TPC Benchmark B

Full Disclosure Report

for the

DECsystem 5500

Using

ULTRIX 4.2 and INFORMIX-OnLine 4.10

Company Name	System Name	Database Software	Operating System Software
Digital Equipment Corporation	**DECsystem 5500**	**INFORMIX-OnLine 4.10**	**ULTRIX 4.2**

Total System Cost	TPC-B Throughput	Price Performance
-Hardware -Software -5 years Maintenance	Sustained maximum throughput of system running TPC Benchmark B expressed in transactions per second.	Total system cost/ TPC-B throughput ($160,113/40.6 tps-B)
$160,113	40.6 tps-B	$3,944 per tpsB

TM

Submitted for Review: 12/3/91

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Abstract

This report documents the compliance of testing performed on a DECsystem 5500 server running INFORMIX-OnLine 4.10 in conformance to the Transaction Processing Performance Council Benchmark B Standard Specification.

Two standard metrics, transactions per second (TPS) and price per TPS ($/TPS), are reported. Throughout this report, TPS refers to the tpsB performance metric, in accordance with the TPC Benchmark B Standard. The independent auditor's report by KPMG Peat Marwick is included.

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Preface

This report documents the compliance of the Digital TPC Benchmark B testing on a DECsystem 5500 with the *TPC Benchmark™ B Standard Specification*[1]. The TPC Benchmark B Standard represents an effort by Digital Equipment Corporation, Informix Software Inc., and other members of the Transaction Processing Performance Council (TPC) to create an industry-wide benchmark for evaluating the performance and price/performance of transaction processing systems.

These tests were run using the INFORMIX-OnLine relational database running under the Digital ULTRIX operating system.

Document Structure

The *TPC Benchmark B Full Disclosure Report* is organized as follows:

- The main body of the document lists each item in Clause 10 of the TPC Benchmark B Standard and explains how each specification is satisfied.
- Appendix A contains the source code of the application program used to implement the TPC Benchmark B transaction and related programs and scripts.
- Appendix B contains the INFORMIX-OnLine database definitions.
- Appendix C contains the source code used to populate the database.
- Appendix D contains samples of contents of the database files used in the tests.
- Appendix E contains a description of the physical disk partitions.
- Appendix F contains the operating system parameters and options.
- Appendix G contains the Independent Auditor's Report by KPMG Peat Marwick.

Additional Copies

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[1] *TPC Benchmark B Standard Specification,* Transaction Processing Performance Council, August 23, 1990, and addenda as of September 20, 1991.

TPC Benchmark B Full Disclosure

The *TPC Benchmark™ B Standard Specification* requires test sponsors to publish, and make available to the public, a full disclosure report in order for the results to be considered compliant with the standard. The required contents of the full disclosure report are specified in Clause 10.

This report is intended to satisfy the TPC Benchmark B standard's requirement for full disclosure. In the *TPC Benchmark™ B Standard Specification*, the main headings in Clause 10 are keyed to the other standard clauses. The headings in this report use the same sequence, so that they correspond to the titles or subjects referred to in Clause 10.

Each section in this report begins with the text of the corresponding item from Clause 10 of the *TPC Benchmark™ B Standard Specification,* printed in italic type. The plain type text that follows explains how the tests comply with the TPC Benchmark B requirement. In sections where Clause 10 requires extensive listings, the section refers to the appropriate appendix at the end of this report.

1 - General Items

1.1 Sponsor

A statement identifying the sponsor of the benchmark and any other companies who have participated.

This benchmark test was sponsored by both Digital Equipment Corporation and Informix Software, Inc. The results were attested to by KPMG Peat Marwick.

1.2 Application Code and Definition Statements

Program listing of application code and definition language statements for files/tables.

- Appendix A contains the C source code of the application program used to implement the TPC Benchmark B transaction and related programs and scripts.
- Appendix B contains the INFORMIX-OnLine database definitions.
- Appendix C contains the source code used to populate the database.
- Appendix D contains samples of contents of the database files used in the test.
- Appendix E contains a description of the physical disk partitions.
- Appendix F contains the operating system parameters and options.
- Appendix G contains the Independent Auditor's Report by KPMG Peat Marwick.

1.3 Parameter Settings

Settings for all customer-tunable parameters and options that have been changed from the defaults found in actual products; including but not limited to:

- *Database options*
- *Recovery/commit options*
- *Consistency/locking options*
- *System parameters, application parameters, and configuration parameters*

Test sponsors may optionally provide a full list of all parameters and options.

A listing of all parameters and options is provided.

Appendixes A, B, E, and F contain the application, database configuration, partition, and operating system parameters used in the TPC Benchmark B tests.

1.4 Configuration Diagrams

Configuration diagrams of both benchmark configuration and the priced system, and a description of the differences.

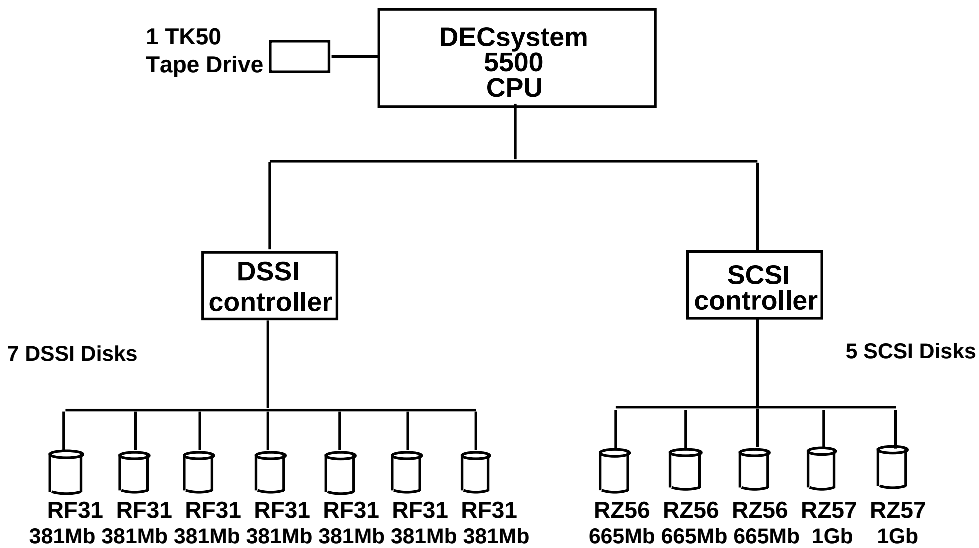
The configurations used for the benchmark and the priced system were the same.

The configuration consisted of a DECsystem 5500 with 32 Megabytes (MB) of main memory. Two (2) embedded controllers were utilized; a DSSI controller supporting seven (7) 381MB RF31 disk drives and a SCSI controller supporting three (3) 665 MB RZ56 and two (2) 1 GB RZ57 disk drives.

We enabled continuous archiving of the logical logs. The logical logs were backed up to an archive device. Two 1 Gbyte RZ57 disk drives were used for this purpose. These disk drives provided the necessary storage capacity so that 8 hours of log data could be kept on-line. Informix transaction logging was at all times set to unbuffered mode.

Benchmark and Priced System Configuration

The diagram that follows represents the benchmark configuration and priced system configuration.



2 - Clause 2 Related Items

ACID Properties

Results of the ACIDity test (specified in Clause 2) must describe how the requirements were met.

Clause 2 of the TPC Benchmark B Standard lists specific tests to ensure the atomicity, consistency, isolation, and durability (ACID) properties of the SUT (System Under Test). The following subsections show how the tests required in Clause 2 were performed. All mechanisms needed to ensure full ACID properties were enabled during both the measurement and test periods. A fully-scaled database was used for the atomicity, consistency, and isolation tests.

2.1 Atomicity Tests

Atomicity of Completed Transaction

Perform the standard TPC Benchmark B transaction for a randomly selected account and verify that the appropriate records have been changed in the Account, Branch, Teller, and History files/tables.

The following test was performed and verified the atomicity of completed transactions:

1. Select a random Branch record.
2. Select a random Teller record.
3. Select a random Account record.
4. Count the History records.
5. Using the randomly selected records, perform the following steps:
   A. Update the Branch record.
   B. Update the Teller record.
   C. Update the Account record.
   D. Insert the History record.
   E. Commit the transaction.
   F. Select the Branch record.
   G. Select the Teller record.
   H. Select the Account record.
6. Count the History records. Verify that the History record count reflects the committed transaction.

Atomicity of Aborted Transaction

Perform the standard TPC Benchmark B transaction for a randomly selected account, substituting an ABORT of the transaction account for the COMMIT of the transaction. Verify that the appropriate records have not been changed in the Account, Branch, Teller, and History files/tables.

The following test was performed, and verified the atomicity of aborted transactions:

1. Select a random Branch record.
2. Select a random Teller record.
3. Select a random Account record.
4. Count the History records.
5. Using the randomly selected Branch, Teller and Account records from above, do the following:

   A. Update the Branch record.
   B. Update the Teller record.
   C. Update the Account record.
   D. Insert the History record.
   E. Abort the transaction and perform a rollback recovery.
   F. Select the Branch record.
   G. Select the Teller record.
   H. Select the Account record.
6. Count the History records. Verify that the History record count has not changed.

2.2 Consistency Tests

Consistency is the property of the application that requires any execution of the transaction to take the database from one consistent state to another.

The following tests were performed and verified the consistency property of transactions:

1. Consistency of Branch and Teller records before transactions
   A. Select Branch balances for each Branch record.
   B. Select the sum of Teller balances for each Branch record.
   C. Verify that the balance for each Branch record is equal to the balance of its Teller records.
2. Consistency of Branch and Teller records after transactions
   A. For the entire History file, count the History records and sum their delta values.
   B. Perform the standard TPC Benchmark B test and record the number of committed transactions.
   C. Repeat step 1.
3. Consistency of History files
   A. For the entire History file, count the History records and sum their delta values.
   B. Verify that this History record count equals the sum of History record count taken in step 2A plus the number of committed transactions.
   C. Verify that the difference between the final History delta sum and the initial History delta sum equals the difference between the final and initial Branch record balances.

2.3 Isolation Tests

Operations of concurrent transactions must yield results which are indistinguishable *from the results which would be obtained by forcing each transaction to be serially executed to completion in some order.*

The following tests were performed and verified the isolation property of the transactions for conventional locking used by the database system:

Isolation of Completed Transactions

1. Select the Branch balance for a Branch record (Branch B).
2. Start transaction 1.
   A. Update the Branch B record with delta(1).
   B. Stop just prior to committing transaction 1.
3. Start transaction 2.
   A. Attempt to update Branch B with delta(2).
   B. Transaction 2 hangs.
4. Resume transaction 1.
   A. Update the Teller record.
   B. Update the Account record.
   C. Insert the History record.
   D. Commit transaction 1.
5. Resume transaction 2.
   A. Update the Teller record.
   B. Update the Account record.
   C. Insert the History record.
   D. Commit transaction 2.
6. Select the Branch balance for Branch B. The balance should equal the previous balance plus delta(1) and delta(2).

Isolation of Aborted Transactions

1. Start transaction 1.
   A. Update Branch B with delta(3).
   B. Stop just prior to committing transaction 1.
2. Start transaction 2.
   A. Attempt to update Branch B with delta(4).
   B. Transaction 2 hangs.
3. Resume transaction 1.
   A. Update the Teller record.
   B. Update the Account record.

   C. Insert the History record.
   D. Abort transaction 1 and perform a rollback recovery.

4. Resume transaction 2.
   A. Update the Teller record.
   B. Update the Account record.
   C. Insert the History record.
   D. Commit transaction 2.
5. Select the Branch balance for Branch B. The balance should equal the previous balance plus delta(4).

The preceding isolation tests were repeated for Teller and Account files (that is, by generating a conflict on a Teller and then an Account record).

2.4 Durability Tests

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

- *Permanent irrecoverable failure of any single durable medium containing database, ABTH (Accounts, Branch, Teller, and History) files/tables, or recovery log data.*
- *Instantaneous interruption (system crash/system hang) in processing which requires system reboot to recover.*
- *Failure of all or part of memory (loss of contents).*

The following test was performed for each of the preceding types of failures to verify the durability property of the SUT:

- For the entire History file, count the History records.
- Perform the standard TPC Benchmark B test and record the committed transactions in the success file.
- Cause one of the preceding types of failure.
- Restart the system under test for this failure as required in Clause 2.5.3.
- Verify that every record in the success file has a corresponding record in the History file.
- For the entire History file,count the History records. Verify that the number of records in the History file is greater than or equal to the original count obtained in step 1 plus the number of records in the success file. If they are different, the new History file must contain additional records and the difference must be less than or equal to the number of terminals (tellers) simulated.

The durability tests were run on a database sized at 10% of the fully loaded database, i.e., 5 TPS, in order to comply with future, expected TPC requirements.

In addition, the durability test "failure of all or part of memory (loss of contents)," i.e., complete power failure, was applied to the fully loaded database under full load conditions. This too was done to comply with future, expected TPC requirements.

In addition, the test sponsors must guarantee that, to the best of their knowledge, a fully-loaded system would pass the durability tests.

To the best of the test sponsor's knowledge, a fully-loaded and fully-scaled system would pass the durability tests.

3 - Clause 3 Related Items

3.1 ABTH Data Storage Distribution

The distribution across storage media of ABTH (Accounts, Branch, Teller, and History) files/tables and all logs must be explicitly depicted.

The following diagram shows how the databases were distributed on disk media on the DECsystem 5500 test system for both the benchmark and priced system configurations.

The physical log was placed on a RF31 (381 Mbyte) disk drive using a partition of 350 Mbytes. The rootdbs space containing the logical logs and catalog were located on another RF31 (381 Mbytes) disk drive using 350 Mbytes for the partition. The rootdbs mirror (logical log) was located on another RF31.

ABTH Data Storage Distribution Diagram

	Partition	File/ Data	Kbytes Used (000's)	Percent of Data
RF31	ra0a	/root	15.6	
	ra0b	swap dump	83	
	ra0g	/usr	273.4	
RF31	rra1c	physical log	350	100.0%
RF31	rra2c	rootdbs (logical logs)	350	100.0%
RF31	rra3c	mirror rootdbs (logical logs)	350	100.0%
RF31	rra4c	account	90	16.6%
		history	282.2	13.1%
RF31	rra5c	account	90	16.6%
		history	282.2	13.1%
RF31	rra6c	account	90	16.6%
		history	282.2	13.1%
RZ56	rrz2g	account	90	16.6%
	rrz2h	teller	0.0047	100.0%
		branch	0.047	100.0%
		history (active)	500	23.3%
RZ56	rrz3c	account	90	16.6%
		history	400	18.6%
RZ56	rrz4c	account	90	16.6%
		history	400	18.6%
RZ57	rrz0c	logical log archive	801	50.0%
RZ57	rrz1c	logical log archive	801	50.0%

The distribution of the database is further evidenced and illustrated by the Informix tbstat utility tbstat_d.

tbstat_d Listing

RSAM Version 4.10.UE1P1 -- On-Line -- Up 00:54:59 -- 12016 Kbytes

Dbspaces

address	number	flags	fchunk	nchunks	flags	owner	name
80b47c	1	2	1	1	M	informix	rootdbs
80b4ac	2	1	2	1	N	informix	physdbs
80b4dc	3	1	3	1	N	informix	tbhdbs
80b50c	4	1	4	6	N	informix	acctdbs

4 active, 20 total

Chunks

address	chk/dbs		offset	size	free	bpages	flags	pathname
8084fc	1	1	500	175000	163978		PO-	/dev/rra2c
809cbc	1	1	500	175000	0		MO-	/dev/rra3c
808594	2	2	500	175000	23242		PO-	/dev/rra1c
80862c	3	3	500	105000	101222		PO-	/dev/rrz2h
8086c4	4	4	62500	45000	42		PO-	/dev/rra4c
80875c	5	4	62500	45000	497		PO-	/dev/rra5c
8087f4	6	4	62500	45000	497		PO-	/dev/rra6c
80888c	7	4	25000	45000	497		PO-	/dev/rrz2g
808924	8	4	125000	45000	497		PO-	/dev/rrz3c
8089bc	9	4	125000	45000	997		PO-	/dev/rrz4c

9 active, 40 total

3.1.1 History Storage and Recovery

Within the priced system, there must be sufficient on-line storage to support 8 hours of recovery log data, if required to recover from any single point of failure, plus any other expanding system files (see Clause 7.1) and durable history records/rows for 30 eight-hour days at the published tpsB rate (i.e., 30 x 8 x 60 x 60 = 864,000 records/rows per tpsB).

The history and log file storage calculations are shown below:

<u>History File Storage</u>

The following calculations were used to determine the aggregate size of the history file.

INFORMIX-OnLine Page Size	2048 bytes
Overhead per Page	32 bytes
Overhead per Row	4 bytes
History Table Row Size	50 bytes

History Rows per Page = (Page Size - Page Overhead)/(Row Size + Row Overhead)
truncated to next lowest integer value = 37 History Rows per Page

History Rows Needed = (tpsB * 3600 * 8 * 30) = 38,880,000 Rows

History Space = (Rows Needed/37) * 2048 = 2,101,621.62 Kbytes

Logfile Storage

During the benchmark run, the Informix logical logs were mirrored. In addition, the inactive logfile segments were archived to disk using INFORMIX-OnLine Continuous Archiving. In all cases unbuffered logging was used. Two disk drives were used; one for the logical logs and one for the mirror.

The Informix tbstat utility (tbstat_l) was used to record write data and logfile data production rates. In the audited reported run, the values were

Number of Writes	33,675
Pages/Write	1.6

The run had a two minute (120 seconds) ramp-up and a 32 minute measurement window. Although the number of writes occurred over the entire 34 minute period, only the steady state portion of the interval should be used for calculation because during ramp-up the log write rate would have been less. As a result, logfile space needed was as follows:

Total logfile storage required/8 hours=
33,675 writes/32 minutes * 1.6 pages/write * 2048 bytes/page =
3,448,320 bytes/minute * 480 minutes/8 hours =
1,655,193,600 bytes/8 hours

Total Logfile Space Needed:	1,655,193,600 bytes
Active Log Space Supplied	- 15,000,000 bytes

	1,640,193,600 bytes

Additional 8 hour log space was required. Two 1 Gbyte drives were used to accommodate this requirement.

In addition, because INFORMIX-OnLine records a timestamp for every completed logical log archived, we used the timestamp to calculate the average time to archive one logical log during the steady state run. The average time to fill a 5 Mbyte logical log was approximately 93 seconds which equates to an 8 hour logfile requirement of 1,548,387,097 bytes.

Because the earlier calculation showed a worst case condition, we used those figures. We supplied 2,030,000,000 bytes for logical log and archive.

Informix tbstat output for the logical logs and part of the message log follow.

Clause 3 Related Items

tbstat_l listing

RSAM Version 4.10.UE1P1 -- On-Line -- Up 00:54:59 -- 12016 Kbytes

Physical Logging

Buffer	bufused	bufsize	numpages	numwrits	pages/io
P-1	12	16	84698	5297	15.99
	phybegin	physize	phypos	phyused	%used
	2006de	150000	32814	4524	3.02

Logical Logging Buffer

bufused	bufsize	numrecs	numpages	numwrits	recs/page	pages/io
L-3 0	16	749244	52766	33675	14.2	1.6

address	number	flags	uniqid	begin	size	used	%used
884408	1	U-B---L	1018	100fb2	2500	2500	100.00
884424	2	U---C--	1019	101976	2500	267	10.68
884440	3	F------	0	10233a	2500	0	0.00

Message Log File Listing

RSAM Version 4.10.UE1P1 -- On-Line -- Up 00:54:59 -- 12016 Kbytes

Message Log File: /usr/informix/online.log

12:31:39	Logical Log 1011 Complete
12:31:47	Checkpoint Completed
12:32:17	Logical Log 1011 Backed Up
12:33:17	Logical Log 1012 Complete
12:33:34	Logical Log 1012 Backed Up
12:34:51	Logical Log 1013 Complete
12:34:59	Checkpoint Completed
12:35:21	Logical Log 1013 Backed Up
12:36:29	Logical Log 1014 Complete
12:37:08	Logical Log 1014 Backed Up
12:38:03	Logical Log 1015 Complete
12:38:20	Checkpoint Completed
12:38:24	Logical Log 1015 Backed Up
12:39:45	Logical Log 1016 Complete
12:40:10	Logical Log 1016 Backed Up
12:41:19	Logical Log 1017 Complete
12:41:28	Checkpoint Completed
12:41:58	Logical Log 1017 Backed Up
12:42:57	Logical Log 1018 Complete
12:43:14	Logical Log 1018 Backed Up

Appendix E contains a complete listing of the disk devices to support the test.

3.2 Database Contents and Method of Population

A description of how the database was populated, along with sample contents of each ABTH file/table to meet the requirements described in Clause 3.

Database Contents

Appendix C contains the database population program and Appendix D contains samples of the contents of the database files used in the tests.

3.3 Type of Database

A statement of the type of database utilized, e.g., relational, Codasyl, flat file, etc.

These TPC Benchmark B tests used INFORMIX-OnLine, a relational database management system.

4 - Clause 4 Related Items

There are no Clause 4 Related Items in the checklist for TPC-B.

5 - Clause 5 Related Items

5.1 Method of Verification of Random Number Generator

The method of verification of the random number generator should be described.

Branch, Teller, and Account IDs were generated by the random number generation routines, random() and srandom() in the bench.h code. Random()/srandom() use a non-linear additive feedback random number generator, employing a default table size of 31 long integers to return successive random numbers in the range from 0 to (2**31)-1. These routines produce a more random sequence than earlier subroutines such as rand(). Random() and srandom() are well known random number generation routines. Randomness of the generated values are further verified by observing the 85/15 distribution rule, which showed that approximately 85% of the transactions submitted to a Branch had the Account belong to that Branch.

5.2 Horizontal Partitioning Disclosure

Vendors must clearly disclose if horizontal partitioning is used. Specifically, vendors must:

- *Describe textually the extent of transparency of the implementation*
- *Which tables/files were accessed using partitioning*
- *How partitioned tables/files were accessed*

Horizontal partitioning of the database was not used. Horizontal partitioning, i.e. the partitioning of a table according to some logical order, was not used. The account relation records were randomly distributed over multiple (6) disk drives.

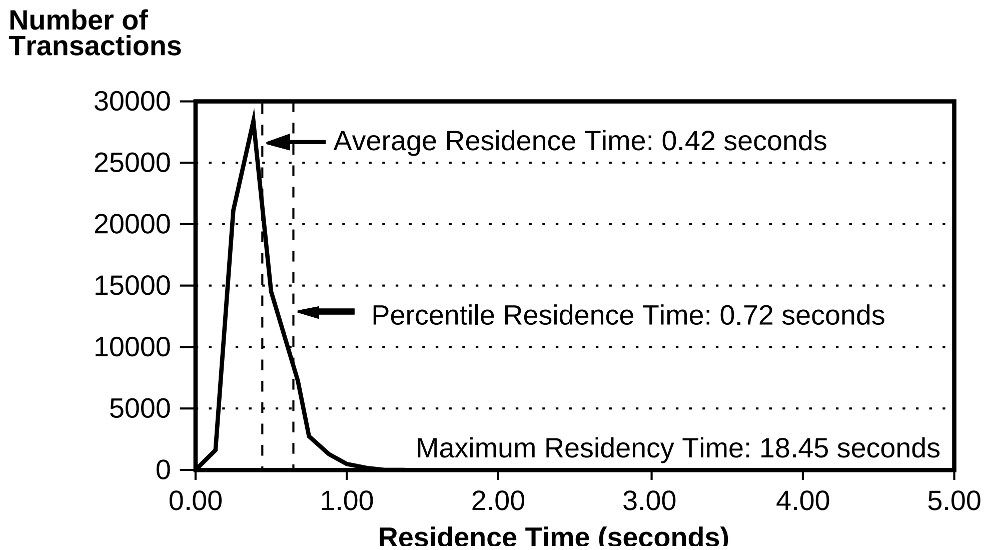
6 - Clause 6 Related Items

Report all the data specified in Clause 6.6, including maximum and average residence time, as well as performance curves for number of transactions vs. residence time (see Clause 6.6.1) and throughput vs. level of concurrency for three data points (see Clause 6.6.5).

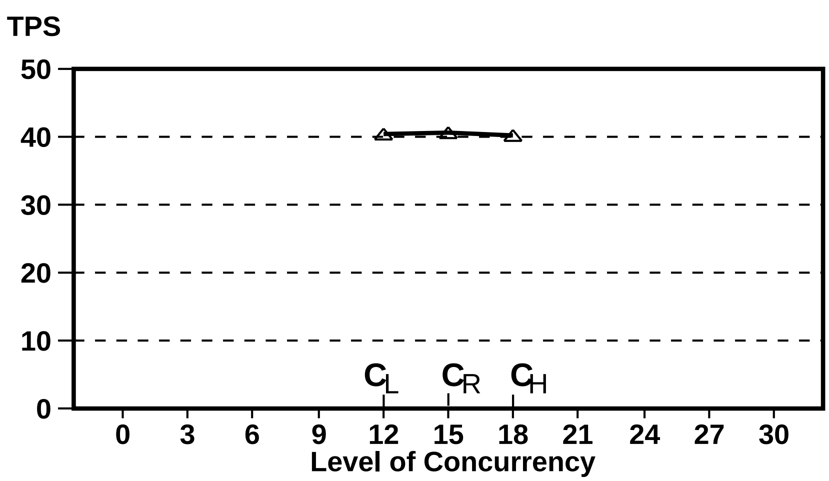
The graphs and tables in this section show the response time performance results.

Please note that for all performance runs the database was scaled for 45 TPS.

Residence Time Frequency Distribution for All Transactions



Throughput Versus Level of Concurrency



Concurrency Legend

Measured Points	Level of Concurrency	TPS	Average Residence Time (seconds)
C_L	12	40.5	0.35
C_R	15	40.6	0.42
C_H	18	40.3	0.49

Profile of Executed Transactions

Description	Result
Remote Transactions (see Clause 6.6.2)	15.00%
Home Transactions	85.00%
Transactions started and not completed during measurement interval (see Clause 6.6.3)	0.02%
Number of transaction started but not completed	15
Total number of transactions	77,967
Average residence time for all transactions	0.42 seconds
Maximum residence time for all transactions	18.45 seconds
Percent of all transactions qualified within 2 second response time constraint	99.81
Maximum qualified throughput	40.6 tpsB

7 - Clause 7 Related Items

7.1 Determining Steady State

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

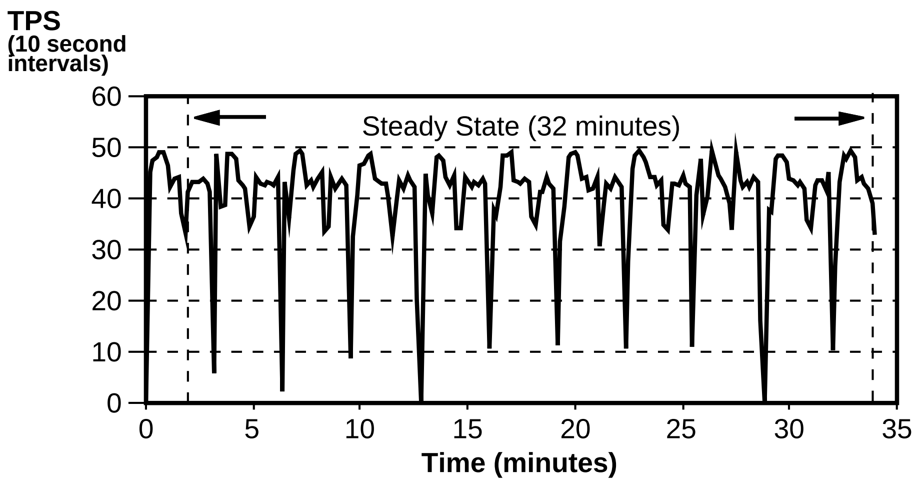
Confirmation that the SUT has reached steady state prior to the beginning of the data collection measurement interval is based on a visual inspection of the plot of TPS versus time.

The design of the benchmark driver program was such that all processes wait to be signaled to commence ramp-up work. During ramp-up, the processes begin executing identical TPC-B transactions as they do during the steady state run.

During the ramp-up, which lasted for 120 seconds, all processes began executing the identical TPC-B transaction that they do during the timed steady state run. At the end of the ramp-up period, each process independently kept track of the numbers and characteristics of its committed transactions that started during the steady state interval. The audited benchmark steady state period lasted for 32 minutes. When the run was completed, the processes individually and independently reported their accumulated transactions and residence time results. The driver then calculated the required numbers to report.

To confirm that steady state was reached, the history table was examined. The graph titled "TPS Versus Time" indicates the number of transactions completed in each 10 second interval. The steady state portion is labeled on the graph. Note the pronounced dips (checkpoints) in transaction rate that occurred 10 times during the steady state for the run. Also, note the less pronounced dip that occurred as each 5 Mbyte logical log is backed up.

TPS Versus Time



7.2 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., as required by Clause 7.2), actually occurred during the measurement interval.

When INFORMIX-OnLine receives a SQL statement from the application, it determines how to best access the data. Using an index (B-tree), INFORMIX-OnLine determines the page number from the database that the record is located on, and searches for the page in shared memory.

If the page is not in shared memory, INFORMIX-OnLine chooses a LRU Buffer in shared memory and reads the page from the database into the buffer. Typically this will take two disk reads. The first read acquires the bottom level of the B-tree index, the second disk read actually acquires the data.

When a transaction starts, a BEGIN WORK is written to the logical log buffers. When the application issues a SQL UPDATE statement (Account, Teller, and Branch) to modify a record, the copy of the record, if it is already in shared memory, is locked and updated. A transaction record is written to the logical log buffer.

At the same time, if the page in shared memory has not previously been written to, a copy of the before image of the page is written to the physical log buffer in shared memory. In addition, the before and after images of the record are written to the logical log buffer in shared memory. So, the physical log buffer contains a copy of the page that a record is on, as it looked prior to making any modification.

When the application issues a SQL COMMIT WORK statement, the logical log buffer is flushed from shared memory to the logical log on disk in a single I/O. The database pages remain in shared memory and are not written to the database at that time. Any locks that were placed by the transaction are released. This means that when an application commits a transaction to the database, the logical log buffer is written to a corresponding logical log on disk with a single I/O, and successful completion code is returned to the application.

Periodically INFORMIX-OnLine will automatically write all modified pages in shared memory to their appropriate locations in the database during a checkpoint. A checkpoint is preceded by a write of the physical log buffer to the physical log on disk. Checkpoints occur periodically during the run. With INFORMIX-OnLine there are several ways of controlling when a checkpoint occurs. For our benchmark, checkpointing occurs every time INFORMIX-OnLine starts the last logical log. We configured INFORMIX-OnLine with three logical logs. Thus, every time two logs were filled and the third started, a checkpoint would occur. In our benchmark run of 32 minutes, 10 checkpoints occurred.

When the checkpoint occurs, one or more background processes called page cleaners "wake up" and write all the modified pages from shared memory to the database on disk. A checkpoint record is written to the logical log buffer. A checkpoint message is written to the message log.

The page reading and writing activity to the individual chunk partitions in the database are reflected in the Informix utility tbstat_D and tbstat_p.

tbstat_D

RSAM Version 4.10.UE1P1 -- On-Line -- Up 00:54:59 -- 12016 Kbytes

Dbspaces

address	number	flags	fchunk	nchunks	flags	owner	name
80b47c	1	2	1	1	M	informix	rootdbs
80b4ac	2	1	2	1	N	informix	physdbs
80b4dc	3	1	3	1	N	informix	tbhdbs
80b50c	4	1	4	6	N	informix	acctdbs

4 active, 20 total

Chunks

address	chk/dbs		offset	page Rd	page Wr	pathname
8084fc	1	1	500	52503	52784	/dev/rra2c
809cbc	1	1	500	0	52784	/dev/rra3c
808594	2	2	500	0	84693	/dev/rra1c
80862c	3	3	500	4099	2729	/dev/rrz2h
8086c4	4	4	62500	27850	13261	/dev/rra4c
80875c	5	4	62500	27550	13163	/dev/rra5c
8087f4	6	4	62500	28227	13486	/dev/rra6c
80888c	7	4	25000	28354	13543	/dev/rrz2g
808924	8	4	125000	27896	13295	/dev/rrz3c
8089bc	9	4	125000	27512	13112	/dev/rrz4c

9 active, 40 total

tbstat_p

RSAM Version 4.10.UE1P1 -- On-Line -- Up 00:54:59 -- 12016 Kbytes

Profile

dskreads	pagreads	bufreads	%cached	dskwrits	pagwrits	bufwrits	%cached
174482	223973	2416938	92.78	154138	272843	337867	54.38

isamtot	open	start	read	write	rewrite	delete	commit	rollbk
3071705	97	249692	250137	83274	249633	0	83517	0

ovtbls	ovlock	ovuser	ovbuff	usercpu	syscpu	numckpts	flushes
0	0	0	0	951.87	682.60	10	20

bufwaits	lokwaits	lockreqs	deadlks	dltouts	lchwaits	ckpwaits	compress
6892	10362	1946418	0	0	52552	149	1

7.3 Determining Reproducibility

A description of the method used to determine the reproducibility of the measurement results.

Experiments were repeated at least 3 times at the maximum targeted TPS level to ensure reproducibility. The results are shown in the following table. The variation in TPS was less than 2%.

DECsystem 5500 TPC-B Benchmark Runs

Run #	Processes	CPUs	tpsB	Percent < 2 sec.	Transactions	db Size	Duration
1	15	1	39.9	99.78	76,627	45 tps	32.0 mins
2	15	1	40.6	99.81	77,967	45 tps	32.0 mins
3	15	1	40.5	99.81	77,831	45 tps	32.0 mins

7.4 Duration of Measurement Period

A statement of the duration of the measurement period for the reported tpsB (it should be at least 15 minutes and no longer than 1 hour).

Each experiment used a measurement period of 32 minutes and began approximately 2 minutes after all servers had begun executing transactions.

8 - Clause 8 Related Items

8.1 Description of the Driver

If the driver is commercially available, then its inputs should be specified. Otherwise, a description of the driver should be supplied.

The driver used was an "internal driver" (i.e., the driver software resides on the system under test, not on a remote driver machine) that controls transaction processing and performance data collection for the TPC Benchmark B runs. The driver was comprised of two parts: a control csh script and a set of identical ESQL/C transaction programs that submitted the TPC Benchmark B transactions for execution.

The control script performs the following operations:

1. forks and execs the desired number of transaction programs, passing ramp-up and measurement interval parameters as command line arguments.
2. waits for a short period of time (30 seconds) to ensure that each driver has started up and opened the test database.
3. sends a SIGUSR1 signal to each transaction process to synchronize the start of transaction processing.
4. waits until all transaction processes have completed the benchmark run.
5. invokes a program called sumrun to sum the performance statistics collected by the transaction processes involved in the benchmark run.

   After each transaction program completes a benchmark run, the transaction program stores residence time counts, incomplete transaction counts, and other performance statistics in a database table named "results". The sumrun program sums all "results" records for a run and inserts aggregate run values into a table named "runs".

Each transaction program performs the following operations:

1. examines its command line arguments to determine the ramp-up and measurement intervals to use.
2. waits until it receives a SIGUSR1 signal before initiating transaction processing.
3. continuously submits TPC-B transactions, with 0 sleep time. The transaction program collects response time statistics in internal program data structures, but does not begin collecting them until the ramp-up period has completed.
4. inserts its collected performance statistics into a "results" table record once the measurement interval has completed. It is the contents of these "results" records that are summed by the sumrun program.

"Success files" were implemented through the tpc.ec application program by writing synchronously using fsync() and flushing the confirmation of transactions to standard output. This was captured into a file nohup.out running under the Korn shell.

9 - Clause 9 Related Items

9.1 Hardware and Software Components

A detailed list of hardware and software used in the priced system. Each item must have vendor part number, description, and release/revision level, and either general availability status or committed delivery date. If package pricing is used, contents of the package must be disclosed.

9.1.1 Priced System Configuration Tables

The following tables show the hardware and software components in the priced DECsystem 5500 system:

Component	Product	Quantity
Processor	DECsystem 5500	1
Memory		32 Megabytes
Tape drive	TK50	1
Disk controller	DSSI, SCSI	1 of each
Disks	RF31	7
	RZ57	2
	RZ56	3
Operating system	ULTRIX 4.2	1
Database	INFORMIX-OnLine V4.10 INFORMIX ESQL/C	

9.1.2 Package Pricing

Package Description	Model #
DECsystem 5500 120/240V BA430 Pedestal Enclosure 32 MB Memory SCSI, DSSI Storage Adapter ThinWire/ThickWire Ethernet Included Software Licenses ULTRIX 4 User License UWS Server Support License Prestoserve ™ License English Language H/W Doc US 120 V Power Cord With One Year System Warranty	DU-55HT1-A9

Package Description	Model #
2xRZ57 1GB Disks with BA42 Box	SZ12C-CA

Package Description	Model #
TK50 Tape Drive with Tape Controller and Box	TK50Z-GA

Package Description	Model #
2xRZ56 665 MB Disks with BA42 box	SZ12B-BA

Package Description	Model #
5xRF31 w/R400X in Exp. Cab.	DL-RF31A-A5

9.2 Total Price of System Configuration

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

This section lists the separate components in the priced system and their associated purchase and maintenance costs. All items are currently available. All prices were taken from the Digital Standard Pricing System (DSPS) on November 21, 1991. A description of the packages used in the pricing is contained in Section 9.1.2.

Informix prices were taken from Informix price list, titled "Americas Price List, Advance Products, Release 4.0 or Greater, Class D", dated August 1, 1991.

9.2.1 Hardware Pricing

The Digital TPC Benchmark B DECsystem 5500 test used packaged hardware systems whenever possible to simplify configurations to the fewest number of line items. Disks were connected using DSSI and SCSI controllers. The system used a TK50 tape drive to load the software and back up the database.

The purchase price of all systems includes one year of hardware warranty service. Post-warranty hardware service is configured for an additional four years.

The following levels of post-warranty hardware service are used in the system pricing:

DECsystem Support 9x5 (DS9) and 2-4 hours response time.
Basic Monthly Charge (BMC) warranty level is the same as the DS9 to which the hardware is directly attached.
Basic System Support (BSS) with a warranty upgrade to DS9.

9.2.2 Software Pricing

The priced system uses the following software products:

- ULTRIX V4.2 operating system
- INFORMIX-OnLine relational database management system
- INFORMIX-ESQL/C

The ULTRIX license purchase includes one year of warranty service. Post-warranty service is configured for an additional four years. The software warranty and service level are the same as the service level for the hardware system on which the software operates. The level of post-warranty service is Software Support Service (SSS).

9.2.3 Price Discounts

Digital's five (5) years warranty pricing is as follows:

- the unit price carries one (1) year warranty.
- the price of year 2-5 warranty adder is calculated according to this formula:
  - (warranty/month)*12*(1+1+1.07+$(1.07)^2$)=(1.053725*48*(warranty/month))

The pre-payment maintenance (warranty) discount is calculated at 25% of the year 2-5 warranty price.

Informix's five-year prepaid maintenance option consists of five years of maintenance for four times the price of standard maintenance.

9.2.4 System Pricing Summary

DECsystem TPC-B = 40.6 TPS

US LIST DESCRIPTION	MODEL #	UNIT PRICE 1 YR WARR	QTY	TOTAL PRICE	SERVICE LEVEL	MAIN. $/MO.	# MO	2-5 YRS MAIN. PRICE	PRICE+SRVC 5 YR COST
Digital Price (21 November 1991)									
Host and Database									
DS5500 BA430, 32 MB	DU-55HT1-A9	$38,340.00	1	$38,340.00	BSS	$0.00	48	$0.00	$38,340.00
Warranty Upgrade To DS9	FM-DECUP-12	$648.00	1	$648.00	DS9	$549.00	48	$26,352.00	$27,000.00
2 RZ56 665 MB Disk in BA42 Box	SZ12B-BA	$9,740.00	1	$9.740.00	DS9/BMC	$120.00	48	$5,760.00	$15,500.00
1 RZ56 665 MB Disk in BA42 Box	SZ12B-XA	$5,120.00	1	$5,120.00	DS9/BMC	$60.00	48	$2,880.00	$8,000.00
2 RZ57 1.0 GB Disk in Exp. Box	SZ12C-CA	$16,324.00	1	$16,324.00	DS9/BMC	$152.00	48	$7,296.00	$23,620.00
5xRF31 w/R400X Exp. Cab.	DL-RF31A-A5	$23,900.00	1	$23,900.00	DS9/BMC	$152.00	48	$7,296.00	$31,196.00
RF31 381 MB Disk	RF31E-AA	$4,800.00	2	$9,600.00	DS9/BMC	$25.00	48	$2,400.00	$12,000.00
TK50 Tape Controller Box VJ3100	TK50Z-GA	$3,860.00	1	$3,860.00	DS9/BMC	$30.00	48	$1,440.00	$5,300.00
ULTRIX-32 V4.2 Media & Doc.	QA-VYVAA-H5	$3,240.00	1	$3,240.00	NA	$.00	48	$.00	$3,240.00
Digital Subtotal				$110,772.00				$53,424.00	$164,196.00
Years 2-5 Warranty Adder =5.3725%								$2,870.20	$2,870.20
Digital Subtotal				$110,772.00				$56,294.20	$167,066.20
Prepayment Maintenance Discount=25%								($14,073.55)	($14,073.55)
Digital Total				$110,772.00				$42,220.65	$152,992.65
Informix Price (1 August 1991)									
						$/YEAR	YEAR		
INFORMIX-OnLine (Class "D" License)	Full Dev./Run T	$3,300.00	1	$3,300.00	SSS	$590.00	4	$2,360.00	$5,660.00
INFORMIX-ESQL/C	Full Dev./Run T	$660.00	1	$660.00	SSS	$200.00	4	$800.00	$1,460.00
Informix Total				$3,960.00				$3,160.00	$7,120.00
CONFIGURATION TOTALS				$114,732.00				$45,380.65	$160,112.65
							TPS		40.6
							$/TPS		$3,944

9.3 Performance and Price/Performance

A statement of the measured tpsB, and the calculated price/tpsB.

The following table shows measured tpsB and price/tpsB results for the tested system:

CPU Model	Software	TPS (tpsB)	Price per TPS ($/tpsB)
DECsystem 5500	ULTRIX 4.2 and INFORMIX-OnLine 4.10	40.6	$3,944

10 - Clause 10 Related Items

None.

11 - Clause 11 Related Items

11.1 Independent Auditor's Report

If the benchmark has been independently audited, then the auditor's name, address, phone number, and a brief audit summary report indicating compliance must be included in the full disclosure report. A statement should be included, specifying when the complete audit report will become available and who to contact in order to obtain a copy.

Appendix G contains the complete independent auditor's report by KPMG Peat Marwick for the tests described in this report.

Appendix A

Application Code

This appendix contains the source code of the application programs that implement the TPC Benchmark B transaction.

A.1 tpc.ec source code

```
#include <stdio.h>
#include <sys/signal.h>
#include <sys/types.h>
#include <sys/timeb.h>
#include <math.h>
$include sqlca ;
#include "bench.h"

$long acct_bal, cntr, seconds, intvl, startsec, tot_response ;
$int branch_num, teller_num, acct_num, delta, acct_branch, run, procnum ;
$int notdone, tmslot[BUCKETS+1] ;
int rampup, runtime, timing, thru, measure, bucketval, transactions, verbose ;
int longest_tran;

settimer() {  timing = ~timing ; }

setmeasure()
{
        intvl = (measure) ? rampup : runtime ;
        thru++ ;
        measure = ~measure ;
         startsec = time(0) ;
}

main(argc,argv)
        int argc ;
        char **argv ;
{
        int i, *rnum, do_trans() ;

         runtime = rampup = intvl = 0 ;
        transactions = -1 ;
        procnum = atoi(argv[1]) ;
        i = 1 ;

         while (++i < argc) {
                if (strcmp(argv[i], "-s") == 0)
                runtime += atoi(argv[++i]) ;
                else if (strcmp(argv[i], "-m") == 0)
                runtime += (60 * atoi(argv[++i])) ;
                else if (strcmp(argv[i], "-h") == 0)
                runtime += (3600 * atoi(argv[++i])) ;
```

```
                    else if (strcmp(argv[i], "-t") == 0)
                    transactions = atoi(argv[++i]) ;
                    else if (strcmp(argv[i], "-r") == 0)
                    rampup = atoi(argv[++i]) ;
                    else if (strcmp(argv[i], "-v") == 0)
                    verbose = 1 ;
                    else {
                              fprintf(stderr,"usage: tp1 <proc #> [-t <n>] [-r <n>]
[-h <n> -m <n> -s <n>]\n") ;
                    exit(1) ;
                    }
 }
          RandSeed(getpid()) ;

          if (runtime == 0)
                    runtime = (transactions == -1) ? 300 : 30000 ;

          printf("process %d: procnum=%03d runtime=%d seconds / %d transac
                    tions\n", getpid(),procnum,runtime,transactions) ;

          cntr = tot_response = run = measure = timing = thru = intvl = notdone = 0 ;
          for (i=0; i < 50; i++)
                    tmslot[i] = 0 ;

          $ database tpc ;
            SqlErr("attach to database") ;

          $ select max(number) into $run from results ;
            SqlErr("select from results") ;
          if (run < 0)
                    run = 0 ;
           ++run ;

           do_prepare() ;

           bucketval = RPTINTVL * 1000 / BUCKETS ;
          intvl = rampup ;
          signal(SIGUSR1,settimer) ;
          sigpause(0) ;

          printf("%d starting\n",procnum) ;  do_trans() ;  testend() ;

}

do_prepare()
{
          $char s[512];

             sprintf(s,"%s %s %s%d%s %s commit work",
             "update account set balance = balance + ? where current of sel_acct;",
             "update teller set balance = balance + ? where number = ?;",
             "insert into history",procnum % HISTORY,
             " values(?,?,?,?,CURRENT YEAR TO SECOND,'the rest is history');",
             "update branch set balance = balance + ? where number = ?;") ;
```

```
        $ prepare tpc_trans from $s;
          SqlErr("prepare updall");

        $ prepare bwork from "begin work" ;
          SqlErr("prepare begin work") ;

        $ declare sel_acct cursor for
                select balance into $acct_bal from account
                        where number = $acct_num
                        for update of balance ;
          SqlErr("declare cursor") ;

        $ set isolation to cursor stability ;
          SqlErr("set isolation") ;

        $ set lock mode to wait;
          SqlErr("set lock mode");
}

do_trans()
{
        long timediff ;
        char s[100] ;
        struct timeb clk_beg,clk_end ;

                startsec = time(0) ;
        if (rampup == 0)
                setmeasure() ;
        else
                thru++ ;

        while (timing && (cntr != transactions)) {

            /*
             * select a random branch, a random teller at that branch, and
             * 85% of the time a random account at that branch, and 15% of
             * the time a random acccount at a different branch.
             */

        teller_num = RandVal() % T_RECS ;
        branch_num = teller_num / T_PERB ;
        acct_num = RandVal() % A_PERB ;

        if ((RandVal() % 100) < 85)
                acct_branch = branch_num ;
        else {
                do      /* endless loop when TPS_SIZE=1 */
                        acct_branch = RandVal() % B_RECS ;
                 while (acct_branch == branch_num) ;
        }

        acct_num = acct_branch * A_PERB + acct_num ;
        delta = RandVal() % 1999999 - 999999 ;
        if (measure)
                 notdone++ ;
```

```
ftime(&clk_beg) ;

$ execute bwork ;

$ open sel_acct ;
   SqlErr("open cursor") ;

$ fetch sel_acct ;
   SqlErr("fetch cursor") ;

if (sqlca.sqlcode == 0) {
 $ execute tpc_trans using
                    $delta,
                    $delta, $teller_num,
                    $acct_num, $teller_num, $branch_num, $delta,
                    $delta, $branch_num ;
}

ftime(&clk_end) ;

if (sqlca.sqlcode != 0) {
         sprintf(s,"in transaction %d acc#: %d branch#: %d teller#: %d",
                              cntr, acct_num, branch_num, teller_num) ;
 SqlFatal(s) ;
 /*
 $ rollback work ;
 */
}

timediff = clk_end.time - startsec ;
if (timediff > intvl) {
                    if (thru == 2)
                              settimer() ;
                     else
                              setmeasure() ;
}

if (measure) {
        timediff = (clk_end.time - clk_beg.time) * 1000
                              + clk_end.millitm - clk_beg.millitm ;
 if(timediff > longest_tran)
        longest_tran = timediff;
 tot_response += timediff ;
 timediff /= bucketval ; /* 0-.124, .125-0.249, etc. seconds */
 if (timediff > BUCKETS)
         timediff = BUCKETS ;
 tmslot[timediff]++ ;
 cntr++ ;
 if(verbose)
 {
        printf("procnum %3d: tran %d completed!\n",procnum,cntr);
        fflush(stdout);
        fsync(1);
 }
```

```
                notdone-- ;
              }
        }
        seconds = (transactions > 0) ? (time(0)-startsec) : runtime ;
}
testend()
{
        int hrs, min, sec ;
              hrs = seconds / 3600 ;
              min = (seconds - hrs * 3600) / 60 ;
              sec = seconds - hrs * 3600 - min * 60 ;
              printf("procnum %3d completed %6d transactions in %4d:%02d:%02d, long-
est=%d msec.\n",
                          procnum, cntr, hrs, min, sec, longest_tran) ;
              $ insert into results values(
                          $run, $procnum, $seconds, $cntr, $notdone, $tot_response,
                          $tmslot[0],$tmslot[1],$tmslot[2],$tmslot[3],$tmslot[4],
                          $tmslot[5],$tmslot[6],$tmslot[7],$tmslot[8],$tmslot[9],
                          $tmslot[10],$tmslot[11],$tmslot[12],$tmslot[13],$tmslot[14],
                          $tmslot[15],$tmslot[16],$tmslot[17],$tmslot[18],$tmslot[19],
                          $tmslot[20],$tmslot[21],$tmslot[22],$tmslot[23],$tmslot[24],
                          $tmslot[25],$tmslot[26],$tmslot[27],$tmslot[28],$tmslot[29],
                          $tmslot[30],$tmslot[31],$tmslot[32],$tmslot[33],$tmslot[34],
                          $tmslot[35],$tmslot[36],$tmslot[37],$tmslot[38],$tmslot[39],
                          $tmslot[40]) ;
                          SqlErr("insert into results") ;
              $ close database ;
                SqlErr("close database") ;
}
```

A.2   createdb.ec source code

```
#include <stdio.h>
#include "bench.h"
 $include sqlca ;

/*
* FILE: createdb.ec (for OnLine)
*
* Creates the database and related tables, except result-consolidation
* tables. It is possible to place the tables on different drives by
* adding location options to the CREATE TABLE statements.
*
* You can also decide to place logging on the database by adding it
* to the CREATE DATABASE statement. However, the loading programs
* provided assume no transaction logging, so you should turn on logging
* afterward via archiving and changing the database logging mode.
*
* The configuration here accommodates scaling to 100 TPS.
*
*/

main()
{
        $ create database tpc in TBHDBS ;
          SqlErr("create database") ;

        $ grant dba to public ;
           SqlErr("grant dba") ;

        printf("Database created, permission granted\n") ;

        $ create table branch     (
                number numeric(2,0),
                balance numeric(10,0),
                fillstr char(92)
        )
        lock mode row
        ;
          SqlErr("create branch") ;
        printf("Branch created\n") ;

        $ create table teller
        (
                number numeric(4,0),
                balance numeric(10,0),
                branch numeric(2,0),
                fillstr char(89)
        )
        extent size 200
        next size 100
        lock mode row
```

```
;
  SqlErr("create teller") ;
printf("Teller created\n") ;

$ create table account      (
number        numeric(8,0),
balance       numeric(10,0),
branch        numeric(2,0),
fillstr        char(87)
)
in acctdbs
extent size 5000
next size 1000
;
  SqlErr("create account") ;
printf("Account created\n") ;

$ close database ;
  SqlErr("close database") ;

 exit(0) ;
}
```

A.3 createhist.ec source code

```
#include <stdio.h>
#include "bench.h"
 $include sqlca ;

/*
* FILE: createhist.ec (for OnLine)
*
* Creates the history tables. Number of tables is HISTORY in "bench.h".
*
* The configuration here accommodates scaling to 100 TPS.
*
*/

main()
{
        $char dstr[200] ;
        $int cnt, i ;

         $ database tpc ;
           SqlErr("connect to database") ;

        $ select count(*) into $cnt from systables
                where tabname matches "hist" ;
          SqlErr("test for history tables") ;

        $ select count(*) into $cnt from systables
                where tabname matches "hist*" ;
          SqlErr("test for history tables") ;

        if (cnt) {
                printf("Dropping History tables...\n") ;
                for (i=0; i < cnt; i++) {
                        sprintf(dstr,"drop table history%d",i) ;
                        $ prepare drop_tab from $dstr ;
                          SqlErr("prepare drop") ;
                        $ execute drop_tab ;
                          SqlErr(dstr) ;
                }
         }

        for (i=0; i < HISTORY; i++) {

                sprintf(dstr, "%s%d (%s,%s,%s,%s,%s,%s) %s %s %s",
                        "create table history", i,
                                "account integer",
                                "teller integer",
                                "branch integer",
                                "delta char(11)",
                                "tstamp datetime year to second",
                                "fillstr char(22)",
                                "extent size 1000",
                                "next size 1000",
```

```
                                        "lock mode row"
                                ) ;
                        $ prepare make_tab from $dstr ;
                          SqlErr("prepare create") ;
                        $ execute make_tab ;
                          SqlErr("execute history") ;
                        printf("History%d table created\n",i) ;

 }

 $ close database ;
   SqlErr("close database") ;

 exit(0) ;
}
```

A.4   createruns.ec source code

```
#include <stdio.h>
#include "bench.h"
$include sqlca ;

/*
 * FILE:  createruns.ec
 *
 * Creates the results tables for cumulative reporting
 *
 */

main()
{
    $int cnt ;

                     $ database tpc ;
                        SqlErr("open database") ;

                    $ select count(*) into $cnt from systables
                                        where tabname = "runs" ;
                        SqlErr("test for runs table") ;

                    if (cnt) {
                                        $ drop table runs ;
                                           SqlErr("drop table runs") ;
                    }

                    $ select count(*) into $cnt from systables
                                        where tabname = "results" ;
                       SqlErr("test for results table") ;

                    if (cnt) {
                                        $ drop table results ;
                                           SqlErr("drop table results") ;
 }

    $ create table runs
                    (
                     num            serial,
                     numprocs       integer,
                     test_intvl     integer,
                     total_xact     integer,
                     total_inc      integer,
                     resp_time      integer,
                     cpus           integer,
                     test_size      integer,
                     tslot01        integer,
                     tslot02        integer,
                     tslot03        integer,
                     tslot04        integer,
                     tslot05        integer,
                     tslot06        integer,
```

```
                tslot07     integer,
                tslot08     integer,
                tslot09     integer,
                tslot10     integer,
                tslot11     integer,
                tslot12     integer,
                tslot13     integer,
                tslot14     integer,
                tslot15     integer,
                tslot16     integer,
                tslot17     integer,
                tslot18     integer,
                tslot19     integer,
                tslot20     integer,
                tslot21     integer,
                tslot22     integer,
                tslot23     integer,
                tslot24     integer,
                tslot25     integer,
                tslot26     integer,
                tslot27     integer,
                tslot28     integer,
                tslot29     integer,
                tslot30     integer,
                tslot31     integer,
                tslot32     integer,
                tslot33     integer,
                tslot34     integer,
                tslot35     integer,
                tslot36     integer,
                tslot37     integer,
                tslot38     integer,
                tslot39     integer,
                tslot40     integer,
                tslot41     integer
               ) ;
  SqlErr("create runs") ;
printf("Runs table created\n") ;

  $ create table results    (
                number      integer,
                procnum     integer,
                seconds     integer,
                xactcnt     integer,
                notdone     integer,
                response    integer,
                tslot01     integer,
                tslot02     integer,
                tslot03     integer,
                tslot04     integer,
```

```
                    tslot05        integer,
                    tslot06        integer,
                    tslot07        integer,
                    tslot08        integer,
                    tslot09        integer,
                    tslot10        integer,
                    tslot11        integer,
                    tslot12        integer,
                    tslot13        integer,
                    tslot14        integer,
                    tslot15        integer,
                    tslot16        integer,
                    tslot17        integer,
                    tslot18        integer,
                    tslot19        integer,
                    tslot20        integer,
                    tslot21        integer,
                    tslot22        integer,
                    tslot23        integer,
                    tslot24        integer,
                    tslot25        integer,
                    tslot26        integer,
                    tslot27        integer,
                    tslot28        integer,
                    tslot29        integer,
                    tslot30        integer,
                    tslot31        integer,
                    tslot32        integer,
                    tslot33        integer,
                    tslot34        integer,
                    tslot35        integer,
                    tslot36        integer,
                    tslot37        integer,
                    tslot38        integer,
                    tslot39        integer,
                    tslot40        integer,
                    tslot41        integer
                   ) ;
   SqlErr("create results") ;
 printf("Results table created\n") ;

 $ close database ;
   SqlErr("close database") ;

 exit(0) ;
}
```

A.5 createidx.ec source code

```
#include <stdio.h>
#include "bench.h"
$include sqlca ;

/*
 * FILE: createidx.ec
  *
  * Creates the indices for the main database tables. This is a separate
  * process in case loads without indices are desired.
  *
  */

main()
 {

                $ database tpc ;
                  SqlErr("open database") ;

                $ create unique index ibranch on branch(number) ;
                  SqlErr("create branch index") ;  printf("Branch index created\n") ;

                $ create unique index iteller on teller(number) ;
                  SqlErr("create teller index") ;  printf("Teller index created\n") ;

                $ create unique index iaccount on account(number) ;
                  SqlErr("create account index") ;
                 printf("Account index created\n") ;

                $ close database ;
                  SqlErr("close database") ;

                 exit(0) ;
}
```

A.6 config.scr source code

```
echo Going into Quiescent mode
tbmode -uy
echo Creating physdbs...
tbspaces -c -d physdbs -p /dev/rra1c -o 1000 -s 350000
echo Creating tbhdbs...
tbspaces -c -d tbhdbs -p /dev/rrz2h -o 1000 -s 210000
echo Creating acctdbs...
tbspaces -c -d acctdbs -p /dev/rra4c -o 125000 -s 90000
echo Adding chunk to acctdbs...
tbspaces -a acctdbs -p /dev/rra5c -o 125000 -s 90000
echo Adding chunk to acctdbs...
tbspaces -a acctdbs -p /dev/rra6c -o 125000 -s 90000
echo Adding chunk to acctdbs...
tbspaces -a acctdbs -p /dev/rrz2g -o 50000 -s 90000
echo Adding chunk to acctdbs...
tbspaces -a acctdbs -p /dev/rrz3c -o 250000 -s 90000
echo Adding chunk to acctdbs...
tbspaces -a acctdbs -p /dev/rrz4c -o 250000 -s 90000
echo Moving Physical Log
tbparams -p -s 300000 -d physdbs -y
echo Going back On-Line
 tbmode -m echo Configuration
done
```

A.7 bench.h code

```
*
 PURPOSE: to set up the sizing of the TPC database
*
* the scale factors for TPC per 1 TPS are:
 *              1 Branch, 10 Tellers, 100000 Accounts
 *
* Modify the TPS_SIZE to the desired rating.
* DO NOT modify any but the first 4 lines.  *
*/

#define TPS_SIZE        45
#define HISTORY         1
#define RandVal         random
#define RandSeed        srandom
#define BUCKETS         40
#define RPTINTVL        5

#define T_PERB          10
#define A_PERB           100000

#define B_RECS           TPS_SIZE
#define T_RECS           (T_PERB * B_RECS)
#define A_RECS           (A_PERB * B_RECS)

#define IsqlCode        sqlca.sqlcode
#define IsamCode        sqlca.sqlerrd[1]
#define SqlErr(x)       if (IsqlCode) Sqlmsg(x)
#define SqlErrNF(x)     if (IsqlCode && IsqlCode != SQLNOTFOUND) Sqlmsg(x)
```

Appendix B

Database Definitions

```
#*****************************************************************************************
#
#                               INFORMIX SOFTWARE, INC.
#
# Title:                        tbconfig.std
# Sccsid:                       @(#)tbconfig.std 7.2 11/20/90 11:06:55
#Description:                   INFORMIX-OnLine Configuration Parameters
#
#*****************************************************************************************

# Root Dbspace Configuration

ROOTNAME            rootdbs      # Root dbspace name
ROOTPATH            /dev/rra2c   # Path for device containing root dbspace
ROOTOFFSET          1000         # Offset of root dbspace into device (Kbytes)
ROOTSIZE            350000       # Size of root dbspace (Kbytes)

# Disk Mirroring Configuration Parameters

MIRROR              1            # Mirroring flag (Yes = 1, No = 0)
MIRRORPATH          /dev/rra3c   # Path for device containing mirrored root
MIRROROFFSET        1000         # Offset into mirrored device (Kbytes)

# Physical Log Configuration

PHYSDBS             physdbs      # Location (dbspace) of physical log
PHYSFILE            300000       # Physical log file size (Kbytes)

# Logical Log Configuration

LOGFILES            3            # Number of logical log files
LOGSIZE             5000         # Logical log size (Kbytes)

# Message Files

MSGPATH             /usr/informix/online.log     # System message log file path
CONSOLE             /usr/informix/console.log    # System console message path

# System Archive Tape Device

TAPEDEV             /dev/null    # Tape device path
TAPEBLK             16           #  Tape block size (Kbytes)
TAPESIZE            90000        #  Maximum amount of data to put on tape
                                 #   (Kbytes)

# Log Archive Tape Device

LTAPEDEV            /dev/rrz1c   # Log tape device path
LTAPEBLK            16           # Log tape block size (Bytes)
```

```
LTAPESIZE          1000472    # Max amount of data to put on log tape (Kbytes)

# System Configuration

SERVERNUM          0          # Unique id corresponding to an OnLine instance
SERVERNAME         dectpc     #
DEADLOCK_TIMEOUT   30         # max time to wait of lock in distributed env.
RESIDENT           0          # Forced residency flag (Yes = 1, No = 0)

# Shared Memory Parameters

USERS              50         # Maximum number of concurrent users (proc
                              #  esses)
LOCKS              5000       # Maximum number of locks
BUFFERS            5000       # Maximum number of shared buffers
TBLSPACES          1200       # Maximum number of open tblspaces
CHUNKS             40         # Maximum number of chunks
DBSPACES           20         # Maximum number of dbspaces
PHYSBUFF           32         # Physical log buffer size (Kbytes)
LOGBUFF            32         # Logical log buffer size (Kbytes)
LOGSMAX            3          # Maximum number of logical log files
CLEANERS           8          # Number of buffer cleaner processes
SHMBASE            0x800000   # Shared memory base address
CKPTINTVL          720        # Check point interval (in sec)

# System Page Size

BUFFSIZE           2048       # Page size (do not change!)

#System LRU Parameters

LRUS               8          #Number of LRU’s
 LRU_MAX_DIRTY     60         #Start page cleaning
 LRU_MIN_DIRTY     50         #Stop page cleaning
 LRU_SEARCH        70         #First Level search for free buffers
```

Appendix C

Code to Populate Database

This appendix contains the program used to populate the database used in the TPC Benchmark B tests.

C.1 Database Population Program

The following program was used to populate the database:

```
#include <stdio.h>
#include <math.h>
#include <sys/types.h>
#include <sys/wait.h>
#include "bench.h"
$include sqlca ;
/*
 * FILE: load_db.ec
 *
 * PURPOSE: load the Branch and Teller tables, and kick off the Account
 *              table load procedures. The Account table is loaded by
 *              dividing the key range into equal parts (according to the
 *              number of load processes), and the "load_act" program is
 *              forked off for each process. The program then waits for
 *              them to finish and reports the total load time.
 *
 * NOTE: The type "pid_t" may be system-dependent. Under Ultrix it's
 * equivalent to an "int".
 *
 */

FILE *flog,*fopen() ;
int logfile ;

main(argc,argv)
            int argc ;
            char *argv[] ;
{
            int i, load_procs, skip, freespace ;
            char begnum[15], endnum[15], log_fname[40], rpt_str[80] ;
            long load_accts, startacct, acct_hunk, beg_time, end_time, totsecs ;
            pid_t pid ;
            union wait wait_status ;

            $int branch, teller, branch_idx ;
            $char filler[100] ;

                        RandSeed(getpid()) ;
```

```
		load_procs = 1 ;
		i = logfile = skip = freespace = branch_idx = 0 ;

		while (++i < argc) {
			if (strcmp(argv[i], "-p") == 0)
				load_procs = atoi(argv[++i]) ;
			else if (strcmp(argv[i], "-s") == 0)
				skip = atoi(argv[++i]) ;
			else if (strcmp(argv[i], "-f") == 0)
				freespace = atoi(argv[++i]) ;
			else if (strcmp(argv[i], "-l") == 0) {
				strcpy(log_fname,argv[++i]) ;
				logfile = 1 ;
			}
			else {
				printf("usage: load_db -p <#> -s <#> -
f <#> -l <file>\n") ;
			exit(0) ;
			}
		 }

		if (load_procs && ((A_PERB % load_procs) != 0)) {
			printf("Cannot split up load of accounts evenly. Try
again.\n") ;
			exit(0) ;
		}

		load_accts = (B_RECS - skip) * A_PERB ;
			if (load_procs) acct_hunk = load_accts /
load_procs ;
		for (i=0; i < 10; i++)
			bycopy("1234567890",&filler[i*10],10) ;
		if (logfile) {	if ((flog=fopen(log_fname,"w")) == NULL) {
			perror("on opening log file") ;
			logfile = 0 ;
		}
	}

	$ database tpc ;
	  SqlErr("database open") ;

	if (freespace) {
		$ select count(*) into $branch_idx from sysindexes
			where idxname = "ibranch" ;
		   SqlErr("load_db -- select branch index") ;
		if (branch_idx) {
			$ drop index ibranch ;
			   SqlErr("load_db -- delete branch index") ;
		}
	}

	for (branch=skip; branch < B_RECS; branch++) {
		$ insert into branch values($branch, 0, $filler) ;
```

```
                SqlErr("load_db -- branch insert") ;
            for (i=0; i < freespace; i++) {
                        $ insert into branch values(0, -1, $filler) ;
                            SqlErr("load_db -- branch free insert") ;
            }
    }
    if (freespace) {
            $ delete from branch where balance < 0 ;
                SqlErr("load_db -- delete branch records") ;
     }
    if (branch_idx) {
            $ create unique index ibranch on branch(number) ;
                SqlErr("load_db -- create branch index") ;
    }
     print_log("branch table loaded") ;
    for (teller=T_PERB*skip; teller < T_RECS; teller++) {
            branch = teller / T_PERB ;
            $ insert into teller values($teller, 0, $branch, $filler) ;
                SqlErr("load_db -- insert into teller") ;
     }
     print_log("teller table loaded") ;
    $ update statistics for table branch ;
      SqlErr("load_db -- update stats on branch") ;
    $ update statistics for table teller ;
      SqlErr("load_db -- update stats on teller") ;
    $ close database ;
      SqlErr("load_db -- close database") ;
    sqlexit() ;
    if (load_procs) {
            beg_time = time(0) ;
            startacct = skip * A_PERB ;
            for (i=0; i < load_procs; i++) {
                        sprintf(begnum,"%d",startacct) ;
                        startacct += acct_hunk ;
                        sprintf(endnum,"%d",startacct-1) ;
                        pid = fork() ;
                         if (pid == -1) {
                                    perror("on fork of loadact process") ;
                                    exit(1) ;
            }
            if (pid == 0)
            if (logfile)
             execl("load_act","load_act",begnum,endnum,"1",log_fname,0) ;
            else
             execl("load_act","load_act",begnum,endnum,"0"," ",0) ;
```

```
                }
                while (i--) {
                        pid = wait(&wait_status) ;
                        if (pid == -1) {
                                perror("on return from loadact") ;
                                exit(1) ;
                        }
                        end_time = time(0) ;
                        totsecs = end_time - beg_time ;
                        sprintf(rpt_str,"\nprocess %d completed in ",pid) ;
                        report_time(rpt_str,totsecs) ;
                        if (i > 0)
                                sprintf(rpt_str,"%s;  %d  procs  still
working",rpt_str,i) ;
                         print_log(rpt_str) ;
                }
                sprintf(rpt_str,"\nAll          processes          finished          at
%s",ctime(&end_time)) ;
                print_log(rpt_str) ;
                sprintf(rpt_str,"loaded %d account records in ",load_accts) ;
                report_time(rpt_str,totsecs) ;
                sprintf(rpt_str,"%s = %d rows/sec\n",rpt_str,load_accts/totsecs)
;
                print_log(rpt_str) ;
                $ database tpc ;
                  SqlErr("Open Database") ;
                $ update statistics for table account ;
                  SqlErr("Update Statistics on account") ;
                $ close database ;
                  SqlErr("Close Database") ;
         }
         if (logfile)    fclose(flog) ;
        exit(0) ;
}
report_time(s,secs)
        char s[] ;
        long secs ;
{
        int hrs, mins, slen ;
        hrs = secs / 3600 ;
        secs = secs % 3600 ;
        mins = secs / 60 ;
        secs = secs % 60 ;
        slen = strlen(s) ;
        sprintf(&s[slen],"%2d:%02d:%02d",hrs,mins,secs) ;
}
```

```
print_log(s)
        char *s ;
{
        if (logfile) {
                fprintf(flog,"%s\n",s) ;
                fflush(flog) ;
 }
else {
                printf("%s\n",s) ;
                fflush(stdout) ;
        }
}
```

Appendix D

Database Contents Samples

This appendix contains the database contents samples for the TPC Benchmark B run on the DECsystem 5500.

D.1 Branch Table

Following is a sample of the Branch table contents:

number	5
balance	-6004309
fillstr	12345678901234567890123456789012345678901234567890123456789012345678901234567890123456789012

number	6
balance	356395575
fillstr	12345678901234567890123456789012345678901234567890123456789012345678901234567890123456789012

number	7
balance	-10939855
fillstr	12345678901234567890123456789012345678901234567890123456789012345678901234567890123456789012

D.2 Teller Table

Following is a sample of the Teller table contents:

number	10
balance	-25340103
branch	1
fillstr	12345678901234567890123456789012345678901234567890123456789012345678901234567890123456789

number	11
balance	43345491
branch	1
fillstr	12345678901234567890123456789012345678901234567890123456789012345678901234567890123456789

number	12
balance	-18705273
branch	1
fillstr	12345678901234567890123456789012345678901234567890123456789012345678901234567890123456789

D.3 History Table

Following is a sample of the History table contents:

account	3812872
teller	380
branch	38
delta	24901
tstamp	1991-11-08 13:02:11
fillstr	the rest is history

account	299394
teller	85
branch	8
delta	36671
tstamp	1991-11-08 13:02:11
fillstr	the rest is history

account	3032051
teller	300
branch	30
delta	-833240
tstamp	1991-11-08 13:02:11
fillstr	the rest is history

D.4 Account Table

Following is a sample of the Account table contents:

number	1244
balance	381120
branch	0
fillstr	12345678901234567890123456789012345678901234567890123456789012345678 901234567890123456789012345678901234567

number	1245
balance	818867
branch	0
fillstr	12345678901234567890123456789012345678901234567890123456789012345678 901234567890123456789012345678901234567

number	1246
balance	-248031
branch	0
fillstr	12345678901234567890123456789012345678901234567890123456789012345678 901234567890123456789012345678901234567

Appendix E

Device Configurations

This appendix contains a description of the physical disk configurations tested for the DECsystem 5500 configuration.

/dev/rra0a
Current partition table:

partition	bottom	top	size	overlap
a	0	32767	32768	c,d,e,h
b	32768	163839	131072	c,d,e
c	0	744399	744400	a,b,d,e,f,g,h
d	0	163839	163840	a,b,c,e,h
e	0	471039	471040	a,b,c,d,g,h
f	471040	744399	273360	c,g
g	163840	744399	580560	c,e,f
h	0	0	0	a,c,d,e

/dev/rra1a
Current partition table:

partition	bottom	top	size	overlap
a	0	65535	65536	c,d,e,h
b	65536	265143	199608	c,d,e
c	0	744399	744400	a,b,d,e,f,g,h
d	0	163839	163840	a,b,c,e,h
e	0	471039	471040	a,b,c,d,g,h
f	471040	744399	273360	c,g
g	265144	744399	479256	c,e,f
h	0	0	0	a,c,d,e

/dev/rra2a
Current partition table:

partition	bottom	top	size	overlap
a	0	482255	482256	c,d,e,f,g,h
b	482256	744399	262144	c,f
c	0	744399	744400	a,b,d,e,f,g,h
d	0	163839	163840	a,c,e,g,h
e	0	471039	471040	a,c,d,g,h
f	471040	744399	273360	a,b,c
g	0	0	0	a,c,d,e,h
h	0	0	0 a	,c,d,e,g

/dev/rra3a
Current partition table:

partition	bottom	top	size	overlap
a	0	32767	32768	c,d,e,h
b	32768	163839	131072	c,d,e
c	0	744399	744400	a,b,d,e,f,g,h
d	0	163839	163840	a,b,c,e,h
e	0	471039	471040	a,b,c,d,g,h
f	471040	744399	273360	c,g
g	163840	744399	580560	c,e,f
h	0	0	0	a,c,d,e

/dev/rra4a
Current partition table:

partition	bottom	top	size	overlap
a	0	32767	32768	c,d,e,h
b	32768	163839	131072	c,d,e
c	0	744399	744400	a,b,d,e,f,g,h
d	0	163839	163840	a,b,c,e,h
e	0	471039	471040	a,b,c,d,g,h
f	471040	744399	273360	c,g
g	163840	744399	580560	c,e,f
h	0	0	0	a,c,d,e

/dev/rra5a
Current partition table:

partition	bottom	top	size	overlap
a	0	32767	32768	c,d,e,h
b	32768	163839	131072	c,d,e
c	0	744399	744400	a,b,d,e,f,g,h
d	0	163839	163840	a,b,c,e,h
e	0	471039	471040	a,b,c,d,g,h
f	471040	744399	273360	c,g
g	163840	744399	580560	c,e,f
h	0	0	0	a,c,d,e

/dev/rra6a
Current partition table:

partition	bottom	top	size	overlap
a	0	32767	32768	c,d,e,h
b	32768	163839	131072	c,d,e
c	0	744399	744400	a,b,d,e,f,g,h
d	0	163839	163840	a,b,c,e,h
e	0	471039	471040	a,b,c,d,g,h
f	471040	744399	273360	c,g
g	163840	744399	580560	c,e,f
h	0	0	0	a,c,d,e

/dev/rrz0a
No partition table found in superblock... using default table from device driver.
Current partition table:

partition	bottom	top	size	overlap
a	0	32767	32768	c
b	32768	217087	184320	c
c	0	1954049	1954050	a,b,d,e,f,g,h
d	831488	1130495	299008	c,h
e	1130496	1429503	299008	c,h
f	1429504	1954049	524546	c,h
g	217088	831487	614400	c
h	831488	1954049	1122562	c,d,e,f

/dev/rrz1a
Current partition table:

partition	bottom	top	size	overlap
a	0	32767	32768	c
b	32768	217087	184320	c
c	0	1954049	1954050	a,b,d,e,f,g,h
d	831488	1130495	299008	c,h
e	1130496	1429503	299008	c,h
f	1429504	1954049	524546	c,h
g	217088	831487	614400	c
h	831488	1954049	1122562	c,d,e,f

/dev/rrz2a
Current partition table:

partition	bottom	top	size	overlap
a	0	32767	32768	c
b	32768	163839	131072	c
c	0	1299173	1299174	a,b,d,e,f,g,h
d	163840	456369	292530	c,g
e	456370	748899	292530	c,g,h
f	748900	1299173	550274	c,h
g	163840	731505	567666	c,d,e
h	731506	1299173	567668	c,e,f

/dev/rrz3a
No partition table found in superblock... using default table from device driver.
Current partition table:

partition	bottom	top	size	overlap
a	0	32767	32768	c
b	32768	163839	131072	c
c	0	1299173	1299174	a,b,d,e,f,g,h
d	163840	456369	292530	c,g
e	456370	748899	292530	c,g,h
f	748900	1299173	550274	c,h
g	163840	731505	567666	c,d,e
h	731506	1299173	567668	c,e,f

/dev/rrz4a
Current partition table:

partition	bottom	top	size	overlap
a	0	32767	32768	c
b	32768	163839	131072	c
c	0	1299173	1299174	a,b,d,e,f,g,h
d	163840	456369	292530	c,g
e	456370	748899	292530	c,g,h
f	748900	1299173	550274	c,h
g	163840	731505	567666	c,d,e
h	731506	1299173	567668	c,e,f

Appendix F

System Parameter Settings

This appendix contains the operating system parameters and database options in the TPC Benchmark B test system.

F.1 System Parameters

ULTRIX version 4.2 system parameters were configured as shown below. In all instances default values were used except for

- MAXUSERS was set to 128
- MAXUPRC was set to 128
- SMMAX was set to 1024
- SMSEG was set to 128

Additionally, two semaphore constant values were changed in the ULTRIX IPC Semaphore Facility sem.h (/usr/sys/h/sem.h). The value SEMMNI, the number of semaphore identifiers, was set to 40, and the SEMMNS, the number of semaphores in the system, was set to 120. A copy of sem.h appears in this appendix.

The following operating system parameters were used for the test system.

```
ident           "DIMES"
machine         mips
cpu             "DS5500"
maxusers        128
processors      1
maxuprc         128
physmem         32
timezone        5 dst 1
smmax           1024
smseg           128

options         LAT
options         QUOTA
options         INET
options         EMULFLT
options         NFS
options         RPC
options         DLI
options         NETMAN
options         UFS
```

```
F-2options                      DECNET

makeoptions         ENDIAN="-EL"

config              vmunix      root on ra0a  swap on ra0b  dumps on ra0b


adapter             uba0        at nexus?
adapter             msi0        at nexus?
adapter             ibus0       at nexus?
controller          dssc0       at msi0       msinode 0
disk                ra0         at dssc0      drive 0
controller          dssc1       at msi0       msinode 1
disk                ra1         at dssc1      drive 1
controller          dssc2       at msi0       msinode 2
disk                ra2         at dssc2      drive 2
controller          dssc3       at msi0       msinode 3
disk                ra3         at dssc3      drive 3
controller          dssc4       at msi0       msinode4
disk                ra4         at dssc4      drive 4
controller          dssc5       at msi0       msinode 5
disk                ra5         at dssc5      drive 5
controller          dssc6       at msi0       msinode 6
disk                ra6         at dssc6      drive 6
controller          asc0        at ibus?      vector ascintr
disk                rz0         at asc0       drive 0
disk                rz1         at asc0       drive 1
disk                rz2         at asc0       drive 2
disk                rz3         at asc0       drive 3
disk                rz4         at asc0       drive 4
tape                tz6         at asc0       drive 6
device              ne0         at ibus?      vector neintr

scs_sysid           1

pseudo-device       pty
pseudo-device       loop
pseudo-device       inet
pseudo-device       ether
pseudo-device       lat
pseudo-device       lta
pseudo-device       rpc
pseudo-device       nfs
pseudo-device       dli
pseudo-device       netman
pseudo-device       ufs
pseudo-device       decnet
pseudo-device       presto
```

F.2 IPC Semaphore Facility

```
/* @(#)sem.h              4.1 (ULTRIX)          7/2/90 */
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 ************************************************************************/
/*  *  * Modification history:
 *
 * 19 Mar 90 -- burns
 *              Added ifdef kernel around SMP lock imbedded in
 *              a user visable data structure (msqid_ds).
 *
 * 13 Dec 89 -- scott
 *              xpg compliance changes
 *
 * 16 Aug 88 -- miche
 *              Add support for SMP
 *
 * 02 Apr 86 -- depp
 *              Moved sizing constants from /sys/h/param.h to here.
 *
 * 01 Mar 85 -- depp  *     New file derived from System V IPC
 *
 */
```

```
/*
 **         IPC Semaphore Facility.
*/

#ifndef KERNEL
#include <sys/smp_lock.h>
extern int semctl();
extern int semget();
extern int semop();
#endif /* KERNEL */

#if !defined(_POSIX_SOURCE)
/*
**          Implementation Constants.
*/

#define     PSEMN     (PZERO + 3)     /* sleep priority waiting for greater value */
#define     PSEMZ     (PZERO + 2)     /* sleep priority waiting for zero */

/*
**          Permission Definitions.
*/

#define     SEM_A     0200      /* alter permission */
#define     SEM_R     0400      /* read permission */

#endif /* !defined(_POSIX_SOURCE) */
/*
**          Semaphore Operation Flags.
*/

#define     SEM_UNDO010000      /* set up adjust on exit entry */

/*
**          Semctl Command Definitions.
*/

#define     GETNCNT   3         /* get semncnt */
#define     GETPID    4         /* get sempid */
#define     GETVAL    5         /* get semval */
#define     GETALL    6         /* get all semval's */
#define     GETZCNT   7         /* get semzcnt */
#define     SETVAL    8         /* set semval */
#define     SETALL    9         /* set all semval's */

/*
**          Structure Definitions.
*/

/*
**          There is one semaphore id data structure for each set of semaphores
**                    in the system. The ipc_perm structure must be first and
**                    the lock must be last.
*/
```

```
struct semid_ds {
        struct ipc_perm         sem_perm;   /* operation permission struct */
        struct sem    *sem_base; /* ptr to first semaphore in set */
        unsigned short          sem_nsems;/* # of semaphores in set */
        time_t                  sem_otime;  /* last semop time */
        time_t                  sem_ctime;  /* last change time */
#ifdef KERNEL
        struct __lock_t sem_lk;     /* SMP lock for the semaphore queue */
#endif /* KERNEL */ };

/*
**      There is one semaphore structure for each semaphore in the system.
*/

struct sem {
        unsigned short semval;    /* semaphore text map address */
        pid_t sempid;             /* pid of last operation */
        unsigned short semncnt;   /* # awaiting semval > cval */
        unsigned short semzcnt;   /* # awaiting semval = 0 */
        unsigned short semnwakup;/* wake up those waiting on semncnt */
};

#if !defined(_POSIX_SOURCE)

/*
**      There is one undo structure per process in the system.
*/

struct sem_undo {
        struct sem_undo         *un_np;     /* ptr to next active undo structure */
        short                   un_cnt;     /* # of active entries */
        struct undo {
                short           un_aoe;     /* adjust on exit values */
                short           un_num;     /* semaphore # */
                int             un_id;      /* semid */
        }       un_ent[1];      /* undo entries (one minimum) */
};

/*
** semaphore information structure
*/
struct  seminfo {
        int     semmap,     /* # of entries in semaphore map */
                semmni,     /* # of semaphore identifiers */
                semmns,     /* # of semaphores in system */
                semmnu,     /* # of undo structures in system */
                semmsl,     /* max # of semaphores per id */
                semopm,     /* max # of operations per semop call */
                semume,     /* max # of undo entries per process */
                semusz,     /* size in bytes of undo structure */
                semvmx,     /* semaphore maximum value */
                semaem;     /* adjust on exit max value */
};
```

```
/*
**          User semaphore template for semop system calls.
*/

struct sembuf {
          unsigned short sem_num;          /* semaphore # */
          short          sem_op;           /* semaphore operation */
          short          sem_flg;          /* operation flags */
};

/*
 * Sizing constants
 */

#define SEMMAP 10
#define SEMMNI 40
#define SEMMNS 120
#define SEMMNU 30
#define SEMMSL 25
#define SEMOPM 10
#define SEMUME 10
#define SEMVMX 32767
#define SEMAEM 16384

#endif /* !defined(_POSIX_SOURCE) */
```

Appendix G

Independent Auditor’s Report