SPC BENCHMARK 1™

FULL DISCLOSURE REPORT

IBM CORPORATION
IBM TOTALSTORAGE® SAN VOLUME CONTROLLER 1.2.1

SPC-1 V1.8

Submitted for Review: December 3, 2004
Submission Identifier: A00037
Accepted: February 1, 2005

First Edition – December 2004

THE INFORMATION CONTAINED IN THIS DOCUMENT IS DISTRIBUTED ON AN AS IS BASIS WITHOUT ANY WARRANTY EITHER EXPRESS OR IMPLIED. The use of this information or the implementation of any of these techniques is the customer's responsibility and depends on the customer's ability to evaluate and integrate them into the customer's operational environment. While each item has been reviewed by IBM Corporation for accuracy in a specific situation, there is no guarantee that the same or similar results will be obtained elsewhere. Customers attempting to adapt these techniques to their own environment do so at their own risk.

This publication was produced in the United States. IBM Corporation may not offer the products, services, or features discussed in this document in other countries, and the information is subject to change with notice. Consult your local IBM Corporation representative for information on products and services available in your area.

Trademarks

SPC Benchmark 1, SPC-1 IOPS, and SPC-1 LRT are trademarks of the Storage Performance Council. IBM Corporation and IBM TotalStorage are registered trademarks of the IBM Corporation in the United States and other countries. All other brands, trademarks, and product names are the property of their respective owners.

Notes

The following terms, used in this document, are defined as:

- Kilobyte (KB) is equal to 1,000 (10^3) bytes.

- Megabyte (MB) is equal to 1,000,000 (10^6) bytes.

- Gigabyte (GB) is equal to 1,000,000,000 (10^9) bytes.

- Terabyte (TB) is equal to 1,000,000,000,000 (10^{12}) bytes.

Table of Contents

AUDIT CERTIFICATION

Bruce McNutt
IBM Corporation
KBV/9062-2
9000 South Rita Road
Tucson, AZ 85744

December 2, 2004

The SPC Benchmark 1™ results listed below for the IBM TotalStorage® SAN Volume Controller 1.2.1 were produced in compliance with the SPC Benchmark 1™ V1.8 Remote Audit requirements.

SPC Benchmark 1™ V1.8 Results	
Tested Storage Configuration (TSC) Name:	
IBM TotalStorage® SAN Volume Controller 1.2.1	
Metric	**Reported Result**
SPC-1 IOPS™	100,128.61
SPC-1 Price-Performance	$12.50/SPC-1 IOPS™
Total ASU Capacity	7,200.000 GB
Data Protection Level	Mirroring
Total TSC Price (including three-year maintenance)	$1,251,984.75

The following SPC Benchmark 1™ Remote Audit requirements were reviewed and found compliant with V1.8 of the SPC Benchmark 1™ specification:

- A Letter of Good Faith, signed by a senior executive.
- The following Data Repository storage items were verified using information supplied by IBM Corporation:
  - ✓ Physical Storage Capacity and requirements.
  - ✓ Configured Storage Capacity and requirements.
  - ✓ Addressable Storage Capacity and requirements.
  - ✓ Capacity of each Logical Volume and requirements.
  - ✓ Capacity of each Application Storage Unit (ASU) and requirements.

- An appropriate diagram of the Benchmark Configuration (BC)/Tested Storage Configuration (TSC).

Storage Performance Council
643 Bair Island Road, Suite 103
Redwood City, CA 94062
AuditService@storageperformance.org
650.556.9384

- Listings and commands to configure the Benchmark Configuration/Tested Storage Configuration, including customer tunable parameters.

- Commands and parameters used to configure the SPC-1 Workload Generator.

- The following Host System requirements were reviewed using documentation supplied by IBM Corporation:

  ✓ The type of Host System including the number of processors and main memory.
  ✓ The presence and version number of the Workload Generator on the Host System.
  ✓ The TSC boundary within the Host System.

- The Test Results Files and resultant Summary Results Files received from IBM Corporation for each of following were authentic, accurate, and compliant with all of the requirements and constraints of Clauses 4 and 5 of the SPC-1 Benchmark Specification:
  ✓ Data Persistence Test
  ✓ Sustainability Test Phase
  ✓ IOPS Test Phase
  ✓ Response Time Ramp Test Phase
  ✓ Repeatability Test

- The difference between the Tested Storage Configuration (TSC) used for the benchmark and Priced Storage Configuration is noted below.

- The final version of the pricing spreadsheet met all of the requirements and constraints of Clause 8 of the SPC-1 Benchmark Specification.

- The Full Disclosure Report (FDR) met all of the requirements in Clause 9 of the SPC-1 Benchmark Specification.

Audit Notes:

The Tested Storage Configuration used a single Cisco 9509 switch, which was replaced by four (4) IBM 2005 B32 switches in the Priced Storage Configuration. Based on documentation supplied by IBM Corporation, use of the four IBM switches in the Tested Storage Configuration rather than the single Cisco switch would not have a negative impact on the reported SPC-1 performance.

Respectfully,
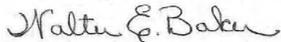
Walter E. Baker

Walter E. Baker
SPC Auditor

Storage Performance Council
643 Bair Island Road, Suite 103
Redwood City, CA 94062
AuditService@storageperformance.org
650.556.9384

LETTER OF GOOD FAITH

IBM

Route 100
Somers, NY 10589

November 22, 2004

To: Mr. Walter E. Baker, SPC Auditor
Gradient Systems, Inc.
643 Bair Island Road, Suite 103
Redwood City, CA 94063

Subject: SPC-1 Letter of Good Faith for the SAN Volume Controller Release 1.2.1

IBM Corporation is the SPC-1 Test Sponsor for the above listed product. To the best of our knowledge and belief, the required SPC-1 benchmark results and materials we have submitted for that product are complete, accurate, and in full compliance with Version 1.8 of the SPC-1 benchmark specification.

Our disclosure of the Benchmark Configuration and execution of the benchmark includes all items that, to the best of our knowledge and belief, materially affect the reported results, regardless of whether such items are explicitly required to be disclosed by the SPC-1 benchmark specification.

Sincerely,

Jens Tiedemann
General Manager
TotalStorage Software

EXECUTIVE SUMMARY

Test Sponsor and Contact Information

Test Sponsor and Contact Information	
Test Sponsor Primary Contact	IBM Corporation – http://www.ibm.com Bill Bostic – wbostic@us.ibm.com KBV/9062-2 9000 South Rita Road Tucson, AZ 85744 Phone: (520) 799-2942 FAX: (520) 799-5530
Test Sponsor Alternate Contact	IBM Corporation – http://www.ibm.com Bruce McNutt – bmcnutt@us.ibm.com KBV/9062-2 9000 South Rita Road Tucson, AZ 85744 Phone: (520) 799-2460 FAX: (520) 799-5530
Auditor	Storage Performance Council – http://ww.storageperformance.org Walter E. Baker – AuditService@StoragePerformance.org 643 Bair Island Road, Suite 103 Redwood City, CA 94063 Phone: (650) 556-9380 FAX: (650) 556-9385

Revision Information and Key Dates

Revision Information and Key Dates	
SPC-1 Specification revision number	V1.8
SPC-1 Workload Generator revision number	V2.00.04a
Date Results were first used publicly	December 3, 2004
Date FDR was submitted to the SPC	December 3, 2004
Date the TSC will be available for shipment to customers	October 29, 2004
Date the TSC completed audit certification	December 2, 2004

Summary of Results

SPC-1 Results	
Tested Storage Configuration (TSC) Name: IBM TotalStorage® SAN Volume Controller 1.2.1	
Metric	**Reported Result**
SPC-1 IOPS™	100,128.61
SPC-1 Price-Performance	$12.50/SPC-1 IOPS™
Total ASU Capacity	7,200.000 GB
Data Protection Level	Mirroring
Total TSC Price (including three-year maintenance)	$1,251,984.75

SPC-1 IOPS™ represents the maximum I/O Request Throughput at the 100% load point.

Total ASU (Application Storage Unit) **Capacity** represents the total storage capacity read and written in the course of executing the SPC-1 benchmark.

A **Data Protection Level** of Mirroring configures two or more identical copies of user data.

Storage Capacities and Relationships

The following diagram documents the various storage capacities, used in this benchmark, and their relationships.
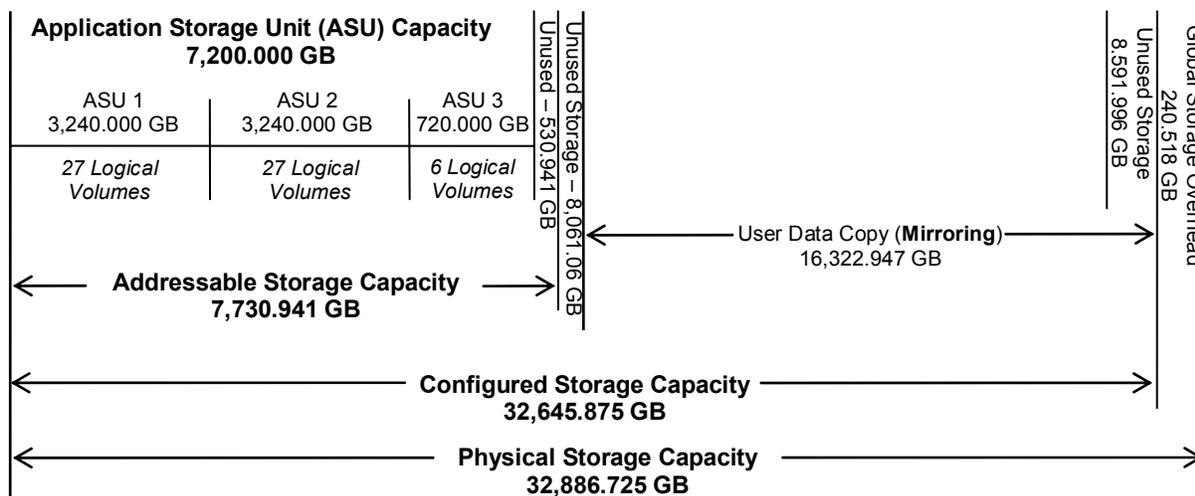
Response Time – Throughput Curve
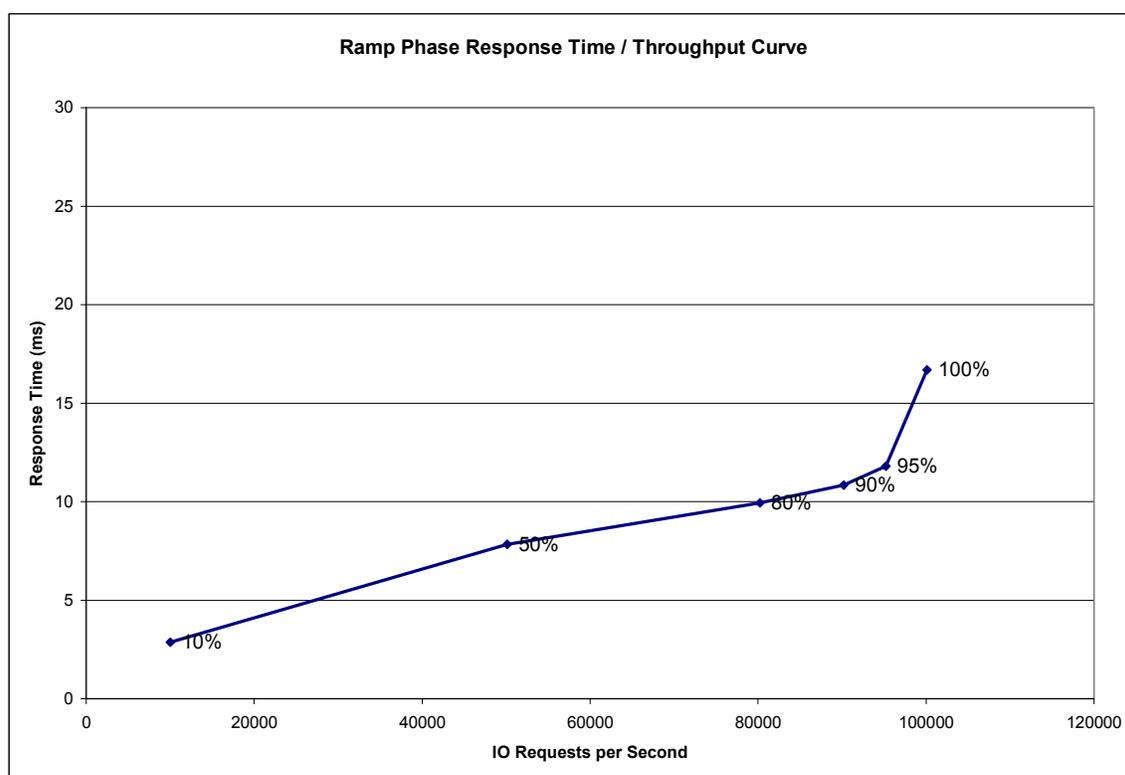
The Response Time-Throughput Curve illustrates the Average Response Time (milliseconds) and I/O Request Throughput at 100%, 95%, 90%, 80%, 50%, and 10% of the workload level used to generate the SPC-1 IOPS™ metric.

The Average Response Time measured at any of the above load points cannot exceed 30 milliseconds or the benchmark measurement is invalid.

Response Time – Throughput Data

	10% Load	50% Load	80% Load	90% Load	95% Load	100% Load
I/O Request Throughput	10,002.25	50,107.23	80,228.63	90,196.93	95,200.02	100,128.61
Average Response Time (ms):						
ASU-1	3.96	10.66	13.23	14.18	15.28	21.20
ASU-2	2.93	9.63	12.31	13.26	14.36	20.11
ASU-3	0.47	1.07	1.92	2.72	3.30	5.59
Reads	6.61	18.36	22.45	23.57	25.15	34.17
Writes	0.41	0.99	1.79	2.56	3.11	5.29

Tested Storage Configuration Pricing *(Priced Storage Configuration)*

Component	Comments	Quantity	Unit Price	Unit Maint	List w/ Maint	% discount	Total Price
SVC Processor		8	13,750.00	3,564.00	138,512.00	30	96,958.40
UPS		4	5,000.00	9,720.00	58,880.00	30	41,216.00
Master Console		1	7,499.00	3,312.00	10,811.00	30	7,567.70
SVC Software license	up to 32 virtualized TB	1	125,000.00	34,000.00	159,000.00	30	111,300.00
19 inch rack (7014-T42)		4	3,433.00	0.00	13,732.00	50	6,866.00
24 port fibre channel switch (2005-B32)	24 of 32 ports enabled	4	26,750.00	2,278.00	116,112.00	20	92,889.60
Ethernet switch (22P-8743)		2	489.99	35.00	1,049.98	42	608.99
DS4300 with 14 15K RPM drives (73 GB)	w/ 6 SFP, 4 5m cables	16	47,895.00	2,499.00	806,304.00	39	491,845.44
EXP700 with 14 15K RPM drives (73 GB)	w/ 4 SFP, 2 1m cables	16	35,544.00	760.00	580,864.00	39	354,327.04
SFP (4 pack)	in addition to items 11, 12	4	550.00	0.00	2,200.00	20	1,760.00
Short wave 2Gbit fibre channel cable (25 m)		16	210.00	0.00	3,360.00	20	2,688.00
Ethernet cable (7 feet)		24	6.99	0.00	167.76	0	167.76
Ethernet cable (25 feet)		18	14.99	0.00	269.82	0	269.82
2 Gbit P5 590 adapter (5716)		16	2,720.00	0.00	43,520.00	0	43,520.00

Total Price   **$ 1,251,984.75**

Maintenance/support is provided 24 hours per day, 7 days per week for three years with four hour acknowledgement and four hour subsequent response (support engineer onsite or customer replaceable part available).

Differences between the Tested Storage Configuration (TSC) and Priced Storage Configuration

The TSC used a single Cisco 9509 switch and the Priced Storage Configuration substituted four (4) IBM 2005 B32 switches in its place. The latencies of fibre channel switch technology are measured in small numbers of microseconds, and hence represent a vanishingly small fraction of typical SPC-1 response times. Under these circumstances, the exact choice of fibre channel switch should be expected to have no measurable impact on SPC-1 performance. In addition, to the degree that there might be any difference in performance in using four IBM 2005-B32 switches versus a single Cisco 9509 switch, this small difference should be expected to favor the four B32 switches. The 9509 used in the TSC is a 2 Gbit switch made approximately two years ago, and is not fully non-blocking. By comparison, the technology of the each B32 supports 4 Gbit speeds and is fully non-blocking.

Benchmark Configuration/Tested Storage Configuration Diagram
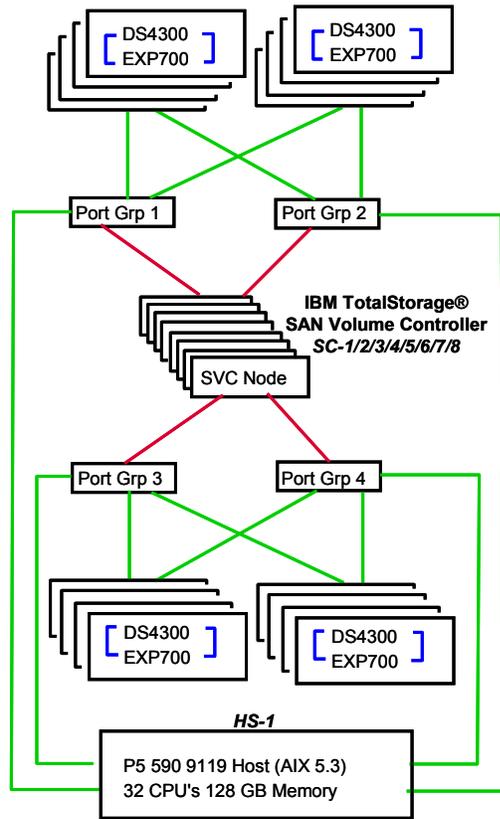
Notes:

All storage is managed by each node (single image).

Each DS4300 and EXP700 has 14 disks (total of 448). Disks are 73 GB, 15K RPM.

Each group of 20 ports has one zone for node-to-host traffic, one zone for node-to-storage traffic

—————— Represents 1 FC path per line drawn

—————— Represents 4 FC paths per line drawn

—————— Represents 8 FC paths per line drawn

Host Systems:	Tested Storage Configuration (TSC):
UID=HS-1	12 – 2 Gbit P5 590 HBAs
IBM P5 590 Model 9119	**UID=SC-1/2/3/4/5/6/7/8:** 8 – TotalStorage® SAN Volume Controllers Per controller:
32 – 1.65 GHz CPUs – 2 CPUs/POWER5 chip 32 KB L1 cache, 960 KB L2 cache, and 18 MB L3 cache per CPU	xSeries 335 processor which contains: 2 – 2.4 GHz Intel P4 CPUs
128 GB main memory	4 GB memory/cache 4 – 2 Gbit FC ports
AIX 5.3	
PCI-X/RIO	4 – 32 port FC switches
WG	1 – Ethernet switch
	16 – DS4300 enclosures 16 – EXP700 enclosures 14 – 73 GB, 15K RPM disk drives per enclosure
	4 – 19 inch racks
	4 – UPS

CONFIGURATION INFORMATION

Benchmark Configuration (BC)/Tested Storage Configuration (TSC) Diagram

Clause 9.2.4.4.1

A one page Benchmark Configuration (BC)/Tested Storage Configuration (TSC) diagram shall be included in the Executive Summary…

The Benchmark Configuration (BC)/Tested Storage Configuration (TSC) is illustrated on page 13 *(Benchmark Configuration/Tested Storage Configuration Diagram).*

Storage Network Configuration

Clause 9.2.4.4.2

If a storage network is employed in the BC/TSC, the FDR shall contain a topology diagram… . This diagram should include, but is not limited to the following components:

1. *Storage Controller and Domain Controllers (see Clause 9.2.4.4.1)*
2. *Host Systems (see Clause 9.2.4.4.1)*
3. *Routers and Bridges*
4. *Hubs and Switches*
5. *HBAs to Host Systems and Front End Port to Storage Controllers*

Additionally the diagram shall:

- *Illustrate the physical connection between components.*
- *Describe the type of each physical connection.*
- *Describe the network protocol used over each physical connection.*
- *The maximum theoretical transfer rate of each class of interconnect used in the configuration.*
- *Correlate with the BC Configuration Diagram in Clause 9.2.4.4.1.*

The Test Sponsor shall additionally supply (referenced in an appendix) a wiring diagram of the physical connections and physical port assignments used in the storage network. The diagram should allow anyone to exactly replicate the physical configuration of the storage network.

The storage network configuration is illustrated on page 13 *(Benchmark Configuration/Tested Storage Configuration Diagram).*

Host System Configuration

Clause 9.2.4.4.3

The FDR shall minimally contain, for each Host System running the Workload Generator, a listing of the following:

1. *Number and type of CPUs.*
2. *Main memory capacity.*
3. *Cache memory capacity.*
4. *Number and type of disk controllers or Host Bus Adapters.*

The details of the Host System configuration may be found on page 13 *(Benchmark Configuration/Tested Storage Configuration Diagram).*

Customer Tunable Parameters and Options

Clause 9.2.4.5.1

All Benchmark Configuration (BC) components with customer tunable parameter and options that have been altered from their default values must be listed in the FDR. The FDR entry for each of those components must include both the name of the component and the altered value of the parameter or option.

"Appendix A: Customer Tunable Parameters and Options" on page 49 contains the customer tunable parameters and options that have been altered from their default values for this benchmark.

Tested Storage Configuration (TSC) Description

Clause 9.2.4.5.2

The FDR must include sufficient information to recreate the logical representation of the TSC. In addition to customer tunable parameters and options (Clause 4.2.4.5.3), that information must include, at a minimum, a diagram and/or description of the following:

- *All physical components that comprise the TSC. Those components are also illustrated in the Benchmark Configuration (BC) diagram in Clause 9.2.4.4.1 and, if applicable, the Storage Network Configuration Diagram in Clause 9.2.4.4.2.*

- *The logical representation of the TSC, configured from the above components that will be presented to the Workload Generator.*

In addition the FDR may include listings of scripts and/or commands used to configure the physical components that comprise the TSC.

"Appendix B: Tested Storage Configuration (TSC) Creation" on page 50 contains the detailed information that describes how to create and configure the logical TSC.

SPC-1 Workload Generator Storage Configuration

Clause 9.2.4.5.3

The FDR must include all SPC-1 Workload Generator storage configuration commands and parameters.

The SPC-1 Workload Generator storage configuration commands and parameters for this measurement appear in "Appendix C: SPC-1 Workload Generator Storage Commands and Parameters" on page 54.

DATA REPOSITORY

Definitions

Total ASU Capacity: The total storage capacity read and written in the course of executing the SPC-1 benchmark.

Application Storage Unit (ASU): The logical interface between the storage and SPC-1 Workload Generator. The three ASUs (Data, User, and Log) are typically implemented on one or more Logical Volume.

Logical Volume: The division of Addressable Storage Capacity into individually addressable logical units of storage used in the SPC-1 benchmark. Each Logical Volume is implemented as a single, contiguous address space.

Addressable Storage Capacity: The total storage (sum of Logical Volumes) that can be read and written by application programs such as the SPC-1 Workload Generator.

Configured Storage Capacity: This capacity includes the Addressable Storage Capacity and any other storage (parity disks, hot spares, etc.) necessary to implement the Addressable Storage Capacity.

Physical Storage Capacity: The formatted capacity of all storage devices physically present in the Tested Storage Configuration (TSC).

Data Protection Overhead: The storage capacity required to implement the ECC data protection.

Required Storage: The amount of Configured Storage Capacity required to implement the Addressable Storage Configuration, excluding the storage required for the three ASUs.

Global Storage Overhead: The amount of Physical Storage Capacity that is required for storage subsystem use and unavailable for use by application programs.

Total Unused Storage: The amount of storage capacity available for use by application programs but not included in the Total ASU Capacity.

Storage Capacities and Relationships

Two tables and an illustration documenting the storage capacities and relationships of the SPC-1 Storage Hierarchy (Clause 2.1) shall be included in the FDR.

SPC-1 Storage Capacities

SPC-1 Storage Capacities		
Storage Hierarchy Component	**Units**	**Capacity**
Total ASU Capacity	Gigabytes (GB)	7,200.000
Addressable Storage Capacity	Gigabytes (GB)	7,730.941
Configured Storage Capacity	Gigabytes (GB)	32,645.875
Physical Storage Capacity	Gigabytes (GB)	32,886.725
Data Protection Overhead (mirror)	Gigabytes (GB)	15,201.920
Required Storage	Gigabytes (GB)	0.000
Global Storage Overhead	Gigabytes (GB)	240.518
Total Unused Storage	Gigabytes (GB)	17,183.992

SPC-1 Storage Hierarchy Ratios

	Addressable Storage Capacity	Configured Storage Capacity	Physical Storage Capacity
Total ASU Capacity	93.13%	22.05%	21.89%
Required for Data Protection (Mirroring)		46.57%	46.23%
Addressable Storage Capacity		23.68%	23.51%
Required Storage		0.00%	0.00%
Configured Storage Capacity			99.27%
Global Storage Overhead			0.73%
Unused Storage:			
Addressable	6.87%		
Configured		52.64%	
Physical			0.00%

The Physical Storage Capacity consisted of 32,886.725 GB distributed over 448 disk drives each with a formatted capacity of 73.408 GB. There was 0.00 GB (0.00%) of Unused Storage within the Physical Storage Capacity. Global Storage Overhead consisted of 240.518 GB (0.73%) of Physical Storage Capacity. There was 17,183.992 GB (52.64%) of Unused Storage within the Configured Storage Capacity. The Total ASU Capacity utilized 93.13 % of the Addressable Storage Capacity resulting in 530.941 GB (6.87%) of Unused Storage within the Addressable Storage Capacity.

SPC-1 Storage Capacities and Relationships Illustration

The various storage capacities configured in the benchmark result are illustrated below (not to scale).
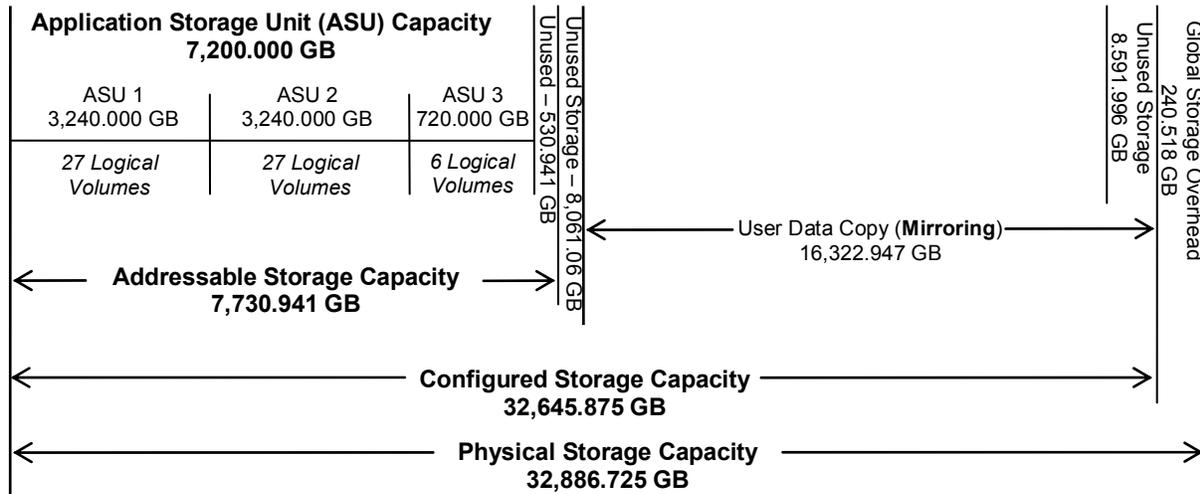
Logical Volume Capacity and ASU Mapping

Clause 9.2.4.6.2

A table illustrating the capacity of each ASU and the mapping of Logical Volumes to ASUs shall be provided in the FDR. Logical Volumes shall be sequenced in the table from top to bottom per its position in the contiguous address space of each ASU. The capacity of each Logical Volume shall be stated. … In conjunction with this table, the Test Sponsor shall provide a complete description of the type of data protection (see Clause 2.4.5) used on each Logical Volume.

Logical Volume Capacity and Mapping		
ASU-1 (GB)	ASU-2 (GB)	ASU-3 (GB)
27 Logical Volumes 128.849 GB per Logical Volume (120.000 GB used/Logical Volume)	27 Logical Volumes 128.849 GB per Logical Volume (120.000 GB used/Logical Volume)	6 Logical Volume 128.849 GB per Logical Volume (120.000 GB used/Logical Volume)

The Data Protection Level used for all Logical Volumes was Mirroring as described on page 10. See "ASU Configuration" in the **IOPS Test Results File** for more detailed configuration information.

SPC-1 BENCHMARK EXECUTION RESULTS

Definitions

Average Response Time: *The sum of the Response Times for all Measured I/O Requests divided by the total number of Measured I/O Requests.*

I/O Request Throughput: *The total number of Measured I/O requests in an SPC-1 Test Run divided by the duration of the Measurement Interval in seconds.*

Measurement Interval: *The finite and contiguous time period, after the Tested Storage Configuration (TSC) has reached Steady State, when data is collected by a Test Sponsor to generate an SPC-1 test result or support an SPC-1 test result.*

Steady State: *The consistent and sustainable throughput of the TSC. During this period the load presented to the TSC by the Workload Generator is constant. Comment: Steady Stated is achieved only after caches in the TSC have filled and as a result the I/O Request throughput of the TSC has stabilized.*

Test: *A collection of Test Phases or Test Runs sharing a common objective.*

Test Phase: *A collection of one or more SPC-1 Test Runs sharing a common objective and intended to be run in a specific sequence.*

Test Run: *The execution of SPC-1 for the purpose of producing or supporting an SPC-1 test result. SPC-1 Test Runs may have a finite and measured Ramp-Up period, Start-Up period, Shut-Down period, and Ramp-Down period as illustrated in the Figure 5-1 below. All SPC-1 Test Runs shall have a Steady State period and a Measurement Interval.*

The SPC-1 benchmark consists of the following Tests, Test Phases, and Test Runs:

- **Data Persistence Test**
  - ➢ Data Persistence Test Run 1
  - ➢ Data Persistence Test Run 2

- **Primary Metrics Test**
  - ➢ Sustainability Test Phase and Test Run
  - ➢ IOPS Test Phase and Test Run
  - ➢ Response Time Ramp Test Phase
    - o 95% of IOPS Test Run
    - o 90% of IOPS Test Run
    - o 80% of IOPS Test Run
    - o 50% of IOPS Test Run
    - o 10% of IOPS Test Run (LRT)

- **Repeatability Test**
  - ➢ Repeatability Test Phase 1
    - o 10% of IOPS Test Run (LRT)
    - o IOPS Test Run
  - ➢ Repeatability Test Phase 2
    - o 10% of IOPS Test Run (LRT)
    - o IOPS Test Run

Each Test is an atomic unit that must be executed from start to finish before any other Test, Test Phase, or Test Run may be executed. The Tests may be executed in any sequence.

The results from each Test, Test Phase, and Test Run are listed below along with a more detailed explanation of each component.

Primary Metrics Test – Sustainability Test Phase

Clause 5.4.2.1

The Sustainability Test Phase consists of one Test Run at the 100% load point with a Measurement Interval of three (3) hours. The intent is to demonstrate a sustained maximum I/O Request Throughput as well as insuring the Tested Storage Configuration (TSC) has reached steady state prior to measuring the maximum I/O Request Throughput (SPC-1™ IOPS).

The reported I/O Request Throughput of the Sustainability Test Run must be within 5% of the reported SPC-1™ IOPS primary metric. The Average Response Time measured in Sustainability Test Run cannot exceed thirty (30) milliseconds.

Clause 9.2.4.7.1

For the Sustainability Test Phase the FDR shall contain:

   1. *A Data Rate Distribution (data table and graph).*
   2. *I/O Request Throughput Distribution (data table and graph).*
   3. *The human readable Test Run Results File produced by the Workload Generator.*
   4. *A listing or screen image of all input parameters supplied to the Workload Generator.*
   5. *The Measured Intensity Multiplier for each I/O stream.*
   6. *The variability of the Measured Intensity Multiplier, as defined in Clause 5.3.13.3.*

SPC-1 Workload Generator Input Parameters

The SPC-1 Workload Generator input parameters for the Sustainability, IOPS, and Response Time Ramp Test Runs are documented in "Appendix D: SPC-1 Workload Generator Input Parameters" on Page 56.

### Sustainability Test Results File

A link to the test results file generated from the Sustainability Test Run is listed below.

Sustainability Test Results File

Sustainability – Data Rate Distribution Data *(MB/second)*

	Start	Stop	Interval	Duration
Ramp-Up/Start-Up	9:55:49	9:58:49	0-2	0:03:00
Measurement Interval	9:58:49	12:58:49	3-182	3:00:00

| Interval	All ASUs	ASU1	ASU2	ASU3	Interval	All ASUs	ASU1	ASU2	ASU3	Interval	All ASUs	ASU1	ASU2	ASU3
0	824.75	319.86	88.21	416.67	63	822.37	319.54	87.69	415.15	126	842.86	327.17	89.66	426.03
1	822.05	319.51	87.83	414.71	64	823.66	319.68	87.69	416.29	127	827.67	320.91	88.25	418.50
2	822.59	319.51	87.79	415.30	65	812.16	315.22	86.94	410.00	128	823.53	320.12	88.14	415.27
3	823.35	320.19	87.89	415.28	66	833.03	323.89	88.88	420.26	129	833.24	323.99	88.79	420.46
4	822.60	318.98	87.87	415.75	67	821.88	319.30	87.68	414.89	130	838.68	325.89	89.67	423.12
5	823.08	319.32	87.77	415.99	68	823.36	319.65	88.29	415.42	131	850.15	329.55	91.19	429.41
6	821.79	319.55	87.83	414.41	69	823.54	319.58	87.69	416.27	132	847.30	329.33	90.54	427.43
7	822.41	319.42	87.79	415.20	70	823.79	319.54	87.88	416.37	133	834.75	324.33	89.06	421.35
8	822.24	319.25	87.57	415.43	71	823.85	319.59	88.16	416.09	134	822.98	319.66	87.85	415.47
9	822.33	319.76	87.74	414.83	72	822.55	319.42	87.67	415.45	135	822.15	319.40	87.90	414.85
10	822.58	319.90	88.00	414.68	73	823.44	319.76	87.95	415.72	136	822.38	319.57	87.63	415.18
11	822.74	319.67	88.12	414.95	74	823.81	319.47	88.07	416.27	137	822.46	319.29	87.84	415.32
12	822.62	319.27	87.74	415.61	75	822.61	319.38	88.03	415.20	138	823.95	319.59	87.99	416.36
13	822.63	319.36	88.23	415.03	76	823.02	320.05	87.84	415.13	139	822.74	319.62	87.91	415.21
14	823.20	319.54	88.31	415.35	77	824.02	319.84	88.12	416.06	140	821.89	319.55	87.46	414.87
15	822.25	319.37	87.60	415.27	78	822.48	319.67	87.77	415.04	141	821.92	319.33	87.75	414.83
16	815.41	317.03	86.91	411.47	79	823.35	319.54	87.92	415.89	142	823.25	319.73	88.11	415.42
17	832.72	322.95	88.84	420.93	80	822.39	319.17	87.74	415.48	143	822.51	319.47	88.09	414.95
18	823.14	319.24	87.77	416.13	81	823.32	319.51	88.26	415.55	144	822.77	319.30	87.73	415.74
19	822.34	319.53	88.11	414.69	82	822.04	319.41	87.68	414.95	145	824.59	319.93	87.75	416.91
20	822.52	319.26	87.72	415.54	83	822.30	319.52	87.72	415.07	146	824.14	319.62	88.10	416.41
21	823.38	319.66	87.94	415.78	84	822.54	319.48	87.87	415.19	147	821.21	318.82	87.36	415.04
22	823.24	319.53	87.67	416.04	85	822.78	319.67	88.22	414.89	148	822.43	319.07	88.18	415.18
23	822.83	319.62	87.82	415.39	86	821.94	318.87	87.68	415.40	149	823.09	319.92	87.82	415.35
24	822.99	319.51	87.70	415.78	87	823.48	319.57	88.14	415.77	150	823.35	319.47	87.76	416.12
25	823.32	319.34	88.03	415.96	88	822.46	319.57	87.82	415.07	151	823.15	319.88	87.71	415.56
26	822.49	319.09	88.19	415.21	89	823.23	319.45	88.33	415.45	152	822.76	319.30	87.89	415.56
27	822.23	319.40	87.97	414.86	90	822.95	320.21	88.25	414.50	153	822.80	319.92	87.75	415.13
28	822.67	319.32	87.81	415.55	91	822.63	319.44	88.13	415.05	154	824.60	320.13	87.85	416.61
29	823.05	319.76	87.56	415.73	92	823.21	318.98	88.07	416.16	155	824.60	319.98	88.14	416.48
30	822.61	319.65	87.89	415.08	93	821.79	319.43	87.47	414.88	156	822.90	319.32	88.02	415.56
31	822.53	319.23	87.88	415.42	94	823.30	319.64	87.95	415.71	157	822.23	319.18	87.78	415.27
32	822.24	319.27	87.70	415.28	95	823.64	319.54	87.91	416.19	158	823.55	320.24	88.02	415.29
33	823.37	319.42	87.88	416.06	96	819.73	318.12	87.44	414.17	159	822.64	319.71	87.70	415.23
34	822.02	318.86	87.97	415.19	97	825.31	320.82	88.10	416.40	160	821.89	319.13	87.84	414.92
35	823.00	319.48	87.96	415.56	98	824.40	320.05	88.00	416.35	161	822.33	319.13	87.98	415.22
36	823.12	319.43	87.81	415.89	99	823.57	319.38	88.23	415.96	162	822.90	319.68	87.94	415.27
37	822.21	319.15	87.72	415.34	100	822.17	319.54	87.97	414.65	163	822.88	319.14	88.10	415.64
38	823.09	319.47	88.04	415.58	101	822.93	319.31	87.86	415.76	164	822.18	319.02	88.06	415.10
39	823.00	319.67	88.01	415.31	102	822.59	319.46	87.80	415.32	165	822.64	319.36	87.78	415.50
40	821.97	319.38	87.76	414.83	103	823.67	319.11	88.00	416.56	166	822.20	319.30	87.88	415.03
41	822.61	319.45	87.89	415.28	104	822.23	319.84	87.84	414.55	167	823.55	319.99	88.02	415.54
42	823.42	319.87	87.78	415.77	105	819.94	318.75	87.55	413.65	168	822.85	319.22	88.08	415.54
43	823.74	320.21	87.76	415.78	106	826.47	320.91	88.42	417.13	169	823.51	319.74	87.96	415.80
44	822.70	319.83	87.63	415.24	107	816.30	316.87	87.10	412.32	170	822.61	319.49	87.70	415.42
45	823.82	319.83	88.12	415.87	108	829.82	322.26	88.70	418.86	171	824.22	319.88	87.96	416.38
46	823.40	319.99	88.24	415.16	109	815.04	316.80	86.87	411.37	172	822.57	319.45	88.00	415.11
47	823.38	319.63	87.72	416.04	110	783.14	303.87	83.67	395.60	173	823.00	319.44	88.02	415.53
48	823.76	319.42	88.05	416.29	111	829.55	322.23	88.52	418.79	174	821.68	319.58	87.47	414.64
49	822.48	319.63	87.58	415.26	112	804.16	311.91	85.81	406.44	175	822.75	319.63	87.91	415.22
50	822.38	319.39	87.83	415.16	113	818.43	317.40	87.35	413.68	176	822.27	319.29	88.13	414.85
51	824.33	319.76	87.93	416.64	114	822.00	319.13	87.84	415.02	177	821.65	319.14	87.72	414.79
52	823.44	319.53	88.01	415.90	115	808.98	314.23	86.33	408.43	178	824.06	320.18	87.80	416.08
53	823.41	319.63	88.24	415.54	116	818.59	317.73	87.60	413.25	179	822.76	319.34	87.94	415.48
54	823.98	319.80	87.86	416.32	117	825.61	320.32	88.00	417.29	180	822.30	319.54	88.14	414.62
55	822.71	319.35	87.46	415.90	118	814.35	315.80	86.87	411.68	181	823.96	319.72	87.70	416.54
56	818.58	317.97	87.19	413.41	119	832.47	323.42	88.92	420.12	182	823.52	319.48	87.98	416.06
57	823.31	319.31	87.87	416.13	120	800.53	311.25	85.55	403.73					
58	826.42	321.32	88.49	416.60	121	831.71	322.55	88.60	420.55					
59	823.18	319.46	87.85	415.87	122	829.26	321.98	88.81	418.47					
60	823.16	319.79	87.80	415.56	123	817.03	317.12	87.42	412.49					
61	822.59	319.49	87.68	415.42	124	807.08	313.16	86.48	407.44					
62	822.83	319.88	87.92	415.03	125	815.14	316.68	86.85	411.60					

Sustainability – Data Rate Distribution Graph
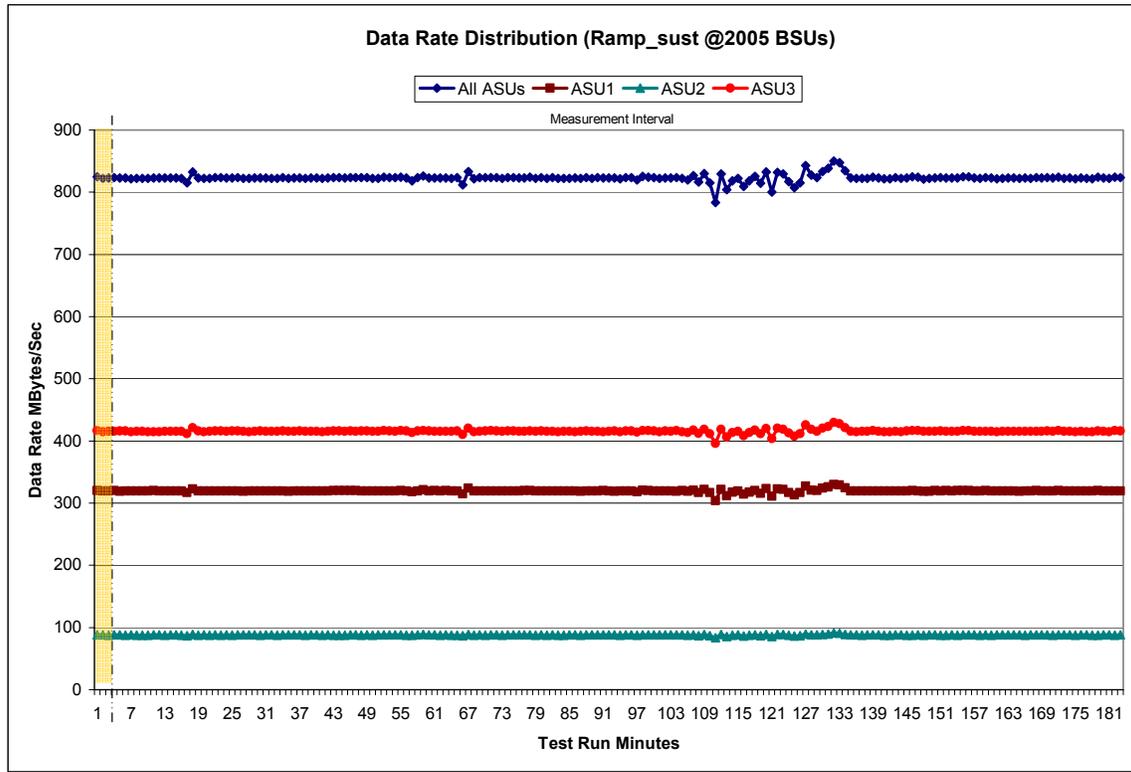
Sustainability – I/O Request Throughput Distribution Data

	Start	Stop	Interval	Duration
Ramp-Up/Start-Up	9:55:49	9:58:49	0-2	0:03:00
Measurement Interval	9:58:49	12:58:49	3-182	3:00:00

Interval	All ASUs	ASU1	ASU2	ASU3	Interval	All ASUs	ASU1	ASU2	ASU3	Interval	All ASUs	ASU1	ASU2	ASU3
0	100,479.30	59,868.02	12,371.12	28,240.17	63	100,219.53	59,726.15	12,334.03	28,159.35	126	102,630.17	61,158.43	12,612.35	28,859.38
1	100,192.32	59,736.57	12,327.30	28,128.45	64	100,257.05	59,743.57	12,319.18	28,194.30	127	100,848.73	60,105.90	12,392.32	28,350.52
2	100,218.07	59,732.25	12,319.00	28,166.82	65	98,909.93	58,919.37	12,192.93	27,797.63	128	100,364.87	59,854.13	12,332.05	28,178.68
3	100,276.68	59,813.18	12,310.00	28,153.50	66	101,520.07	60,530.48	12,464.23	28,525.35	129	101,603.47	60,604.50	12,481.67	28,517.30
4	100,236.35	59,741.00	12,337.25	28,158.10	67	100,232.70	59,766.08	12,316.55	28,150.07	130	102,195.32	60,936.00	12,553.85	28,705.47
5	100,257.05	59,736.68	12,321.90	28,198.47	68	100,288.38	59,764.90	12,351.60	28,171.88	131	103,507.07	61,653.92	12,765.67	29,087.48
6	100,222.17	59,776.95	12,334.13	28,111.08	69	100,223.40	59,719.83	12,305.68	28,197.88	132	103,305.13	61,583.32	12,703.17	29,018.65
7	100,229.25	59,756.35	12,323.78	28,149.12	70	100,299.87	59,796.05	12,326.57	28,177.25	133	101,720.73	60,662.25	12,492.13	28,566.35
8	100,222.17	59,742.52	12,319.32	28,160.33	71	100,299.65	59,762.30	12,344.87	28,192.48	134	100,234.12	59,753.87	12,312.72	28,167.53
9	100,263.00	59,754.75	12,350.93	28,157.32	72	100,233.55	59,775.20	12,307.67	28,150.68	135	100,218.43	59,742.03	12,332.80	28,143.60
10	100,225.90	59,745.60	12,333.70	28,146.60	73	100,220.87	59,740.10	12,315.85	28,164.92	136	100,224.92	59,740.40	12,325.65	28,158.87
11	100,237.28	59,785.93	12,339.15	28,112.20	74	100,254.82	59,729.55	12,353.12	28,172.15	137	100,176.35	59,707.93	12,315.50	28,152.92
12	100,240.32	59,739.40	12,329.75	28,171.17	75	100,275.10	59,763.83	12,342.95	28,168.32	138	100,281.65	59,763.50	12,328.95	28,189.20
13	100,244.28	59,726.43	12,351.05	28,166.80	76	100,244.43	59,778.10	12,316.43	28,149.90	139	100,253.92	59,753.40	12,338.17	28,162.35
14	100,219.60	59,721.48	12,348.27	28,149.85	77	100,313.12	59,807.33	12,325.38	28,180.40	140	100,205.10	59,743.32	12,308.88	28,152.90
15	100,138.78	59,709.98	12,300.25	28,128.55	78	100,142.67	59,670.78	12,328.37	28,143.52	141	100,226.18	59,751.93	12,320.45	28,153.80
16	99,300.37	59,215.60	12,196.17	27,888.60	79	100,256.27	59,736.27	12,336.08	28,183.92	142	100,204.62	59,709.07	12,330.55	28,165.00
17	101,361.07	60,406.25	12,442.98	28,511.83	80	100,197.68	59,711.18	12,319.37	28,167.13	143	100,281.35	59,767.93	12,356.43	28,156.98
18	100,284.55	59,769.08	12,328.67	28,186.80	81	100,279.58	59,763.93	12,365.67	28,149.98	144	100,229.72	59,721.97	12,322.38	28,185.37
19	100,181.88	59,714.23	12,338.75	28,128.90	82	100,235.77	59,757.30	12,317.98	28,160.48	145	100,347.02	59,812.27	12,332.42	28,202.33
20	100,234.47	59,704.67	12,332.05	28,197.75	83	100,225.45	59,756.23	12,315.48	28,153.73	146	100,306.43	59,772.30	12,357.33	28,176.80
21	100,283.98	59,771.42	12,323.88	28,188.68	84	100,197.73	59,736.82	12,322.67	28,138.25	147	100,188.85	59,725.97	12,301.32	28,161.57
22	100,279.32	59,772.18	12,331.98	28,175.15	85	100,260.90	59,782.27	12,340.42	28,138.43	148	100,213.13	59,712.17	12,319.28	28,181.68
23	100,263.63	59,776.42	12,326.28	28,160.93	86	100,121.22	59,697.57	12,291.78	28,131.87	149	100,213.28	59,769.90	12,301.23	28,142.15
24	100,216.23	59,739.53	12,317.40	28,159.30	87	100,345.25	59,795.20	12,336.32	28,213.73	150	100,254.77	59,763.03	12,323.40	28,168.33
25	100,250.43	59,696.38	12,342.68	28,211.37	88	100,268.87	59,776.15	12,312.53	28,178.18	151	100,280.43	59,777.72	12,327.32	28,175.40
26	100,230.93	59,705.97	12,353.80	28,171.17	89	100,294.45	59,766.07	12,360.87	28,167.52	152	100,206.02	59,722.53	12,315.38	28,168.10
27	100,257.57	59,760.20	12,329.18	28,168.18	90	100,285.78	59,808.68	12,343.55	28,133.55	153	100,249.22	59,783.45	12,325.68	28,140.08
28	100,250.83	59,747.88	12,324.65	28,178.30	91	100,212.83	59,710.57	12,364.87	28,137.40	154	100,303.65	59,792.80	12,317.33	28,193.52
29	100,198.95	59,734.73	12,316.67	28,147.55	92	100,233.45	59,667.45	12,355.08	28,210.92	155	100,299.03	59,799.27	12,334.88	28,164.88
30	100,206.87	59,739.05	12,319.90	28,147.92	93	100,214.00	59,766.58	12,315.15	28,132.27	156	100,196.88	59,716.12	12,328.90	28,151.87
31	100,164.17	59,705.67	12,325.13	28,133.37	94	100,239.10	59,772.77	12,322.12	28,144.22	157	100,190.87	59,687.77	12,317.67	28,185.43
32	100,208.00	59,739.85	12,324.25	28,143.90	95	100,276.02	59,743.48	12,329.98	28,202.55	158	100,330.78	59,826.02	12,340.95	28,163.82
33	100,247.40	59,733.63	12,321.57	28,192.20	96	99,872.42	59,514.92	12,284.25	28,073.25	159	100,252.97	59,775.10	12,317.48	28,160.38
34	100,208.92	59,714.23	12,317.43	28,177.25	97	100,545.00	59,928.03	12,368.97	28,248.00	160	100,238.10	59,743.93	12,320.93	28,173.23
35	100,246.38	59,749.50	12,325.72	28,171.17	98	100,324.57	59,802.08	12,316.13	28,206.35	161	100,206.35	59,731.55	12,328.10	28,146.70
36	100,258.75	59,741.57	12,335.82	28,181.37	99	100,278.27	59,732.27	12,356.58	28,189.42	162	100,285.38	59,773.42	12,333.88	28,178.08
37	100,203.17	59,708.58	12,326.23	28,168.35	100	100,179.88	59,733.77	12,340.20	28,105.92	163	100,204.47	59,685.90	12,342.25	28,176.32
38	100,233.15	59,725.67	12,320.62	28,186.87	101	100,202.97	59,725.47	12,319.82	28,157.68	164	100,191.63	59,720.13	12,315.47	28,156.03
39	100,277.17	59,782.12	12,343.58	28,151.47	102	100,229.77	59,742.90	12,328.40	28,158.47	165	100,274.25	59,760.25	12,320.72	28,193.28
40	100,264.08	59,754.77	12,332.45	28,176.87	103	100,249.33	59,724.38	12,317.87	28,207.08	166	100,222.62	59,742.67	12,335.43	28,144.52
41	100,222.17	59,740.62	12,324.07	28,175.70	104	100,261.25	59,826.02	12,319.35	28,115.88	167	100,280.88	59,797.63	12,336.82	28,186.43
42	100,311.30	59,808.60	12,326.00	28,176.70	105	99,869.30	59,554.27	12,278.08	28,036.95	168	100,227.95	59,693.07	12,349.48	28,185.40
43	100,334.03	59,834.72	12,322.57	28,176.75	106	100,661.22	59,977.80	12,392.55	28,290.87	169	100,263.23	59,771.45	12,324.38	28,167.40
44	100,229.22	59,729.15	12,331.37	28,168.70	107	99,410.62	59,272.95	12,214.65	27,923.02	170	100,264.68	59,758.48	12,320.02	28,186.18
45	100,282.33	59,754.88	12,340.57	28,186.88	108	101,051.08	60,240.28	12,425.15	28,385.65	171	100,350.38	59,817.75	12,346.98	28,185.65
46	100,261.60	59,777.80	12,332.65	28,151.15	109	99,295.08	59,207.05	12,201.00	27,887.03	172	100,235.30	59,724.87	12,358.72	28,151.72
47	100,276.63	59,750.20	12,319.00	28,207.43	110	95,370.02	56,856.43	11,732.60	26,780.98	173	100,256.00	59,733.32	12,341.10	28,181.58
48	100,262.30	59,733.25	12,335.93	28,193.12	111	101,040.72	60,276.93	12,410.33	28,353.45	174	100,167.27	59,719.15	12,306.43	28,141.68
49	100,227.87	59,763.03	12,311.68	28,153.15	112	97,979.33	58,370.55	12,062.80	27,545.98	175	100,285.37	59,789.33	12,330.18	28,165.85
50	100,244.75	59,738.90	12,325.88	28,129.97	113	99,588.05	59,331.42	12,274.30	27,982.33	176	100,242.53	59,739.73	12,346.90	28,155.90
51	100,263.30	59,730.17	12,326.20	28,206.93	114	100,189.92	59,706.87	12,350.12	28,132.93	177	100,170.58	59,726.52	12,325.88	28,118.18
52	100,261.78	59,736.27	12,329.80	28,195.72	115	98,622.82	58,795.98	12,113.22	27,713.62	178	100,325.32	59,827.67	12,311.88	28,185.77
53	100,276.67	59,758.57	12,346.15	28,171.95	116	99,614.47	59,372.42	12,264.28	27,977.77	179	100,221.47	59,725.40	12,343.15	28,152.92
54	100,334.92	59,819.10	12,316.12	28,199.70	117	100,636.37	59,987.67	12,368.30	28,280.40	180	100,226.42	59,765.47	12,329.50	28,131.45
55	100,222.53	59,751.92	12,304.12	28,166.50	118	99,192.12	59,096.33	12,177.03	27,918.75	181	100,268.43	59,733.63	12,320.35	28,214.45
56	99,855.57	59,530.03	12,252.55	28,072.98	119	101,399.47	60,464.33	12,482.85	28,452.28	182	100,259.43	59,754.45	12,337.90	28,167.08
57	100,279.22	59,713.13	12,354.22	28,211.87	120	97,599.62	58,169.78	12,022.00	27,407.83	Average	100,246.53	59,751.74	12,328.84	28,165.95
58	100,768.28	60,086.17	12,389.62	28,292.50	121	101,301.10	60,360.52	12,473.03	28,467.55					
59	100,295.75	59,792.13	12,332.73	28,170.88	122	101,008.15	60,226.02	12,434.22	28,347.92					
60	100,257.43	59,778.52	12,328.93	28,149.98	123	99,461.30	59,278.95	12,238.33	27,944.02					
61	100,225.00	59,732.37	12,314.02	28,178.62	124	98,291.87	58,556.60	12,125.50	27,609.77					
62	100,231.43	59,734.88	12,339.37	28,157.18	125	99,298.80	59,197.08	12,190.02	27,911.70					

Sustainability – I/O Request Throughput Distribution Graph
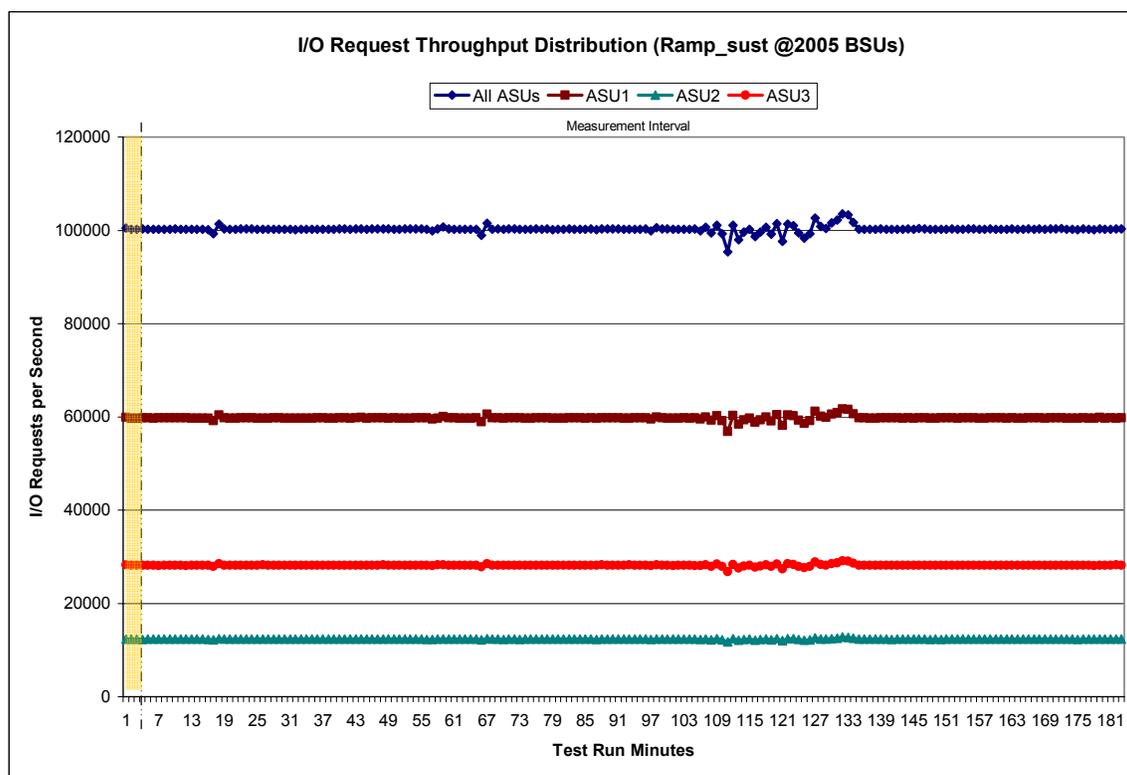
Sustainability – Measured Intensity Multiplier and Coefficient of Variation

	ASU1-1	ASU1-2	ASU1-3	ASU1-4	ASU2-1	ASU2-2	ASU2-3	ASU3-1
IM	0.0350	0.2810	0.0700	0.2100	0.0180	0.0700	0.0350	0.2810
MIM	0.0350	0.2811	0.0700	0.2100	0.0180	0.0700	0.0350	0.2810
COV	0.002	0.001	0.002	0.001	0.003	0.001	0.002	0.001

IM – Intensity Multiplier: *The ratio of I/Os for each I/O stream relative to the total I/Os for all I/O streams (ASU1-1 – ASU3-1) as required by the benchmark specification.*

MIM – Measured Intensity Multiplier: *The Measured Intensity Multiplier represents the ratio of measured I/Os for each I/O stream relative to the total I/Os measured for all I/O streams (ASU1-1 – ASU3-1). This value may differ from the corresponding Expected Intensity Multiplier by no more than 5%.*

COV – Coefficient of Variation: *This measure of variation for the Measured Intensity Multiplier cannot exceed 0.2.*

Primary Metrics Test – IOPS Test Phase

Clause 5.4.2.2

The IOPS Test Phase consists of one Test Run at the 100% load point with a Measurement Interval of ten (10) minutes. The IOPS Test Phase immediately follows the Sustainability Test Phase without any interruption or manual intervention.

The IOPS Test Run generates the SPC-1 IOPS™ primary metric, which is computed as the I/O Request Throughput for the Measurement Interval of the IOPS Test Run.

The Average Response Time is computed for the IOPS Test Run and cannot exceed 30 milliseconds. If the Average Response Time exceeds the 30 millisecond constraint, the measurement is invalid.

Clause 9.2.4.7.2

For the IOPS Test Phase the FDR shall contain:

1. *I/O Request Throughput Distribution (data and graph).*
2. *A Response Time Frequency Distribution.*
3. *An Average Response Time Distribution.*
4. *The human readable Test Run Results File produced by the Workload Generator.*
5. *A listing or screen image of all input parameters supplied t the Workload Generator.*
6. *The total number of I/O Requests completed in the Measurement Interval as well as the number of I/O Requests with a Response Time less than or equal to 30 milliseconds and the number of I/O Requests with a Response Time greater than 30 milliseconds.*

SPC-1 Workload Generator Input Parameters

The SPC-1 Workload Generator input parameters for the Sustainability, IOPS, and Response Time Ramp Test Runs are documented in "Appendix D: SPC-1 Workload Generator Input Parameters" on Page 56.

IOPS Test Results File

A link to the test results file generated from the IOPS Test Run is listed below.

IOPS Test Results File

IOPS Test Run – I/O Request Throughput Distribution Data

2005 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	12:59:42	13:02:43	0-2	0:03:01
Measurement Interval	13:02:43	13:12:43	3-12	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	100,326.00	59,785.20	12,344.53	28,196.27
1	100,275.70	59,769.95	12,346.93	28,158.82
2	100,345.37	59,798.28	12,339.02	28,208.07
3	100,280.88	59,789.73	12,330.50	28,160.65
4	100,238.45	59,773.85	12,310.23	28,154.37
5	99,873.05	59,520.13	12,297.13	28,055.78
6	100,542.67	59,893.65	12,375.63	28,273.38
7	100,212.87	59,686.20	12,347.05	28,179.62
8	100,189.70	59,701.40	12,327.62	28,160.68
9	100,285.47	59,796.35	12,338.17	28,150.95
10	100,225.33	59,775.83	12,327.47	28,122.03
11	100,198.27	59,717.62	12,322.17	28,158.48
12	99,239.40	59,188.60	12,202.72	27,848.08
Average	100,128.61	59,684.34	12,317.87	28,126.40

IOPS Test Run – I/O Request Throughput Distribution Graph
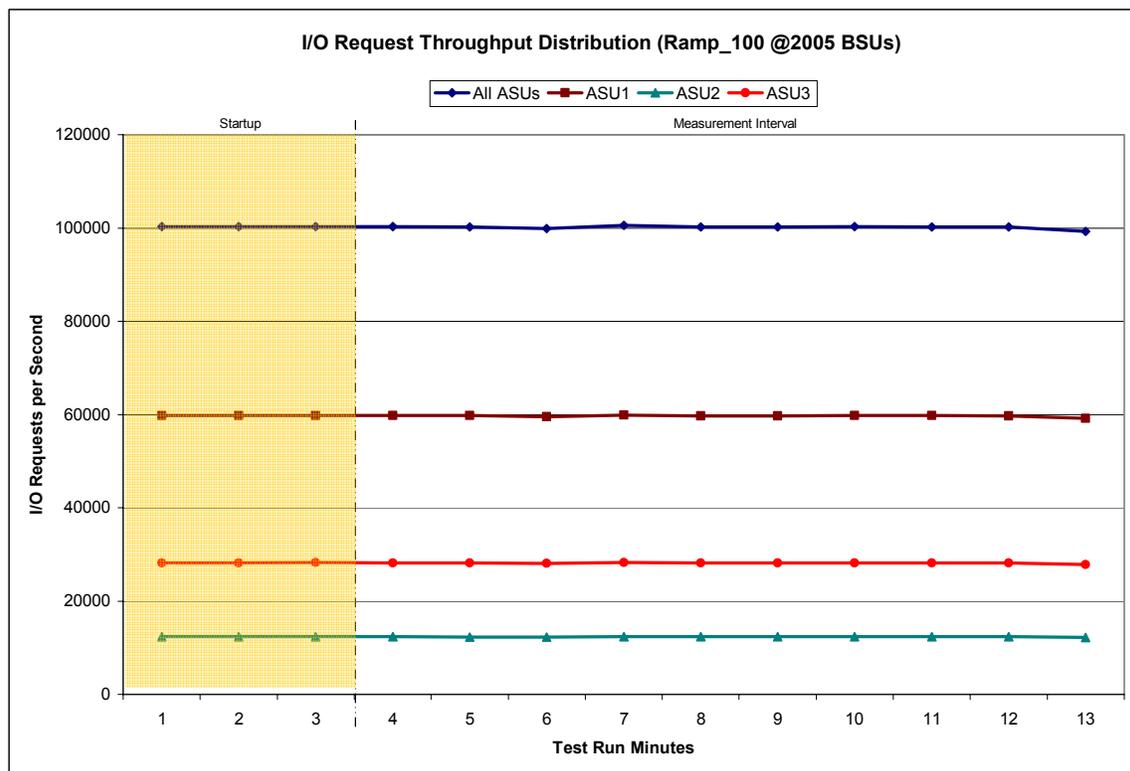
IOPS Test Run – Response Time Frequency Distribution Data

Response Time (ms)	0-0.25	>0.25-0.5	>0.5-0.75	>0.75-1.0	>1.0-1.25	>1.25-1.5	>1.5-1.75	>1.75-2.0
Read	49377	143,548	108,708	92,625	84,674	81,094	80,340	80,698
Write	0	292,638	971,404	1,369,667	1,561,372	1,663,721	1,724,714	1,757,519
All ASUs	49377	436,186	1,080,112	1,462,292	1,646,046	1,744,815	1,805,054	1,838,217
ASU1	46738	298,613	597,360	747,218	811,005	840,577	858,670	867,848
ASU2	2639	46,205	123,005	162,378	180,666	190,546	197,466	200,475
ASU3	0	91,368	359,747	552,696	654,375	713,692	748,918	769,894

| Response Time (ms)	>2.0-2.5	>2.5-3.0	>3.0-3.5	>3.5-4.0	>4.0-4.5	>4.5-5.0	>5.0-6.0	>6.0-7.0
Read	156,450	141,789	120,674	99,237	82,711	73,442	150,601	222,767
Write	3,537,136	3,479,231	3,256,816	2,839,973	2,321,183	1,823,259	2,532,308	1,696,102
All ASUs	3,693,586	3,621,020	3,377,490	2,939,210	2,403,894	1,896,701	2,682,909	1,918,869
ASU1	1,727,761	1,671,797	1,530,747	1,300,123	1,034,987	797,476	1,127,960	865,767
ASU2	401,543	390,924	357,965	304,747	242,044	187,227	259,566	192,624
ASU3	1,564,282	1,558,299	1,488,778	1,334,340	1,126,863	911,998	1,295,383	860,478

Response Time (ms)	>7.0-8.0	>8.0-9.0	>9.0-10.0	>10.0-15.0	>15.0-20.0	>20.0-25.0	>25.0-30.0	>30.0
Read	360,782	522,996	660,277	4,251,368	3,892,820	2,542,690	1,926,876	7,761,284
Write	1,312,168	1,030,897	751,025	1,394,796	357,163	179,881	118,436	413,938
All ASUs	1,672,950	1,553,893	1,411,302	5,646,164	4,249,983	2,722,571	2,045,312	8,175,222
ASU1	845,445	868,559	864,045	4,119,192	3,420,129	2,216,343	1,670,705	6,678,871
ASU2	179,027	176,747	168,020	763,327	635,405	416,445	316,753	1,294,413
ASU3	648,478	508,587	379,237	763,645	194,449	89,783	57,854	201,938

IOPS Test Run –Response Time Frequency Distribution Graph
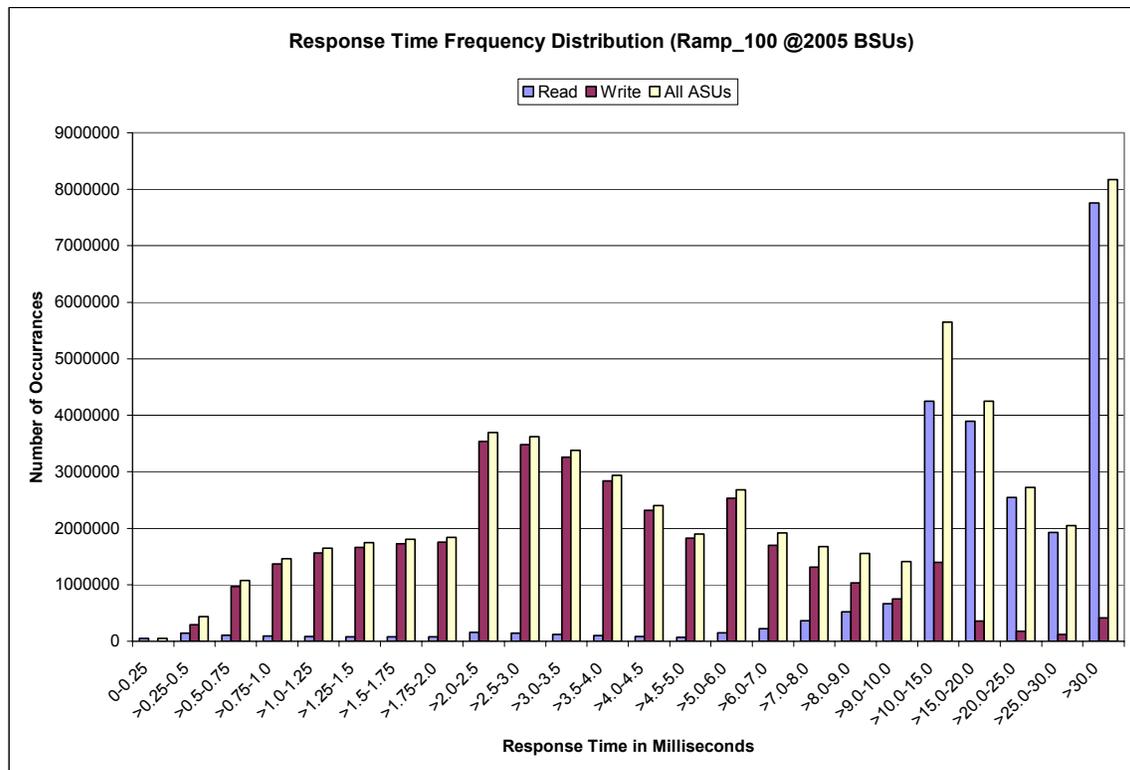
IOPS Test Run – Average Response Time (ms) Distribution Data

2005 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	12:59:42	13:02:43	0-2	0:03:01
Measurement Interval	13:02:43	13:12:43	3-12	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	12.32	15.34	14.54	4.95
1	14.08	18.04	17.24	4.31
2	14.41	18.40	17.46	4.62
3	15.77	19.90	18.84	5.68
4	15.01	19.44	18.20	4.21
5	17.55	22.39	21.02	5.74
6	17.59	22.39	21.22	5.83
7	15.17	19.61	18.69	4.23
8	14.23	18.27	17.22	4.35
9	14.33	18.42	17.36	4.32
10	15.09	19.39	18.28	4.56
11	15.47	19.94	19.19	4.38
12	26.60	32.27	31.05	12.59
Average	16.68	21.20	20.11	5.59

IOPS Test Run – Average Response Time (ms) Distribution Graph
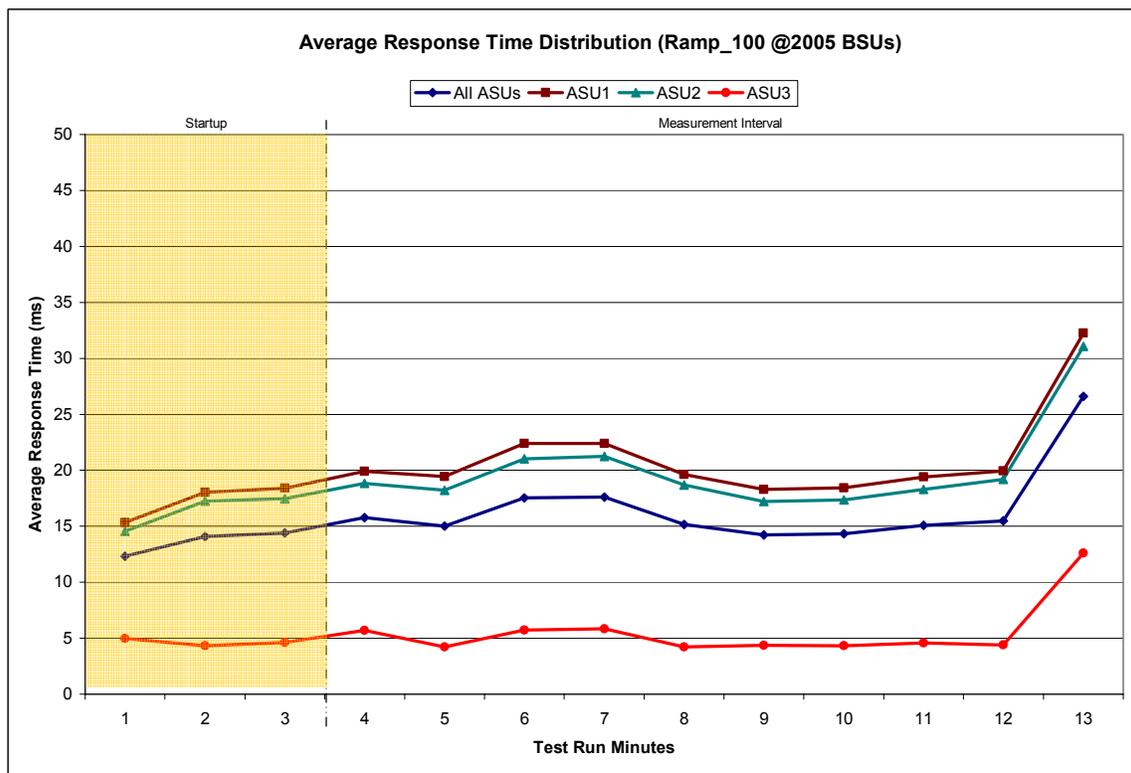
IOPS Test Run – I/O Request Information

I/O Requests Completed in the Measurement Interval	I/O Requests Completed with Response Time = or < 30 ms	I/O Requests Completed with Response Time > 30 ms
60,073,175	51,897,953	8,175,222

IOPS Test Run – Measured Intensity Multiplier and Coefficient of Variation

	ASU1-1	ASU1-2	ASU1-3	ASU1-4	ASU2-1	ASU2-2	ASU2-3	ASU3-1
IM	0.0350	0.2810	0.0700	0.2100	0.0180	0.0700	0.0350	0.2810
MIM	0.0350	0.2811	0.0700	0.2099	0.0180	0.0700	0.0350	0.2809
COV	0.002	0.001	0.001	0.001	0.003	0.001	0.002	0.001

IM – Intensity Multiplier: *The ratio of I/Os for each I/O stream relative to the total I/Os for all I/O streams (ASU1-1 – ASU3-1) as required by the benchmark specification.*

MIM – Measured Intensity Multiplier: *The Measured Intensity Multiplier represents the ratio of measured I/Os for each I/O stream relative to the total I/Os measured for all I/O streams (ASU1-1 – ASU3-1). This value may differ from the corresponding Expected Intensity Multiplier by no more than 5%.*

COV – Coefficient of Variation: *This measure of variation for the Measured Intensity Multiplier cannot exceed 0.2.*

Primary Metrics Test – Response Time Ramp Test Phase

Clause 5.4.2.3

The Response Time Ramp Test Phase consists of five Test Runs, one each at 95%, 90%, 80%, 50%, and 10% of the load point (100%) used to generate the SPC-1 IOPS™ primary metric. Each of the five Test Runs has a Measurement Interval of ten (10) minutes. The Response Time Ramp Test Phase immediately follows the IOPS Test Phase without any interruption or manual intervention.

The five Response Time Ramp Test Runs, in conjunction with the IOPS Test Run (100%), demonstrate the relationship between Average Response Time and I/O Request Throughput for the Tested Storage Configuration (TSC) as illustrated in the response time/throughput curve on page 11.

In addition, the Average Response Time measured during the 10% Test Run is the value for the SPC-1 LRT™ primary metric. That value represents the Average Response Time of a lightly loaded TSC.

Clause 9.2.4.7.3

The following content shall appear in the FDR for the Response Time Ramp Phase:

1. *A Response Time Ramp Distribution.*
2. *The human readable Test Run Results File produced by the Workload Generator for each Test Run within the Response Time Ramp Test Phase.*
3. *For the 10% Load Level Test Run (SPC-1 LRT™ metric) an Average Response Time Distribution.*
4. *A listing or screen image of all input parameters supplied to the Workload Generator.*

SPC-1 Workload Generator Input Parameters

The SPC-1 Workload Generator input parameters for the Sustainability, IOPS, and Response Time Ramp Test Runs are documented in "Appendix D: SPC-1 Workload Generator Input Parameters" on Page 56.

Response Time Ramp Test Results File

A link to each test result file generated from each Response Time Ramp Test Run list listed below.

95% Load Level

90% Load Level

80% Load Level

50% Load Level

10% Load Level

Response Time Ramp Distribution (IOPS) Data

The five Test Runs that comprise the Response Time Ramp Phase are executed at 95%, 90%, 80%, 50%, and 10% of the Business Scaling Unit (BSU) load level used to produce the SPC-1 IOPS™ primary metric. The 100% BSU load level is included in the following Response Time Ramp data tables and graphs for completeness.

100% Load Level - 2005 BSUs	Start	Stop	Interval	Duration	95% Load Level - 1904 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	12:59:42	13:02:43	0-2	0:03:01	Start-Up/Ramp-Up	13:13:12	13:16:13	0-2	0:03:01
Measurement Interval	13:02:43	13:12:43	3-12	0:10:00	Measurement Interval	13:16:13	13:26:13	3-12	0:10:00
(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3	*(60 second intervals)*	All ASUs	ASU-1	ASU-2	ASU-3
0	100,326.00	59,785.20	12,344.53	28,196.27	0	95,279.25	56,800.85	11,732.43	26,745.97
1	100,275.70	59,769.95	12,346.93	28,158.82	1	95,140.42	56,737.17	11,705.13	26,698.12
2	100,345.37	59,798.28	12,339.02	28,208.07	2	95,193.45	56,693.62	11,726.53	26,773.30
3	100,280.88	59,789.73	12,330.50	28,160.65	3	95,250.13	56,761.63	11,726.62	26,761.88
4	100,238.45	59,773.85	12,310.23	28,154.37	4	95,208.02	56,761.52	11,710.73	26,735.77
5	99,873.05	59,520.13	12,297.13	28,055.78	5	95,279.52	56,791.78	11,727.42	26,760.32
6	100,542.67	59,893.65	12,375.63	28,273.38	6	95,176.67	56,747.42	11,710.78	26,718.47
7	100,212.87	59,686.20	12,347.05	28,179.62	7	95,121.82	56,713.98	11,701.62	26,706.22
8	100,189.70	59,701.40	12,327.62	28,160.68	8	95,174.33	56,716.15	11,710.32	26,747.87
9	100,285.47	59,796.35	12,338.17	28,150.95	9	95,251.48	56,743.47	11,715.05	26,792.97
10	100,225.33	59,775.83	12,327.47	28,122.03	10	95,193.70	56,726.28	11,730.95	26,736.47
11	100,198.27	59,717.62	12,322.17	28,158.48	11	95,118.50	56,691.13	11,699.53	26,727.83
12	99,239.40	59,188.60	12,202.72	27,848.08	12	95,226.03	56,743.97	11,715.03	26,767.03
Average	100,128.61	59,684.34	12,317.87	28,126.40	Average	95,200.02	56,739.73	11,714.81	26,745.48

90% Load Level - 1804 BSUs	Start	Stop	Interval	Duration	80% Load Level - 1604 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	13:26:39	13:29:40	0-2	0:03:01	Start-Up/Ramp-Up	13:40:05	13:43:06	0-2	0:03:01
Measurement Interval	13:29:40	13:39:40	3-12	0:10:00	Measurement Interval	13:43:06	13:53:06	3-12	0:10:00
(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3	*(60 second intervals)*	All ASUs	ASU-1	ASU-2	ASU-3
0	90,313.88	53,857.93	11,094.58	25,361.37	0	80,223.73	47,837.67	9,869.15	22,516.92
1	90,304.17	53,829.63	11,110.03	25,364.50	1	80,227.63	47,790.08	9,874.13	22,563.42
2	90,196.48	53,761.52	11,079.42	25,355.55	2	80,193.55	47,791.15	9,880.90	22,521.50
3	90,234.07	53,787.13	11,097.27	25,349.67	3	80,279.33	47,863.85	9,869.78	22,545.70
4	90,255.40	53,800.48	11,078.12	25,376.80	4	80,219.63	47,800.75	9,869.35	22,549.53
5	90,182.38	53,710.68	11,098.42	25,373.28	5	80,240.12	47,833.33	9,870.57	22,536.22
6	90,100.22	53,707.28	11,079.25	25,313.68	6	80,187.88	47,770.08	9,868.37	22,549.43
7	90,163.70	53,709.80	11,101.38	25,352.52	7	80,228.80	47,822.98	9,852.82	22,553.00
8	90,250.58	53,814.15	11,083.63	25,352.80	8	80,264.00	47,814.17	9,871.78	22,578.05
9	90,232.12	53,774.97	11,102.48	25,354.67	9	80,253.48	47,842.63	9,869.85	22,541.00
10	90,219.35	53,766.93	11,097.67	25,354.75	10	80,174.57	47,755.95	9,874.43	22,544.18
11	90,212.10	53,780.90	11,094.62	25,336.58	11	80,174.75	47,806.92	9,850.78	22,517.05
12	90,119.33	53,687.72	11,089.42	25,342.20	12	80,263.77	47,791.50	9,869.60	22,602.67
Average	90,196.93	53,754.01	11,092.23	25,350.70	Average	80,228.63	47,810.22	9,866.73	22,551.68

| 50% Load Level - 1002 BSUs	Start	Stop	Interval	Duration	10% Load Level - 200 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	13:53:27	13:56:28	0-2	0:03:01	Start-Up/Ramp-Up	14:06:45	14:09:46	0-2	0:03:01
Measurement Interval	13:56:28	14:06:28	3-12	0:10:00	Measurement Interval	14:09:46	14:19:46	3-12	0:10:00
(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3	*(60 second intervals)*	All ASUs	ASU-1	ASU-2	ASU-3
0	50,133.07	29,855.05	6,189.50	14,088.52	0	10,015.67	5,972.20	1,230.63	2,812.83
1	50,129.27	29,855.78	6,179.07	14,094.42	1	9,998.88	5,970.72	1,225.12	2,803.05
2	50,075.47	29,860.27	6,148.57	14,066.63	2	10,001.72	5,949.95	1,231.75	2,820.02
3	50,059.25	29,845.02	6,165.37	14,048.87	3	10,012.00	5,956.83	1,236.57	2,818.60
4	50,113.45	29,853.72	6,157.22	14,102.52	4	9,975.98	5,946.97	1,224.37	2,804.65
5	50,142.58	29,889.50	6,161.37	14,091.72	5	10,022.35	5,977.47	1,231.35	2,813.53
6	50,084.58	29,855.27	6,170.27	14,059.05	6	9,980.95	5,955.62	1,226.32	2,799.02
7	50,121.12	29,901.03	6,160.52	14,059.57	7	10,010.60	5,968.07	1,238.15	2,804.38
8	50,081.87	29,839.83	6,169.90	14,072.13	8	10,004.40	5,967.98	1,232.08	2,804.33
9	50,112.45	29,871.40	6,160.25	14,080.80	9	9,998.43	5,960.43	1,236.38	2,801.62
10	50,120.80	29,855.68	6,162.98	14,102.13	10	10,019.10	5,971.53	1,234.48	2,813.08
11	50,110.70	29,869.23	6,160.78	14,080.68	11	10,002.08	5,960.53	1,234.43	2,807.12
12	50,125.53	29,882.62	6,169.10	14,073.82	12	9,996.57	5,957.28	1,228.53	2,810.75
Average	50,107.23	29,866.33	6,163.78	14,077.13	Average	10,002.25	5,962.27	1,232.27	2,807.71

Response Time Ramp Distribution (IOPS) Graph

SPC-1 LRT™ Average Response Time (ms) Distribution Data

200 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	14:06:45	14:09:46	0-2	0:03:01
Measurement Interval	14:09:46	14:19:46	3-12	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	3.18	4.44	3.29	0.48
1	2.05	2.81	2.04	0.45
2	2.04	2.78	2.04	0.46
3	3.95	5.56	4.10	0.48
4	3.22	4.46	3.49	0.46
5	2.37	3.27	2.43	0.45
6	2.54	3.50	2.53	0.50
7	3.80	5.36	3.79	0.48
8	2.06	2.82	2.06	0.45
9	2.35	3.24	2.36	0.46
10	3.51	4.89	3.72	0.48
11	2.67	3.70	2.75	0.45
12	2.06	2.82	2.06	0.45
Average	2.85	3.96	2.93	0.47

SPC-1 LRT™ Average Response Time (ms) Distribution Graph
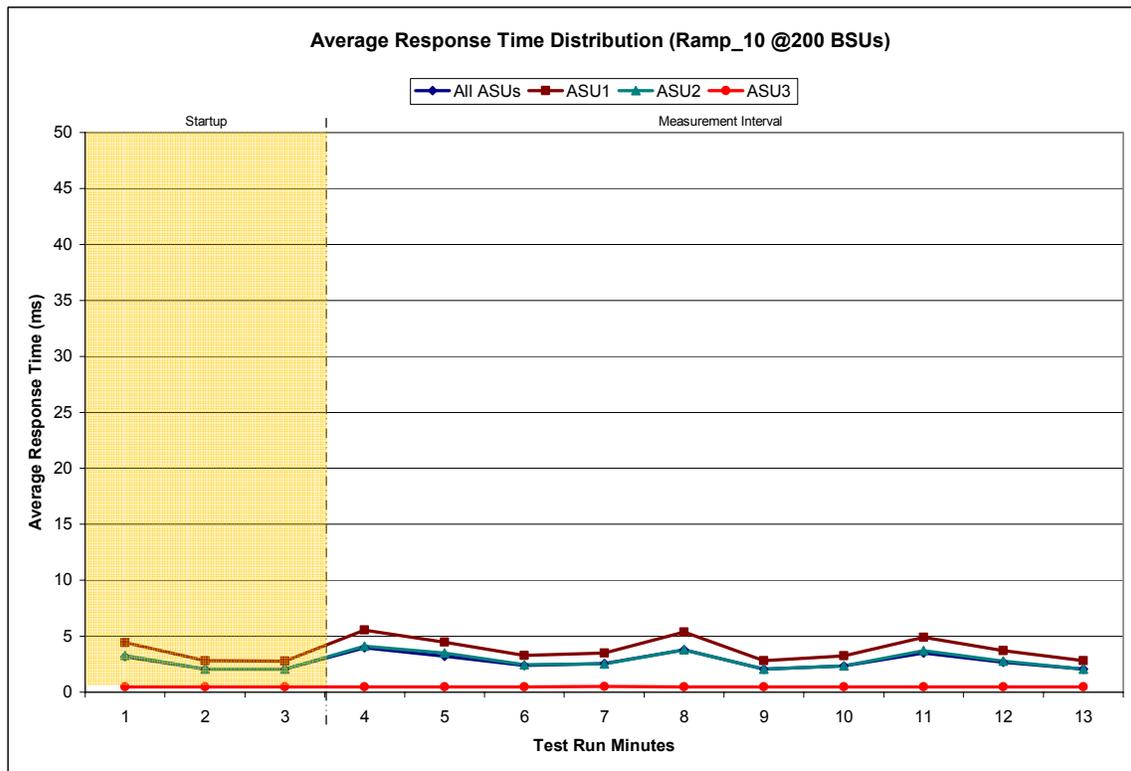
SPC-1 LRT™ (10%) – Measured Intensity Multiplier and Coefficient of Variation

	ASU1-1	ASU1-2	ASU1-3	ASU1-4	ASU2-1	ASU2-2	ASU2-3	ASU3-1
IM	*0.0350*	*0.2810*	*0.0700*	*0.2100*	*0.0180*	*0.0700*	*0.0350*	*0.2810*
MIM	0.0351	0.2812	0.0701	0.2098	0.0180	0.0701	0.0351	0.2807
COV	0.007	0.001	0.003	0.002	0.007	0.006	0.006	0.002

IM – Intensity Multiplier: *The ratio of I/Os for each I/O stream relative to the total I/Os for all I/O streams (ASU1-1 – ASU3-1) as required by the benchmark specification.*

MIM – Measured Intensity Multiplier: *The Measured Intensity Multiplier represents the ratio of measured I/Os for each I/O stream relative to the total I/Os measured for all I/O streams (ASU1-1 – ASU3-1). This value may differ from the corresponding Expected Intensity Multiplier by no more than 5%.*

COV – Coefficient of Variation: *This measure of variation for the Measured Intensity Multiplier cannot exceed 0.2.*

Repeatability Test

Clause 5.4.3

The Repeatability Test demonstrates the repeatability and reproducibility of the SPC-1 IOPS™ and SPC-1 LRT™ primary metrics generated in earlier Test Runs.

There are two identical Repeatability Test Phases. Each Test Phase contains two Test Runs. Each of the Test Runs will have a Measurement Interval of no less than ten (10) minutes. The two Test Runs in each Test Phase will be executed without interruption or any type of manual intervention.

The first Test Run in each Test Phase is executed at the 10% load point. The Average Response Time from each of the Test Runs is compared to the SPC-1 LRT™ primary metric. Each Average Response Time value must be less than the SPC-1 LRT™ primary metric plus 5%.

The second Test Run in each Test Phase is executed at the 100% load point. The I/O Request Throughput from the Test Runs is compared to the SPC-1 IOPS™ primary metric. Each I/O Request Throughput value must be greater than the SPC-1 IOPS™ primary metric minus 5%. In addition, the Average Response Time for each Test Run cannot exceed 30 milliseconds.

If any of the above constraints are not met, the benchmark measurement is invalid.

Clause 9.2.4.7.3

The following content shall appear in the FDR for each Test Run in the two Repeatability Test Phases:

1. *A table containing the results of the two Repeatability Test Phases. The content, appearance, and format of the table are specified in Table 9-11.*
2. *An I/O Request Throughput Distribution (data and graph).*
3. *An Average Response Time Distribution (data and graph).*
4. *The human readable Test Run Results File produced by the Workload Generator.*
5. *A listing or screen image of all input parameters supplied to the Workload Generator.*

SPC-1 Workload Generator Input Parameters

The SPC-1 Workload Generator input parameters for the Repeatability Test Runs are documented in "Appendix D: SPC-1 Workload Generator Input Parameters" on Page 56.

Repeatability Test Results File

The values for the SPC-1 IOPS™, SPC-1 LRT™, and the Repeatability Test measurements are listed below.

	SPC-1 IOPS™	SPC-1 LRT™
Primary Metrics	*100,128.61*	*2.85*
Repeatability Test Phase 1	100,263.16	2.75
Repeatability Test Phase 2	100,252.05	2.70

A link to the test result file generated from each Repeatability Test Run list is listed below.

Repeatability Test Phase 1, Test Run 1 (LRT)
**Repeatability Test Phase 1, Test Run 2 (IOPS)**
Repeatability Test Phase 2, Test Run 1 (LRT)
Repeatability Test Phase 2, Test Run 2 (IOPS)

Repeatability 1 LRT – I/O Request Throughput Distribution Data

| 200 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	14:20:32	14:23:32	0-2	0:03:00
Measurement Interval	14:23:32	14:33:32	3-12	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	10,030.32	5,982.33	1,239.18	2,808.80
1	10,006.88	5,964.55	1,231.00	2,811.33
2	10,000.53	5,957.57	1,231.13	2,811.83
3	9,977.78	5,937.00	1,227.90	2,812.88
4	9,979.08	5,940.13	1,228.80	2,810.15
5	9,990.37	5,955.38	1,225.83	2,809.15
6	10,002.63	5,966.83	1,229.68	2,806.12
7	10,020.93	5,964.32	1,241.45	2,815.17
8	10,017.37	5,979.25	1,229.47	2,808.65
9	10,008.78	5,976.57	1,228.32	2,803.90
10	10,005.38	5,966.48	1,229.38	2,809.52
11	9,982.03	5,943.48	1,233.72	2,804.83
12	9,994.63	5,959.07	1,226.63	2,808.93
Average	9,997.90	5,958.85	1,230.12	2,808.93

Repeatability 1 LRT – I/O Request Throughput Distribution Graph
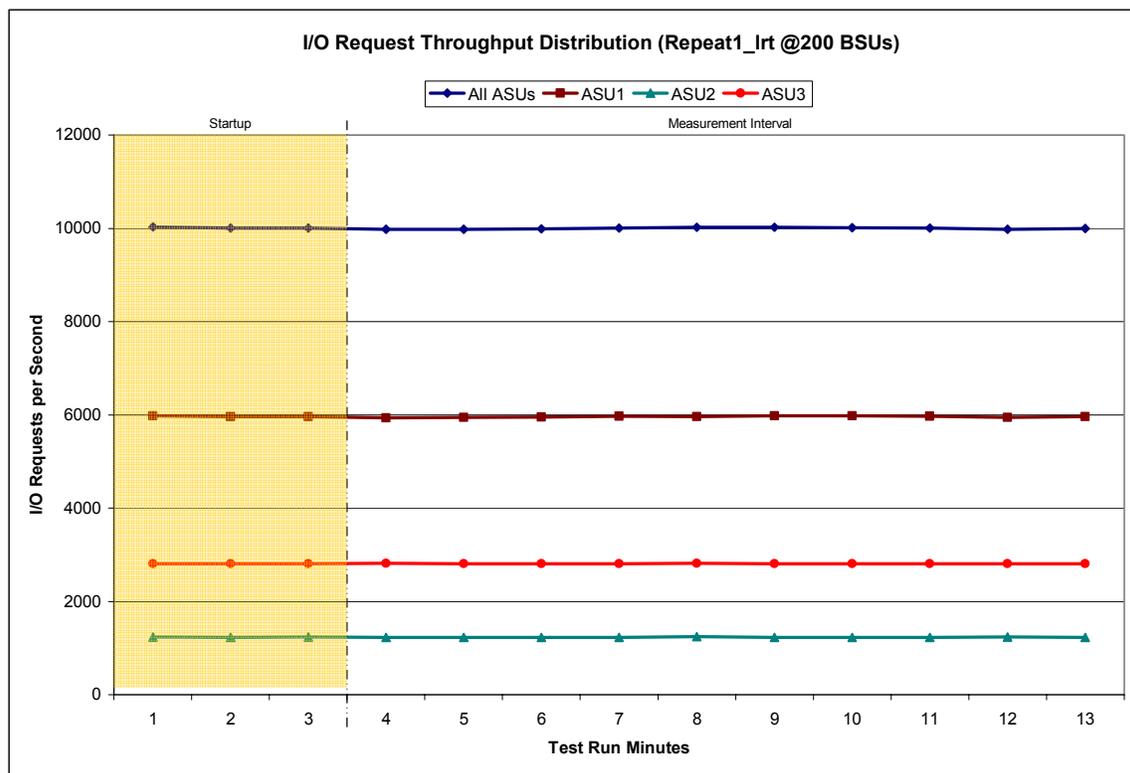
Repeatability 1 LRT –Average Response Time (ms) Distribution Data

| 200 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	14:20:32	14:23:32	0-2	0:03:00
Measurement Interval	14:23:32	14:33:32	3-12	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	2.95	4.06	3.13	0.48
1	3.89	5.44	4.17	0.47
2	2.10	2.83	2.10	0.53
3	2.56	3.54	2.62	0.47
4	3.11	4.34	3.16	0.48
5	2.73	3.78	2.78	0.46
6	2.05	2.80	2.07	0.45
7	2.59	3.58	2.64	0.47
8	3.81	5.34	3.97	0.48
9	2.05	2.80	2.02	0.45
10	2.61	3.61	2.66	0.46
11	3.13	4.36	3.23	0.48
12	2.82	3.91	2.94	0.47
Average	2.75	3.81	2.81	0.47

Repeatability 1 LRT –Average Response Time (ms) Distribution Graph
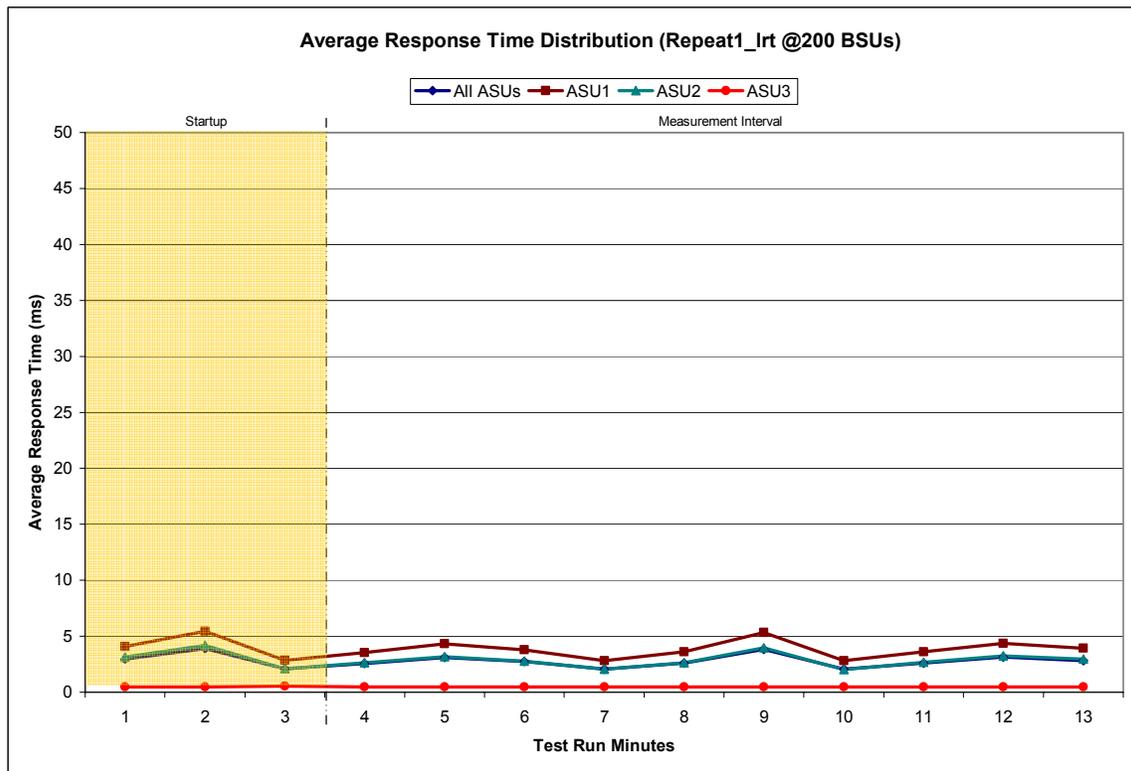
Repeatability 1 IOPS – I/O Request Throughput Distribution Data

2005 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	14:34:05	14:37:06	0-2	0:03:01
Measurement Interval	14:37:06	14:47:06	3-12	0:10:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	100,298.38	59,752.08	12,372.08	28,174.22
1	100,293.28	59,770.68	12,359.87	28,162.73
2	100,255.73	59,783.52	12,328.87	28,143.35
3	100,335.35	59,842.65	12,345.13	28,147.57
4	100,273.75	59,750.65	12,334.08	28,189.02
5	100,264.55	59,780.18	12,324.15	28,160.22
6	100,206.97	59,723.80	12,319.48	28,163.68
7	100,189.38	59,683.55	12,343.28	28,162.55
8	100,324.15	59,835.60	12,323.78	28,164.77
9	100,247.78	59,787.78	12,287.95	28,172.05
10	100,280.18	59,749.52	12,325.52	28,205.15
11	100,288.05	59,764.10	12,349.57	28,174.38
12	100,221.42	59,782.47	12,294.43	28,144.52
Average	100,263.16	59,770.03	12,324.74	28,168.39

## Repeatability 1 IOPS – I/O Request Throughput Distribution Graph
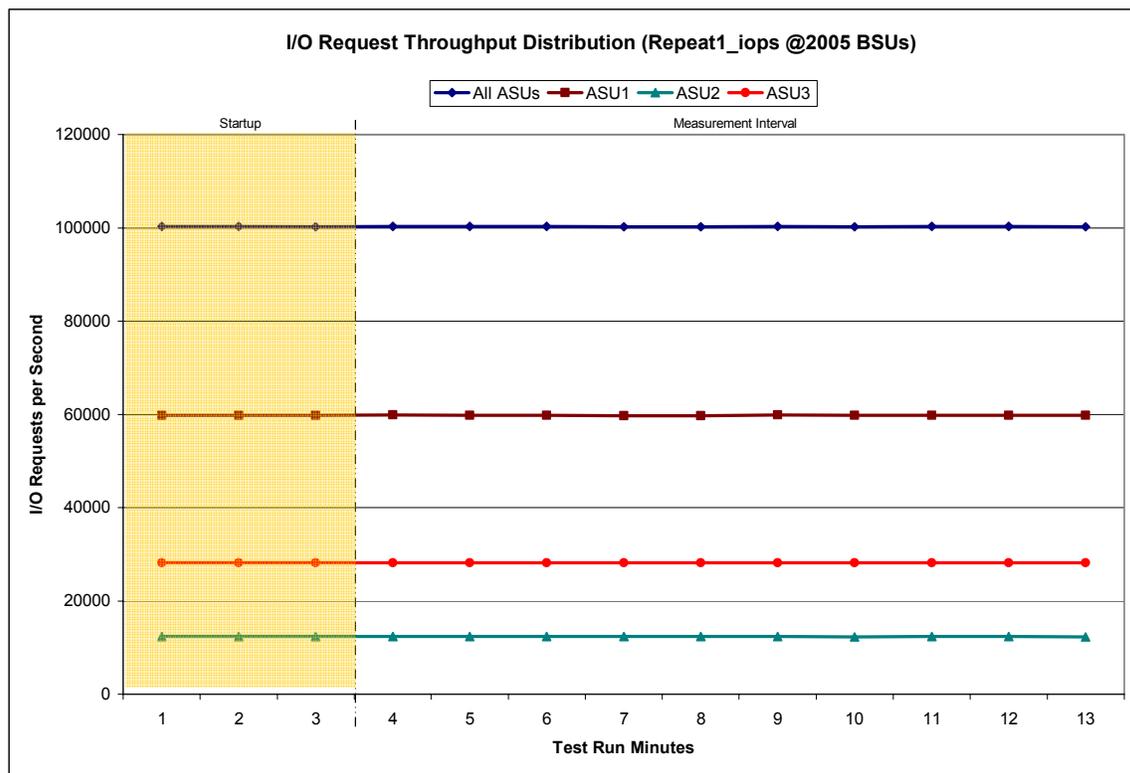
Repeatability 1 IOPS –Average Response Time (ms) Distribution Data

2005 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	14:34:05	14:37:06	0-2	0:03:01
Measurement Interval	14:37:06	14:47:06	3-12	0:10:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	13.67	17.09	16.28	5.27
1	13.67	17.59	16.72	4.00
2	14.00	18.01	17.02	4.17
3	14.41	18.52	17.54	4.31
4	14.49	18.61	17.53	4.44
5	14.91	19.14	18.03	4.55
6	14.62	18.68	17.64	4.70
7	14.67	18.79	17.70	4.63
8	14.41	18.38	17.47	4.64
9	16.12	20.34	19.42	5.74
10	14.81	18.94	17.96	4.69
11	14.90	19.11	18.04	4.59
12	14.78	19.00	17.96	4.44
Average	14.81	18.95	17.93	4.67

## Repeatability 1 IOPS –Average Response Time (ms) Distribution Graph
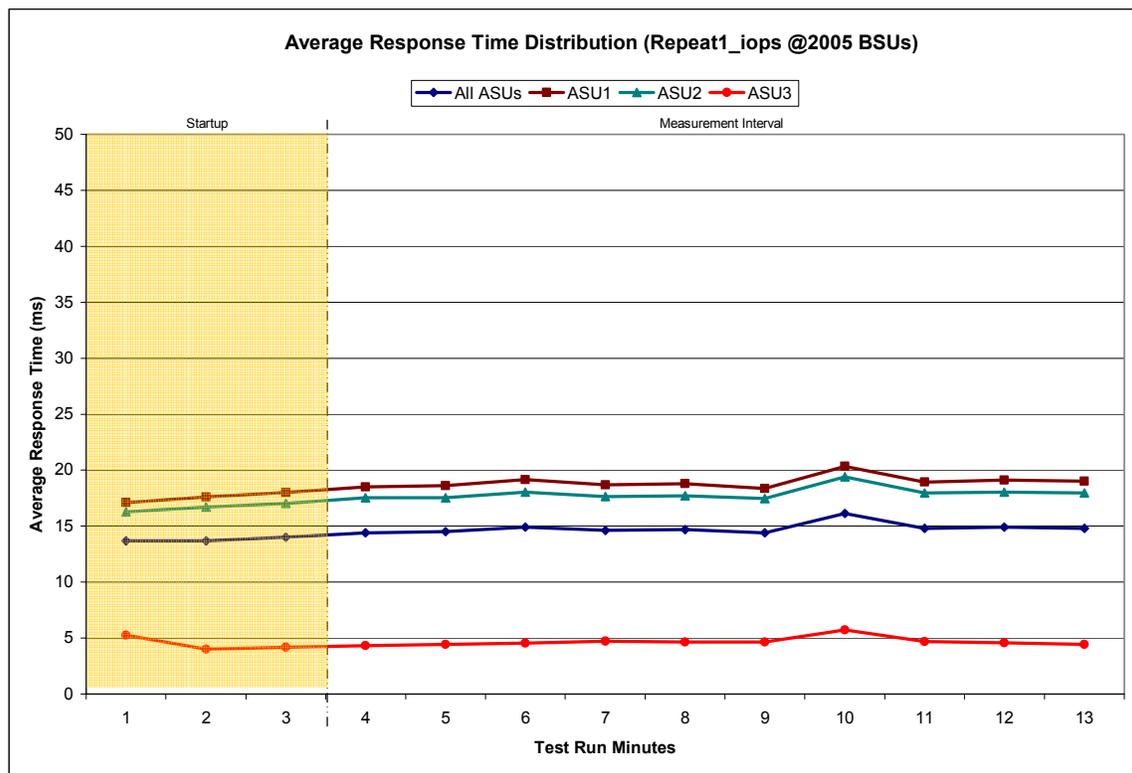
Repeatability 2 LRT – I/O Request Throughput Distribution Data

| 200 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	14:47:52	14:50:52	0-2	0:03:00
Measurement Interval	14:50:52	15:00:52	3-12	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	10,004.73	5,965.82	1,222.52	2,816.40
1	9,988.05	5,950.57	1,225.37	2,812.12
2	9,999.82	5,967.85	1,228.28	2,803.68
3	9,987.30	5,947.72	1,231.62	2,807.97
4	10,007.42	5,967.83	1,233.62	2,805.97
5	9,994.98	5,962.45	1,228.30	2,804.23
6	10,002.20	5,962.70	1,231.18	2,808.32
7	9,983.95	5,953.72	1,229.82	2,800.42
8	9,993.07	5,955.13	1,228.07	2,809.87
9	10,000.98	5,957.38	1,239.28	2,804.32
10	9,990.92	5,950.92	1,229.73	2,810.27
11	9,996.32	5,949.43	1,233.60	2,813.28
12	10,011.38	5,963.42	1,234.07	2,813.90
Average	9,996.85	5,957.07	1,231.93	2,807.85

Repeatability 2 LRT – I/O Request Throughput Distribution Graph
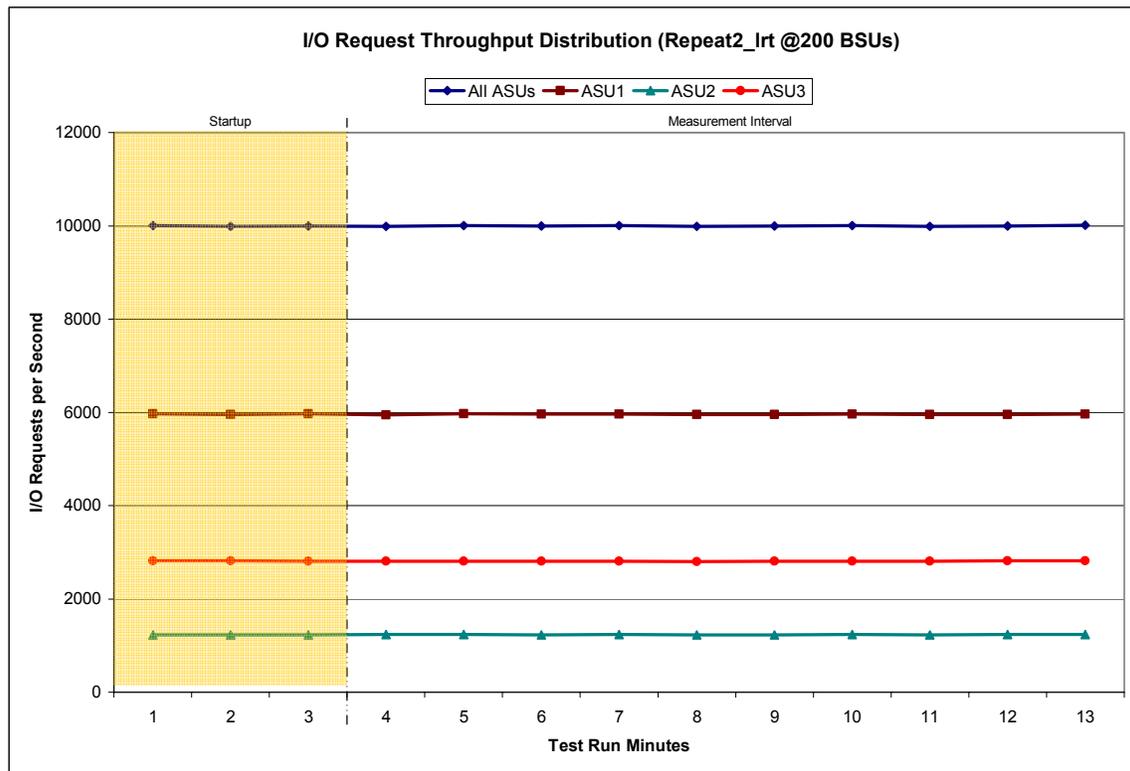
Repeatability 2 LRT –Average Response Time (ms) Distribution Data

| 200 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	14:47:52	14:50:52	0-2	0:03:00
Measurement Interval	14:50:52	15:00:52	3-12	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	1.95	2.66	1.90	0.45
1	3.30	4.58	3.61	0.46
2	3.29	4.59	3.44	0.47
3	2.28	3.14	2.27	0.46
4	3.16	4.41	3.23	0.46
5	2.27	3.08	2.28	0.56
6	3.35	4.68	3.49	0.46
7	2.23	3.05	2.25	0.46
8	3.46	4.84	3.63	0.47
9	2.09	2.86	2.08	0.46
10	2.67	3.70	2.72	0.47
11	2.76	3.82	2.87	0.47
12	2.77	3.87	2.75	0.47
Average	2.70	3.74	2.76	0.47

Repeatability 2 LRT –Average Response Time (ms) Distribution Graph
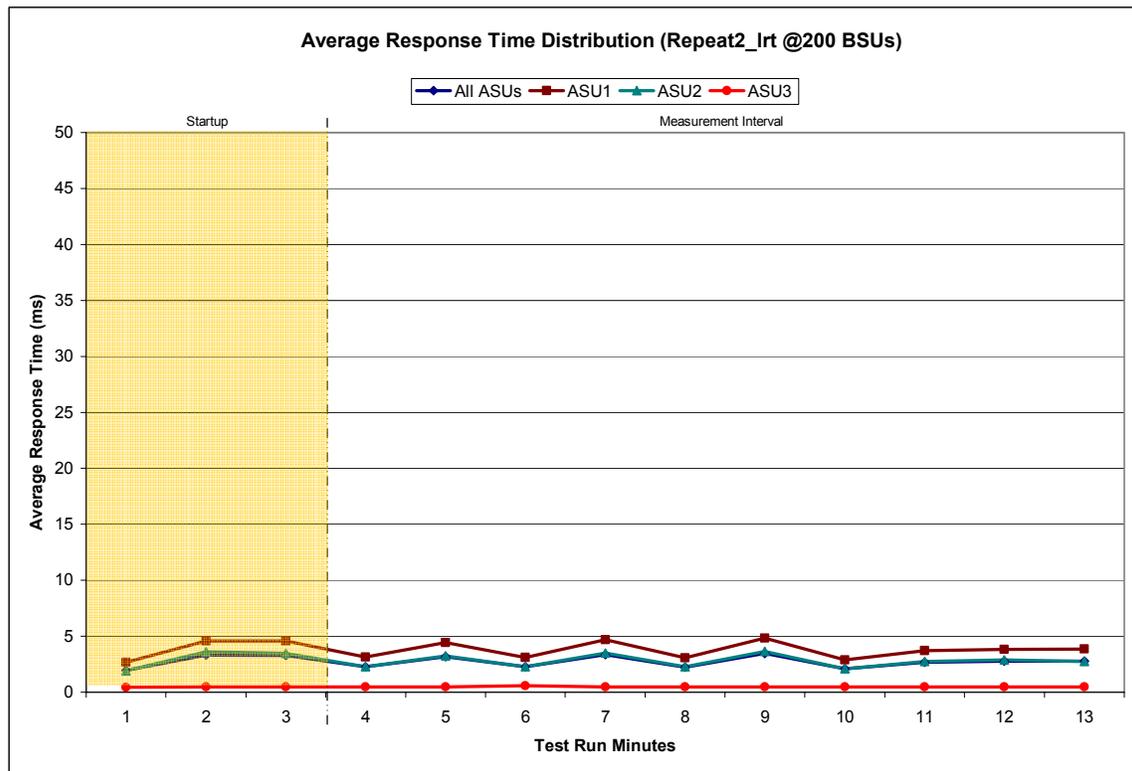
Repeatability 2 IOPS – I/O Request Throughput Distribution Data

| 2005 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	15:01:25	15:04:26	0-2	0:03:01
Measurement Interval	15:04:26	15:14:26	3-12	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	100,247.95	59,756.67	12,336.08	28,155.20
1	100,248.85	59,755.67	12,326.37	28,166.82
2	100,269.52	59,791.38	12,345.98	28,132.15
3	100,294.00	59,780.63	12,341.93	28,171.43
4	100,203.10	59,725.87	12,327.95	28,149.28
5	100,255.90	59,757.23	12,335.80	28,162.87
6	100,246.87	59,719.25	12,337.67	28,189.95
7	100,237.68	59,756.35	12,323.10	28,158.23
8	100,273.18	59,737.45	12,323.73	28,212.00
9	100,268.15	59,740.10	12,335.33	28,192.72
10	100,284.77	59,776.70	12,326.68	28,181.38
11	99,861.22	59,473.15	12,299.97	28,088.10
12	100,595.62	59,942.75	12,360.20	28,292.67
Average	100,252.05	59,740.95	12,331.24	28,179.86

Repeatability 2 IOPS – I/O Request Throughput Distribution Graph
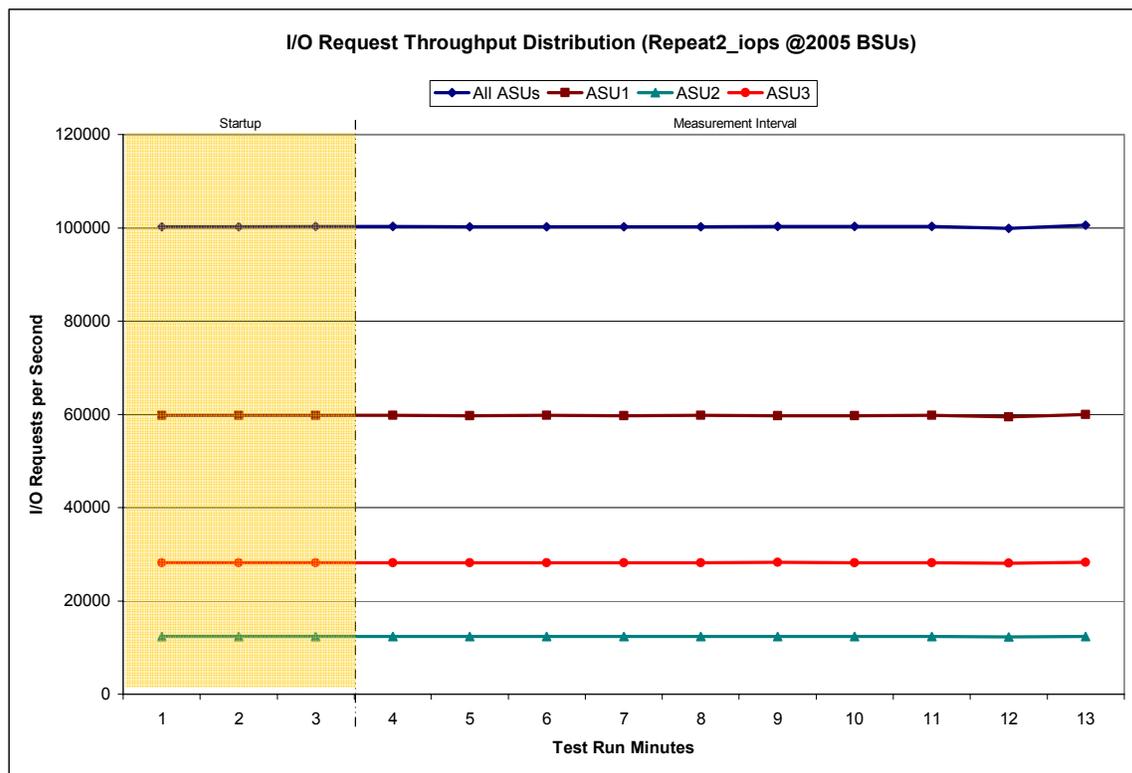
Repeatability 2 IOPS –Average Response Time (ms) Distribution Data

2005 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	15:01:25	15:04:26	0-2	0:03:01
Measurement Interval	15:04:26	15:14:26	3-12	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	14.17	17.47	16.67	6.06
1	14.70	18.58	17.58	5.22
2	13.90	17.77	16.85	4.39
3	14.22	18.18	17.18	4.52
4	14.60	18.74	17.89	4.36
5	17.22	21.86	21.01	5.74
6	17.22	21.99	21.41	5.28
7	24.20	29.81	28.82	10.28
8	15.18	19.54	18.30	4.58
9	15.77	20.27	19.21	4.75
10	23.53	28.54	27.54	11.15
11	21.49	26.87	25.65	8.27
12	20.43	25.37	24.27	8.28
Average	18.39	23.12	22.13	6.72

Repeatability 2 IOPS –Average Response Time (ms) Distribution Graph
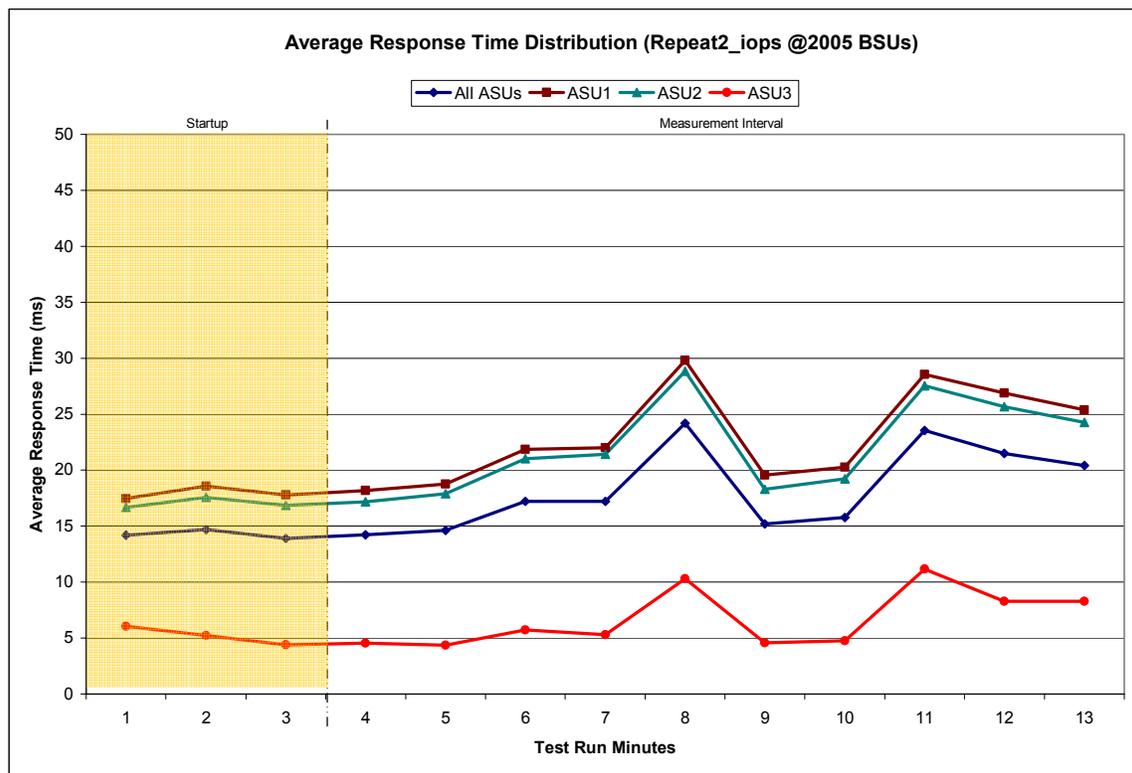
Repeatability 1 (LRT)
Measured Intensity Multiplier and Coefficient of Variation

	ASU1-1	ASU1-2	ASU1-3	ASU1-4	ASU2-1	ASU2-2	ASU2-3	ASU3-1
IM	*0.0350*	*0.2810*	*0.0700*	*0.2100*	*0.0180*	*0.0700*	*0.0350*	*0.2810*
MIM	0.0351	0.2809	0.0700	0.2101	0.0180	0.0700	0.0350	0.2810
COV	0.009	0.001	0.004	0.003	0.007	0.005	0.008	0.002

IM – Intensity Multiplier: *The ratio of I/Os for each I/O stream relative to the total I/Os for all I/O streams (ASU1-1 – ASU3-1) as required by the benchmark specification.*

MIM – Measured Intensity Multiplier: *The Measured Intensity Multiplier represents the ratio of measured I/Os for each I/O stream relative to the total I/Os measured for all I/O streams (ASU1-1 – ASU3-1). This value may differ from the corresponding Expected Intensity Multiplier by no more than 5%.*

COV – Coefficient of Variation: *This measure of variation for the Measured Intensity Multiplier cannot exceed 0.2.*

Repeatability 1 (IOPS)
Measured Intensity Multiplier and Coefficient of Variation

	ASU1-1	ASU1-2	ASU1-3	ASU1-4	ASU2-1	ASU2-2	ASU2-3	ASU3-1
IM	*0.0350*	*0.2810*	*0.0700*	*0.2100*	*0.0180*	*0.0700*	*0.0350*	*0.2810*
MIM	0.0351	0.2811	0.0701	0.2100	0.0180	0.0699	0.0350	0.2809
COV	0.003	0.001	0.001	0.001	0.004	0.001	0.003	0.001

Repeatability 2 (LRT)
Measured Intensity Multiplier and Coefficient of Variation

	ASU1-1	ASU1-2	ASU1-3	ASU1-4	ASU2-1	ASU2-2	ASU2-3	ASU3-1
IM	*0.0350*	*0.2810*	*0.0700*	*0.2100*	*0.0180*	*0.0700*	*0.0350*	*0.2810*
MIM	0.0351	0.2809	0.0698	0.2101	0.0181	0.0700	0.0351	0.2809
COV	0.006	0.002	0.003	0.003	0.006	0.005	0.007	0.001

Repeatability 2 (IOPS)
Measured Intensity Multiplier and Coefficient of Variation

	ASU1-1	ASU1-2	ASU1-3	ASU1-4	ASU2-1	ASU2-2	ASU2-3	ASU3-1
IM	*0.0350*	*0.2810*	*0.0700*	*0.2100*	*0.0180*	*0.0700*	*0.0350*	*0.2810*
MIM	0.0350	0.2809	0.0700	0.2101	0.0180	0.0700	0.0350	0.2811
COV	0.001	0.001	0.001	0.001	0.002	0.001	0.003	0.001

Data Persistence Test

Clause 6

The Data Persistence Test demonstrates the Tested Storage Configuration (TSC):

- *Is capable of maintain data integrity across a power cycle.*

- *Ensures the transfer of data between Logical Volumes and host systems occurs without corruption or loss.*

The SPC-1 Workload Generator will write 16 block I/O requests at random over the total Addressable Storage Capacity of the TSC for ten (10) minutes at a minimum of 25% of the load used to generate the SPC-1 IOP™ primary metric. The bit pattern selected to be written to each block as well as the address of the block will be retained in a log file.

The Benchmark Configuration will be shutdown and restarted using a power off/power on cycle at the end of the above sequence of write operations. In addition, any caches employing battery backup must be flushed/emptied.

The SPC-1 Workload Generator will then use the above log file to verify each block written contains the correct bit pattern.

Clause 9.2.4.8

The following content shall appear in this section of the FDR:

1. *A listing or screen image of all input parameters supplied to the Workload Generator.*

2. *For the successful Data Persistence Test Run, a table illustrating key results. The content, appearance, and format of this table are specified in Table 9-12. Information displayed in this table shall be obtained from the Test Run Results File referenced below in #3.*

3. *For the successful Data Persistence Test Run, the human readable Test Run Results File produced by the Workload Generator.*

SPC-1 Workload Generator Input Parameters

The SPC-1 Workload Generator input parameters for the Persistence Test Runs are documented in "Appendix D: SPC-1 Workload Generator Input Parameters" on Page 56.

Data Persistence Test Results File

A link to each test result file generated from each Data Persistence Test is listed below.

Persistence 1 Test Results File
Persistence 2 Test Results File

Data Persistence Test Results

Data Persistence Test Results	
Data Persistence Test Run Number: 1	
Total Number of Logical Blocks Written	233,750,000
Total Number of Logical Blocks Verified	149,668,688
Total Number of Logical Blocks that Failed Verification	0
Time Duration for Writing Test Logical Blocks	10 minutes
Size in Bytes of each Logical Block	512
Number of Failed I/O Requests in the process of the Test	0

In some cases the same address was the target of multiple writes, which resulted in more Logical Blocks Written than Logical Blocks Verified. In the case of multiple writes to the same address, the pattern written and verified must be associated with the last write to that address.

PRICED STORAGE CONFIGURATION AVAILABILITY DATE

Clause 9.2.4.9

The committed delivery data for general availability (Availability Date) of all products that comprise the Priced Storage Configuration must be reported. When the Priced Storage Configuration includes products or components with different availability dates, the reported Availability Date must be the date at which all components are committed to be available.

The FDR shall state: "The Priced Storage Configuration, as documented in this Full Disclosure Report will be available for shipment to customers on MMMM DD, YYYY." Where Priced Storage Configuration is the TSC Configuration Name as described in Clause 9.2.4.3.3 and MMMM is the alphanumeric month, DD is the numeric day, and YYYY is the numeric year of the date that the Priced Storage Configuration, as documented, is available for shipment to customers as described above.

The IBM TotalStorage® SAN Volume Controller 1.2.1, as documented in this Full Disclosure Report became available for customer purchase and shipment on October 29, 2004.

PRICING INFORMATION

Clause 9.2.4.11

A statement of the respective calculations for pricing must be included.

Pricing information may found in the Tested Storage Configuration Pricing section on page 12.

ANOMALIES OR IRREGULARITIES

Clause 9.2.4.10

The FDR shall include a clear and complete description of any anomalies or irregularities encountered in the course of executing the SPC-1 benchmark that may in any way call into question the accuracy, verifiability, or authenticity of information published in this FDR.

There were no anomalies or irregularities encountered during the SPC-1 Remote Audit of the IBM TotalStorage® SAN Volume Controller 1.2.1.

APPENDIX A: CUSTOMER TUNABLE PARAMETERS AND OPTIONS

The AIX queue depth was set to 128 via the 'prepare.sh' script:

The SVC extent size was set to 256 MiB (268.435 MB) via the 'mkgroup.sh' script.

The contents of both scripts are contained in "Appendix B: Tested Storage Configuration (TSC) Creation" on page 50.

APPENDIX B: TESTED STORAGE CONFIGURATION (TSC) CREATION

Format the mDisks

Before being discovered by the SVC, each mDisk was formatted on the underlying DS4300 storage. The formatting was performed using the DS4300 Storage Manager (SM) interface. Each DS4300 enclosure, together with its associated EXP700 expansion enclosure, represented a storage subsystem managed by the SM containing 28 disks. The left 7 disks in the two enclosures (14 disks altogether), provided the capacity for one mDisk, and similarly for the right 7 disks. In this way, each mDisk was formatted as a mirrored+striped (often called RAID-10) layout using all of the available capacity on 14 disks. In specifying this operation within the SM, the host attachment type was set to 12 (IBM SVC); the segment size and readahead were set to 256K and 1 respectively. Standard caching for host type 12 was provided (read cache enabled, write cache enabled, write cache mirror enabled).

The following scripts complete the creation and configuration of the Tested Storage Configuration.

Create the vDisks (LUNs)

Definition of the mDisk group *(mkgroup.sh)*

```
#makes and mdisk group, extent size 512MB (RAID-5)
#                        256MB (RAID-10).
$VCreq svctask mkmdiskgrp -name thebiggroup -ext 256 -mdisk \
md0:md1:md2:md3:md4:md5:md6:md7:md8:md9:md10:md11:md12:md13:md14:md15:\
md16:md17:md18:md19:md20:md21:md22:md23:md24:md25:md26:md27:md28:md29:md30:md31
```

Definition of vDisks *(mk32vd.sh)*

```
i=0
while [ $i -le 31 ]
do
lode=$((8-(i%8)))
iogrp=$(((7-(i%8))/2))
   $VCreq svctask mkvdisk -size 237 -unit gb -mdiskgrp thebiggroup -iogrp $iogrp -name vd$i -node $lode
   echo $i $lode $iogrp
i=$((i+1))
done
```

Definition of FC paths *(mkperfsh2chosts.sh)*

```
$VCreq svctask mkhost -force -name SH2cfcs0 -hbawwpn 10000000C9409890
$VCreq svctask mkhost -force -name SH2cfcs1 -hbawwpn 10000000C940B81E
$VCreq svctask mkhost -force -name SH2cfcs2 -hbawwpn 10000000C940B800
$VCreq svctask mkhost -force -name SH2cfcs3 -hbawwpn 10000000C940B7CC
$VCreq svctask mkhost -force -name SH2cfcs4 -hbawwpn 10000000C940B756
$VCreq svctask mkhost -force -name SH2cfcs5 -hbawwpn 10000000C9409871
$VCreq svctask mkhost -force -name SH2cfcs6 -hbawwpn 10000000C9409822
$VCreq svctask mkhost -force -name SH2cfcs7 -hbawwpn 10000000C940D95A
$VCreq svctask mkhost -force -name SH2cfcs8 -hbawwpn 10000000C94088FC
$VCreq svctask mkhost -force -name SH2cfcs9 -hbawwpn 10000000C940888F
```

```
$VCreq svctask mkhost -force -name SH2cfcs10 -hbawwpn 10000000C940DE00
$VCreq svctask mkhost -force -name SH2cfcs11 -hbawwpn 10000000C9409841
$VCreq svctask mkhost -force -name SH2cfcs12 -hbawwpn 10000000C940B7C4
$VCreq svctask mkhost -force -name SH2cfcs13 -hbawwpn 10000000C940B789
$VCreq svctask mkhost -force -name SH2cfcs14 -hbawwpn 10000000C940B749
$VCreq svctask mkhost -force -name SH2cfcs15 -hbawwpn 10000000C940B7B7
$VCreq svctask mkhost -force -name SH2cfcs16 -hbawwpn 10000000C94088C2
$VCreq svctask mkhost -force -name SH2cfcs17 -hbawwpn 10000000C940B764
$VCreq svctask mkhost -force -name SH2cfcs18 -hbawwpn 10000000C94088BE
$VCreq svctask mkhost -force -name SH2cfcs19 -hbawwpn 10000000C9409746
$VCreq svctask mkhost -force -name SH2cfcs20 -hbawwpn 10000000C940B769
$VCreq svctask mkhost -force -name SH2cfcs21 -hbawwpn 10000000C940DAC2
$VCreq svctask mkhost -force -name SH2cfcs22 -hbawwpn 10000000C9408873
$VCreq svctask mkhost -force -name SH2cfcs23 -hbawwpn 10000000C9409766
$VCreq svctask mkhost -force -name SH2cfcs24 -hbawwpn 10000000C940974C
$VCreq svctask mkhost -force -name SH2cfcs25 -hbawwpn 10000000C94098A0
$VCreq svctask mkhost -force -name SH2cfcs26 -hbawwpn 10000000C94088B4
$VCreq svctask mkhost -force -name SH2cfcs27 -hbawwpn 10000000C940B7C8
$VCreq svctask mkhost -force -name SH2cfcs28 -hbawwpn 10000000C940B736
$VCreq svctask mkhost -force -name SH2cfcs29 -hbawwpn 10000000C940B752
$VCreq svctask mkhost -force -name SH2cfcs30 -hbawwpn 10000000C940B755
```

Path Mapping subroutine script *(maplist.sh)*

```
#sets vd$2 through vd$3 by $4 to use host path $1
if [[ $# -lt 3 ]]
then
    echo "usage: maplist pathname startvd endvd step"
fi
next=$2
while [ $next -le $3 ]
do
  echo vd$next $1
  $VCreq svctask mkvdiskhostmap -force -host $1 vd$next
  let next="$next + $4"
done
```

vDisk to Path Mapping *(map32to16.sh)*

```
./maplist.sh SH2cfcs27 0 31 16
./maplist.sh SH2cfcs27 1 31 16
./maplist.sh SH2cfcs16 0 31 16
./maplist.sh SH2cfcs16 1 31 16

./maplist.sh SH2cfcs28 2 31 16
./maplist.sh SH2cfcs28 3 31 16
./maplist.sh SH2cfcs17 2 31 16
./maplist.sh SH2cfcs17 3 31 16

./maplist.sh SH2cfcs29 4 31 16
./maplist.sh SH2cfcs29 5 31 16
./maplist.sh SH2cfcs18 4 31 16
./maplist.sh SH2cfcs18 5 31 16

./maplist.sh SH2cfcs30 6 31 16
./maplist.sh SH2cfcs30 7 31 16
```

```
./maplist.sh SH2cfcs19 6 31 16
./maplist.sh SH2cfcs19 7 31 16

./maplist.sh SH2cfcs12 8 31 16
./maplist.sh SH2cfcs12 9 31 16
./maplist.sh SH2cfcs0 8 31 16
./maplist.sh SH2cfcs0 9 31 16

./maplist.sh SH2cfcs13 10 31 16
./maplist.sh SH2cfcs13 11 31 16
./maplist.sh SH2cfcs1 10 31 16
./maplist.sh SH2cfcs1 11 31 16

./maplist.sh SH2cfcs2 12 31 16
./maplist.sh SH2cfcs2 13 31 16
./maplist.sh SH2cfcs14 12 31 16
./maplist.sh SH2cfcs14 13 31 16

./maplist.sh SH2cfcs3 14 31 16
./maplist.sh SH2cfcs3 15 31 16
./maplist.sh SH2cfcs15 14 31 16
./maplist.sh SH2cfcs15 15 31 16
```

Discover the vDisks and Create Logical Volumes

LUN Discovery *(cfg16.sh)*

```
# runs config manager on a list of fcs's
for f in 0 1 2 3 12 13 14 15 16 17 18 19 27 28 29 30
do
cfgmgr -vl fcs$f > fcs$f.cfg
done
```

Set Queue Depth *(prepare.sh)*

```
#run this script before defining the volume group
h=30
while [[ $h -le 157 ]]
do
chdev -l hdisk$h -a queue_depth=128
let "h=h+1"
done
cfallvpath
```

Logical Volume Creation *(mkthinstripe.sh)*

```
# creates 60 logical volumes in a volume group with fine striping

mkvg4vp -fy thinstripevg -d 32 -s 256 \
   vpath0 vpath1 vpath2 vpath3 vpath4 vpath5 vpath6 vpath7 \
   vpath8 vpath9 vpath10 vpath11 vpath12 vpath13 vpath14 vpath15 \
   vpath16 vpath17 vpath18 vpath19 vpath20 vpath21 vpath22 vpath23 \
   vpath24 vpath25 vpath26 vpath27 vpath28 vpath29 vpath30 vpath31
if [[ $? -ne 0 ]] then exit; fi
l=1
```

```
while [[ $l -le 60 ]]
do
mklv -b n -y thin$l -x 1016 -u 32 -S 128K thinstripevg 480
l=$((l+1))
done
```

APPENDIX C: SPC-1 WORKLOAD GENERATOR STORAGE COMMANDS AND PARAMETERS

The contents of the SPC-1 Workload Generator command and parameter file is listed below.

```
*javaparms="-Xms384m -Xmx768m -Xss1024k -Xgcpolicy:optavgpause"
*host=master
*slaves=(S1,S2,S3,S4,S5,S6,S7,S8,S9,S10)
sd=asu1_1,size=120g,lun=/dev/rthin1
sd=asu1_2,size=120g,lun=/dev/rthin2
sd=asu1_3,size=120g,lun=/dev/rthin3
sd=asu1_4,size=120g,lun=/dev/rthin4
sd=asu1_5,size=120g,lun=/dev/rthin5
sd=asu1_6,size=120g,lun=/dev/rthin6
sd=asu1_7,size=120g,lun=/dev/rthin7
sd=asu1_8,size=120g,lun=/dev/rthin8
sd=asu1_9,size=120g,lun=/dev/rthin9
sd=asu1_10,size=120g,lun=/dev/rthin10
sd=asu1_11,size=120g,lun=/dev/rthin11
sd=asu1_12,size=120g,lun=/dev/rthin12
sd=asu1_13,size=120g,lun=/dev/rthin13
sd=asu1_14,size=120g,lun=/dev/rthin14
sd=asu1_15,size=120g,lun=/dev/rthin15
sd=asu1_16,size=120g,lun=/dev/rthin16
sd=asu1_17,size=120g,lun=/dev/rthin17
sd=asu1_18,size=120g,lun=/dev/rthin18
sd=asu1_19,size=120g,lun=/dev/rthin19
sd=asu1_20,size=120g,lun=/dev/rthin20
sd=asu1_21,size=120g,lun=/dev/rthin21
sd=asu1_22,size=120g,lun=/dev/rthin22
sd=asu1_23,size=120g,lun=/dev/rthin23
sd=asu1_24,size=120g,lun=/dev/rthin24
sd=asu1_25,size=120g,lun=/dev/rthin25
sd=asu1_26,size=120g,lun=/dev/rthin26
sd=asu1_27,size=120g,lun=/dev/rthin27
sd=asu2_1,size=120g,lun=/dev/rthin28
sd=asu2_2,size=120g,lun=/dev/rthin29
sd=asu2_3,size=120g,lun=/dev/rthin30
sd=asu2_4,size=120g,lun=/dev/rthin31
sd=asu2_5,size=120g,lun=/dev/rthin32
sd=asu2_6,size=120g,lun=/dev/rthin33
sd=asu2_7,size=120g,lun=/dev/rthin34
sd=asu2_8,size=120g,lun=/dev/rthin35
sd=asu2_9,size=120g,lun=/dev/rthin36
sd=asu2_10,size=120g,lun=/dev/rthin37
sd=asu2_11,size=120g,lun=/dev/rthin38
sd=asu2_12,size=120g,lun=/dev/rthin39
sd=asu2_13,size=120g,lun=/dev/rthin40
sd=asu2_14,size=120g,lun=/dev/rthin41
sd=asu2_15,size=120g,lun=/dev/rthin42
sd=asu2_16,size=120g,lun=/dev/rthin43
sd=asu2_17,size=120g,lun=/dev/rthin44
sd=asu2_18,size=120g,lun=/dev/rthin45
sd=asu2_19,size=120g,lun=/dev/rthin46
sd=asu2_20,size=120g,lun=/dev/rthin47
```

```
sd=asu2_21,size=120g,lun=/dev/rthin48
sd=asu2_22,size=120g,lun=/dev/rthin49
sd=asu2_23,size=120g,lun=/dev/rthin50
sd=asu2_24,size=120g,lun=/dev/rthin51
sd=asu2_25,size=120g,lun=/dev/rthin52
sd=asu2_26,size=120g,lun=/dev/rthin53
sd=asu2_27,size=120g,lun=/dev/rthin54
sd=asu3_1,size=120g,lun=/dev/rthin55
sd=asu3_2,size=120g,lun=/dev/rthin56
sd=asu3_3,size=120g,lun=/dev/rthin57
sd=asu3_4,size=120g,lun=/dev/rthin58
sd=asu3_5,size=120g,lun=/dev/rthin59
sd=asu3_6,size=120g,lun=/dev/rthin60
```

APPENDIX D: SPC-1 WORKLOAD GENERATOR INPUT PARAMETERS

The following script was used to execute the Primary Metrics (Sustainability, IOPS, and Response Time Ramp Test Phases) and Repeatability Tests as well as Persistence Test Run 1 in an interrupted sequence:

```
export CLASSPATH=.
export IBM_JAVADUMP_OUTOFMEMORY=false
export IBM_HEAPDUMP_OUTOFMEMORY=false
java -Xoptionsfile=javaopts.cfg metrics -b 2005
java -Xoptionsfile=javaopts.cfg repeat1 -b 2005
java -Xoptionsfile=javaopts.cfg repeat2 -b 2005
java -Xoptionsfile=javaoptsp.cfg persist1 -b 2005
```

Persistence Test Run 2 was executed using the following command line:

```
java -Xoptionsfile=javaoptsp.cfg persist2
```

Listed below are the Java configuration files.

'javaopts.cfg':

```
-Xms384m -Xmx768m -Xss1024k -Xgcpolicy:optavgpause
```

javaoptsp.cfg':

```
 -Xmx1024m -Xms384m -Xgcpolicy:optavgpause
```