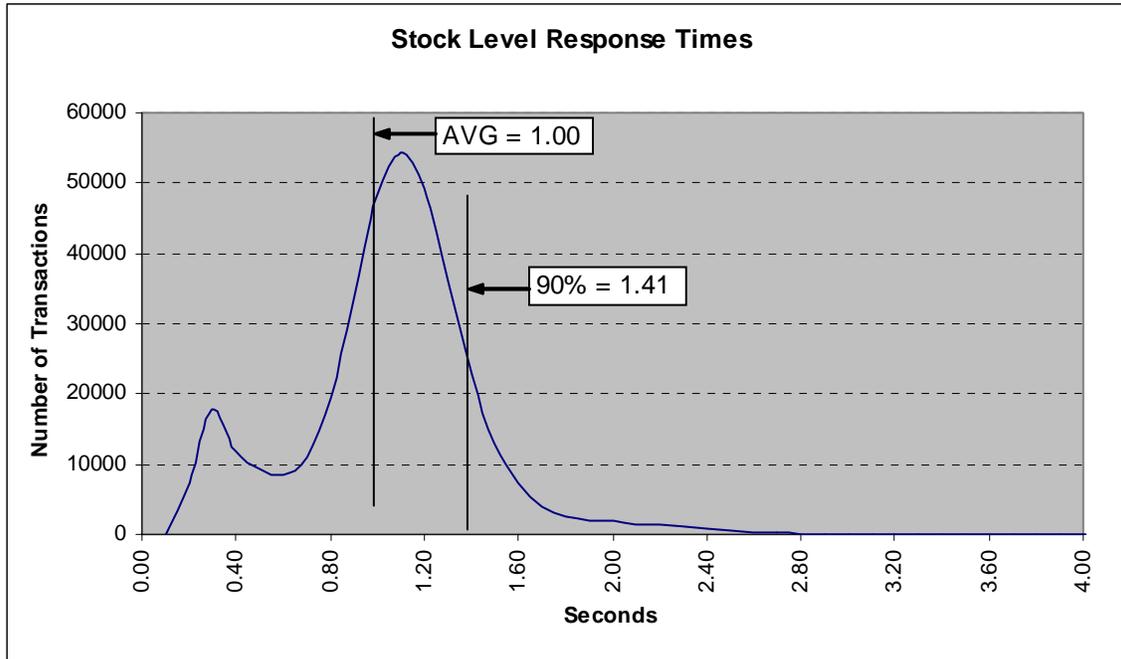**Figure 7. Stock Level Response Time Distribution**

Figure 8. Response Time vs. Throughput
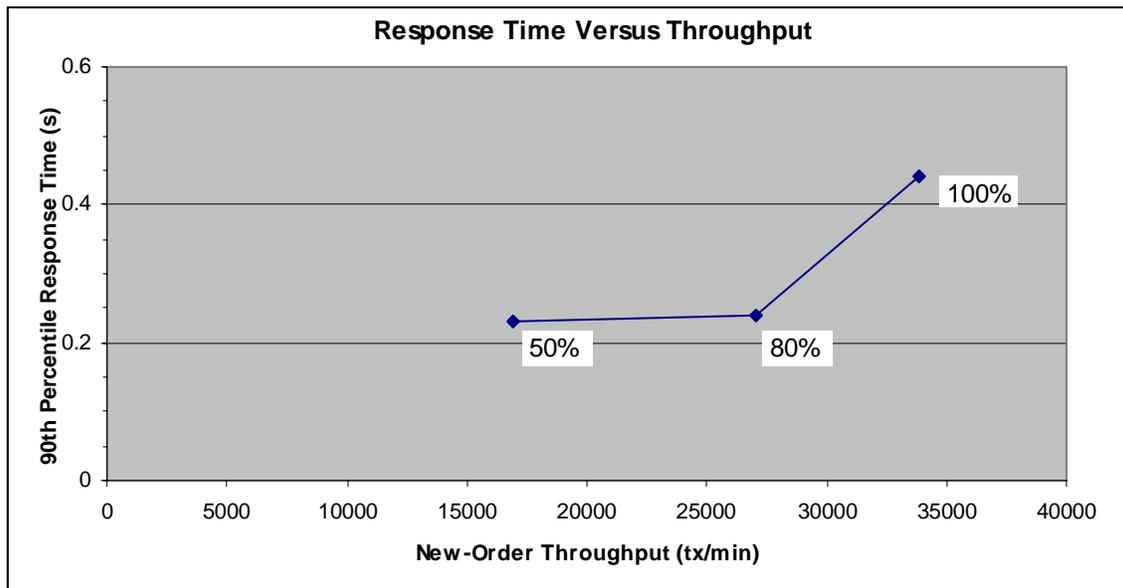
Figure 9. New Order Think Time Distribution

New Order Think Times Distribution

Mean = 12.11

(Y-axis: Number of Transactions, from 0 to 50000)
(X-axis: Seconds, from 0 to 50)
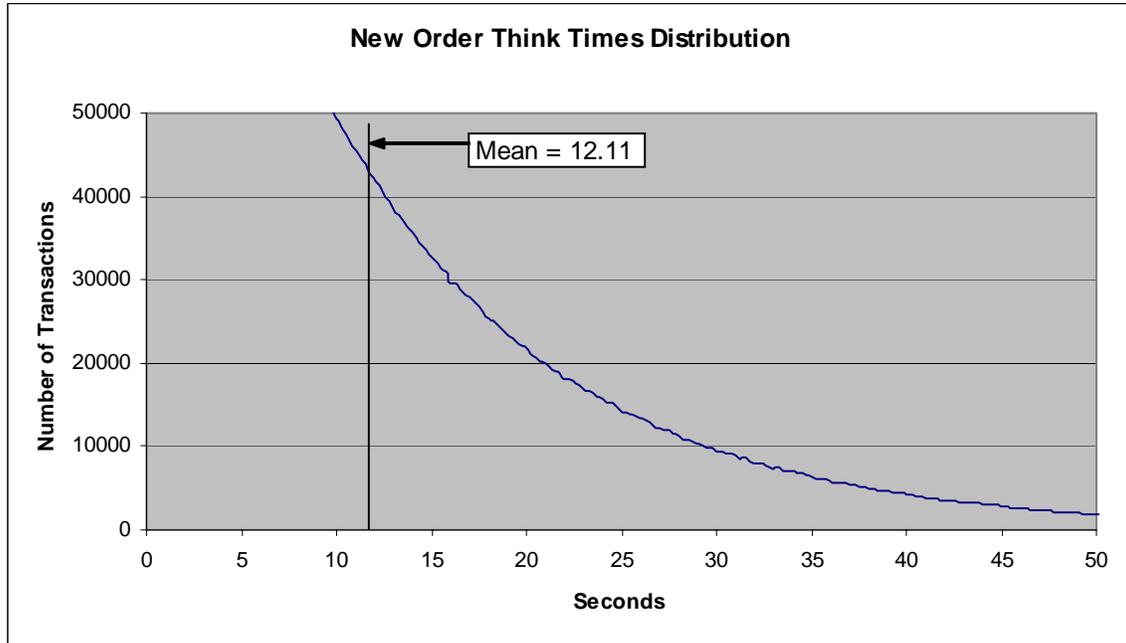
Figure 10. Throughput vs. Time Distribution

Throughput vs Time Distribution

Measurement Interval

checkpoint   checkpoint   checkpoint   checkpoint   checkpoint

(Y-axis: tpmC, from 0 to 40000)
(X-axis: Time, from 13:11 to 15:51)
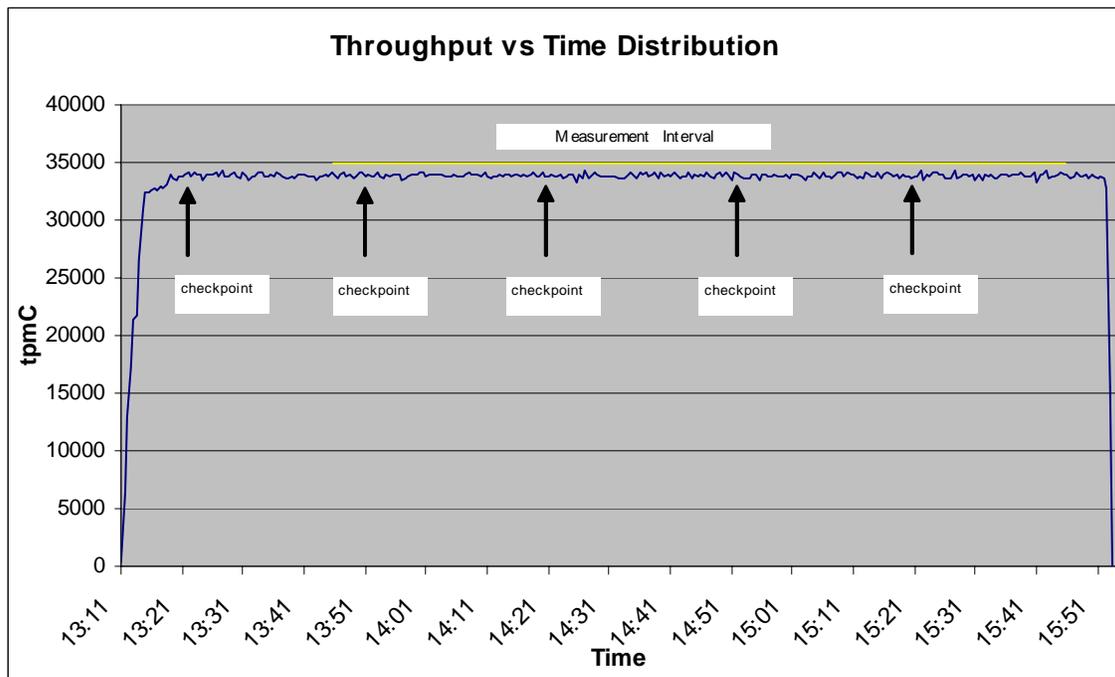
Steady State Determination

The method used to determine that the SUT had reached a steady state prior to commencing the measurement interval must be disclosed.

Steady state was determined using real time monitor utilities from the RTE. Steady state was further confirmed by the throughput data collected during the run and graphed in Figure 10.

Work Performed During Steady State

A description of how the work normally performed during a sustained test (for example checkpointing, writing redo/undo log records, etc.), actually occurred during the measurement interval must be reported.

The RTE generated the required input data to choose a transaction from the menu. This data was timestamped. The input screen for the requested transaction was returned and timestamped. The difference between these two timestamps was the menu response time. The RTE writes to the log file once per transaction on selective fields such as order id. There is one log file per driver engine.

The RTE generated the required input data for the chosen transaction. It waited to complete the minimum required key time before transmitting the input screen. The transmission was timestamped. The return of the screen with the required response data was timestamped. The difference between these two timestamps was the response time for that transaction.

The RTE then waited the required think time interval before repeating the process starting at selecting a transaction from the menu.

The RTE transmissions were sent to application processes running on the client machines through Ethernet LANs. These client application processes handled all screen I/O as well as all requests to the database on the server. The applications communicated with the database server over Ethernet LANs using DBLIB and RPC calls.

To perform checkpoints at specific intervals, the SQL Server *recovery interval* was set to 80 and a script was written to schedule multiple checkpoints at specific intervals. The script included a wait time between each checkpoint equal to 30 minutes so that the checkpoint interval was an integral multiple of the measurement interval, which was 120 minutes. The checkpoint script was started manually after the RTE had all users logged in and the database had achieved steady state.

At each checkpoint, Microsoft SQL Server wrote to disk all memory pages that had been updated but not yet physically written to disk. The positioning of the measurement interval is depicted on the graph in Figure 10.

Measurement Period Duration

A statement of the duration of the measurement interval for the reported Maximum Qualified Throughput (tpmC) must be included.

The reported measured interval was exactly 120 minutes long.

Regulation of Transaction Mix

The method of regulation of the transaction mix (e.g., card decks or weighted random distribution) must be described. If weighted distribution is used and the RTE adjusts the weights associated with each transaction type, the maximum adjustments to the weight from the initial value must be disclosed.

The RTE was given a weighted random distribution, which was not adjusted during the run.

Transaction Statistics

The percentage of the total mix for each transaction type must be disclosed. The percentage of New-Order transactions rolled back as a result of invalid item number must be disclosed. The average number of order-lines entered per New-Order transaction must be disclosed. The percentage of remote order lines per New-Order transaction must be disclosed. The percentage of remote Payment transactions must be disclosed. The percentage of customer selections by customer last name in the Payment and Order-Status transactions must be disclosed. The percentage of Delivery transactions skipped due to there being fewer than necessary orders in the New-Order table must be disclosed.

Table 5.5: Transaction Statistics

Statistic		Value
New Order	Home warehouse order lines	99.00%
	Remote warehouse order lines	1.00%
	Rolled back transactions	1.00%
	Average items per order	10.00
Payment	Home warehouse payments	85.00%
	Remote warehouse payments	15.00%
	Accessed by last name	59.99%
Delivery	Skipped transactions (interactive)	0
	Skipped transactions (deferred)	0
Order Status	Accessed by last name	60.04%
Transaction Mix	New Order	44.89%
	Payment	43.04%
	Order status	4.02%
	Delivery	4.01%
	Stock level	4.03%

Checkpoint Count and Location
The number of checkpoints in the Measurement Interval, the time in seconds from the start of the Measurement Interval to the first checkpoint, and the Checkpoint Interval must be disclosed.

The initial checkpoint was started 11 minutes and 26.2 seconds after the start of the ramp-up. Subsequent checkpoints occurred every 30 minutes. The measurement interval contains four checkpoints.

Checkpoint Duration
The start time and duration in seconds of at least the four longest checkpoints during the Measurement Interval must be disclosed.

Checkpoint Start Time	Duration
1:51:31.65 p.m.	13 minutes, 30.15 seconds
2:21:26.73 p.m.	13 minutes, 11.05 seconds
2:51:21.69 p.m.	13 minutes, 14.68 seconds
3:21:16.74 p.m.	13 minutes, 5.8 seconds

Clause 6 Related Items

RTE Descriptions
If the RTE is commercially available, then its inputs must be specified. Otherwise, a description must be supplied of what inputs (e.g., scripts) to the RTE had been used.

The RTE used was Microsoft Benchcraft RTE. Benchcraft is a proprietary tool provided by Microsoft and is not commercially available. The RTE's input are listed in Appendix A.

Emulated Components
It must be demonstrated that the functionality and performance of the components being emulated in the Driver System are equivalent to the priced system. The results of the test described in Clause 6.6.3.4 must be disclosed.

The driver system consisted of 1 HP ProLiant server. This driver machine emulated the users' web browsers.

Functional Diagrams
A complete functional diagram of both the benchmark configuration and the configuration of the proposed (target) system must be disclosed. A detailed list of all hardware and software functionality being performed on the Driver System and its interface to the SUT must be disclosed.

The driver system performed the data generation and input functions of the priced display device. It also captured the input and output data and timestamps for post-processing of the reported metrics. No other functionality was included on the driver system.

Section 1.4 of this report contains detailed diagrams of both the benchmark configuration and the priced configuration.

Networks
The network configuration of both the tested services and proposed (target) services which are being represented and a thorough explanation of exactly which parts of the proposed configuration are being replaced with the Driver System must be disclosed.

The bandwidth of the networks used in the tested/priced configuration must be disclosed.

In the tested configuration, 1 driver (RTE) machine was connected through a Gigabit switch to the client machines at 1000Mbs, thus providing the path from the RTE to the clients. The server (SUT) was connected to the client through a single Cat 5e Ethernet cable that was connected to the integrated Gigabit network cards in both the server and the client.

The priced configuration was connected in the same manner as the tested configuration.

Operator Intervention
If the configuration requires operator intervention (see Clause 6.6.6), the mechanism and the frequency of this intervention must be disclosed.

This configuration does not require any operator intervention to sustain eight hours of the reported throughput.

Clause 7 Related Items

System Pricing

A detailed list of hardware and software used in the priced system must be reported. Each separately orderable item must have vendor part number, description, and release/revision level, and either general availability status or committed delivery data. If package-pricing is used, vendor part number of the package and a description uniquely identifying each of the components of the package must be disclosed. Pricing source and effective date(s) of price(s) must also be reported.

The total 3 year price of the entire configuration must be reported, including: hardware, software, and maintenance charges. Separate component pricing is recommended. The basis of all discounts used must be disclosed.

The details of the hardware and software are reported in the front of this report as part of the executive summary. All third party quotations are included at the end of this report as Appendix E.

Availability, Throughput, and Price Performance

The committed delivery date for general availability (availability date) of products used in the price calculation must be reported. When the priced system included products with different availability dates, the reported availability date for the priced system must be the date at which all components are committed to be available.

A statement of the measured tpmC as well as the respective calculations for the 5-year pricing, price/performance (price/tpmC), and the availability date must be included.

- **Maximum Qualified Throughput** **33,873.83 tpmC**
- **Price per tpmC** **$2.40 per tpmC**
- **Availability** **December 17, 2003**

Country Specific Pricing

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

This system is being priced for the United States of America.

Usage Pricing

For any usage pricing, the sponsor must disclose:

- *Usage level at which the component was priced.*
- *A statement of the company policy allowing such pricing.*

The component pricing based on usage is shown below:
- 1 Microsoft Windows 2000 Server
- 1 Microsoft Server 2003 Enterprise Edition
- 1 Microsoft SQL Server 2000 Enterprise Edition (per processor)
- 1 Microsoft Visual C++
- HP Servers include 3 years of support.

Clause 9 Related Items

Auditor's Report

The auditor's name, address, phone number, and a copy of the auditor's attestation letter indicating compliance must be included in the Full Disclosure Report.

This implementation of the TPC Benchmark C was audited by Tom Sawyer of Performance Metrics, Inc.

> Performance Metrics, Inc.
> 137 Yankton St., Suite 101
> Folsom, CA 95630
> (phone)   (916) 985-1131
> (fax)   (916) 985-1185
> e-mail: lorna@perfmetrics.com

Availability of the Full Disclosure Report

The Full Disclosure Report must be readily available to the public at a reasonable charge, similar to the charges for similar documents by the test sponsor. The report must be made available when results are made public. In order to use the phrase "TPC Benchmark™ C", the Full Disclosure Report must have been submitted to the TPC Administrator as well as written permission obtained to distribute same.

Requests for this TPC Benchmark C Full Disclosure Report should be sent to:

Transaction Processing Performance Council
c/o Shanley Public Relations
777 North First Street, Suite 600
San Jose, CA 95112-6311

          or

Hewlett-Packard Company
Database Performance Engineering
P.O. Box 692000
Houston, TX 77269-2000
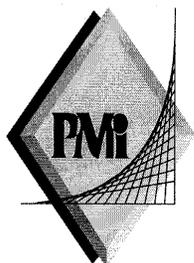
PERFORMANCE METRICS INC.
TPC Certified Auditors

December 16, 2003

Mr. John Ellyson
Hewlett-Packard Company
Database Performance Lab
20555 SH 249
Houston, TX 77070

I have verified the TPC Benchmark™ C client/server for the following configuration:

Platform:	ProLiant DL380
Database Manager:	Microsoft SQL Server 2000 Enterprise Edition
Operating System:	Microsoft Windows 2003 Server, Enterprise Edition
Transaction Manager:	Microsoft COM+

<table>
<tr><th colspan="5">Server: ProLiant ProLiant DL380</th></tr>
<tr><th>CPUs</th><th>Memory</th><th>Disks</th><th>90% Response</th><th>tpmC</th></tr>
<tr><td>1 Xeon™ Processor @ 3.2 GHz</td><td>Main: 12 GB cache: 1MB</td><td>70 18GB 4 72GB</td><td>0.44</td><td>33,873.83</td></tr>
</table>

<table>
<tr><th colspan="3">Client: 1 ProLiant DL360</th></tr>
<tr><th>CPUs</th><th>Memory</th><th>Disks</th></tr>
<tr><td>1 Intel Xeon™ Processor @ 2.8 GHz</td><td>Main: 1 GB Cache: 512KB</td><td>1 @ 18GB</td></tr>
</table>

PERFORMANCE METRICS INC.
TPC Certified Auditors

In my opinion, these performance results were produced in compliance with the TPC requirements for the benchmark. The following attributes of the benchmark were given special attention:

- The transactions were correctly implemented.
- The database was properly sized and populated.
- The database was properly scaled with 2,700 warehouses.
- The ACID properties were met.
- Input data was generated according to the specified percentages.
- Eight hours of mirrored log space was configured on the measured system.
- Eight hours of dynamic table growth space was configured on the measured system.
- The 60-day space calculation was verified; the measured system had sufficient storage.
- Measurement cycle times included a delay of 0.1 seconds.
- There were 27,000 user contexts present on the system.
- Each group of emulated users started with the same random number seed.
- The NURand constants used for database load and at run time were 123 and 233.
- The steady state portion of the test was 2 hours.
- One checkpoint was taken before the measured interval.
- Four checkpoints were taken during the measured interval.
- The system pricing was checked for major components and maintenance.

Auditor Notes:

    None

Sincerely,

Tom Sawyer
Auditor