SPC BENCHMARK 1™

FULL DISCLOSURE REPORT

IBM CORPORATION

IBM SYSTEM STORAGE
DS4800 DISK STORAGE SYSTEM

SPC-1 V1.10.1

Submitted for Review: April 10, 2007
Submission Identifier: A00050
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First Edition – April 2007

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AUDIT CERTIFICATION

Bruce McNutt
IBM Corporation
KBV/9062-2
9000 South Rita Road
Tucson, AZ 8744

April 10, 2007

The SPC Benchmark 1™ results listed below for the IBM System Storage DS4800 Disk Storage System were produced in compliance with the SPC Benchmark 1™ V1.10.1 Remote Audit requirements.

SPC Benchmark 1™ V1.10.1 Results	
Tested Storage Configuration (TSC) Name: IBM System Storage DS4800 Disk Storage System	
Metric	**Reported Result**
SPC-1 IOPS™	45,014.81
SPC-1 Price-Performance	$16.03/SPC-1 IOPS™
Total ASU Capacity	6,871.277 GB
Data Protection Level	Mirroring
Total TSC Price (including three-year maintenance)	$721,618

The following SPC Benchmark 1™ Remote Audit requirements were reviewed and found compliant with V1.10.1 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

AUDIT CERTIFICATION *(CONT.)*

IBM System Storage DS4800 Disk Storage System   Page 2
SPC-1 Audit Certification
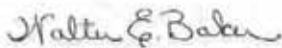
- Listings and commands to configure the Benchmark Configuration/Tested Storage Configuration, including customer tunable parameters.

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

- The following requirements, for each Host System, 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 differences between the Tested Storage Configuration (TSC) used for the benchmark and Priced Storage Configuration were documented and, if applied to the TSC, would not have a negative impact on the reported SPC-1 performance.

- The submitted pricing information 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:

There were no audit notes or exceptions.

Respectfully,

Walter E. Baker

Walter E. Baker
SPC Auditor

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LETTER OF GOOD FAITH

IBM

Vice President & BLE, Disk Storage

IBM Technology & Systems Group
5600 Cottle Road, San Jose, California 95193

Phone 408-256-7406
Fax: 408-256-7420

April 9, 2007

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 IBM System Storage DS4800

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
1.10.1 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,

Barry Rudolph

EXECUTIVE SUMMARY

Test Sponsor and Contact Information

Test Sponsor and Contact Information	
Test Sponsor Primary Contact	IBM Corporation – http://www.ibm.com Peter Leung – leungp@us.ibm.com 65S/9062-2 9000 South Rita Road Tucson, AZ 85744 Phone: (520) 799-2853 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://www.StoragePerformance.org Walter E. Baker – AuditService@StoragePerformance.org 643 Bair Island Road, Suite 103 Redwood City, CA 94063 Phone: (650) 556-9384 FAX: (650) 556-9385

Revision Information and Key Dates

Revision Information and Key Dates	
SPC-1 Specification revision number	V1.10.1
SPC-1 Workload Generator revision number	V2.00.04a
Date Results were first used publicly	April 10, 2007
Date the FDR was submitted to the SPC	April 10, 2007
Date revised FDR was submitted to the SPC Revised pricing and SPC-1 Price-Performance	June 27, 2007
Date the TSC is available for shipment to customers	currently available
Date the TSC completed audit certification	April 10, 2007

Tested Storage Product (TSP) Description

Summary of Results

SPC-1 Results	
Tested Storage Configuration (TSC) Name: IBM System Storage DS4800 Disk Storage System	
Metric	**Reported Result**
SPC-1 IOPS™	45,014.81
SPC-1 Price-Performance	$13.94/SPC-1 IOPS™
Total ASU Capacity	6,871.277 GB
Data Protection Level	Mirroring
Total TSC Price (including three-year maintenance)	$627,538

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.
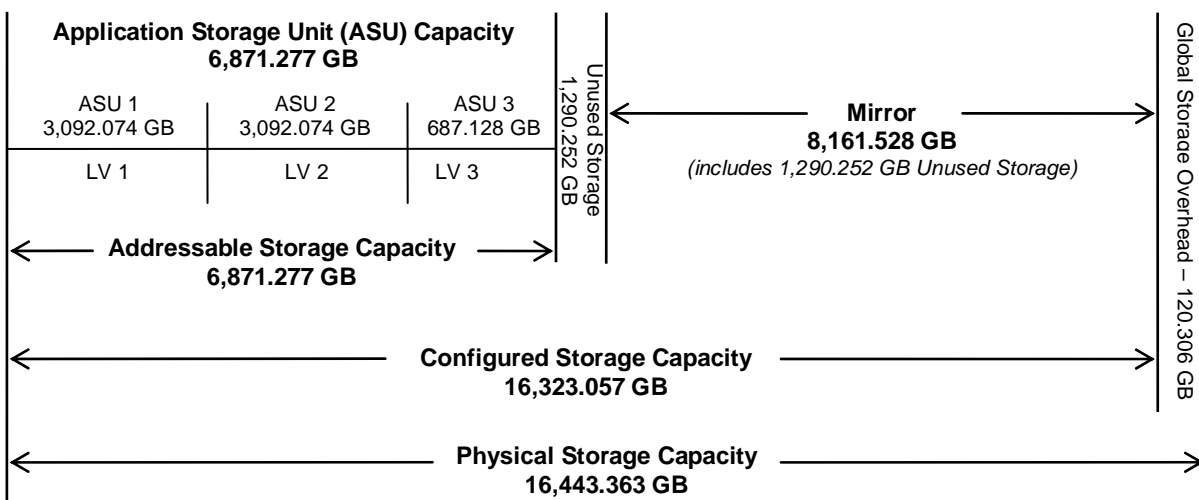
Response Time – Throughput Curve

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.

Ramp Phase Response Time / Throughput Curve
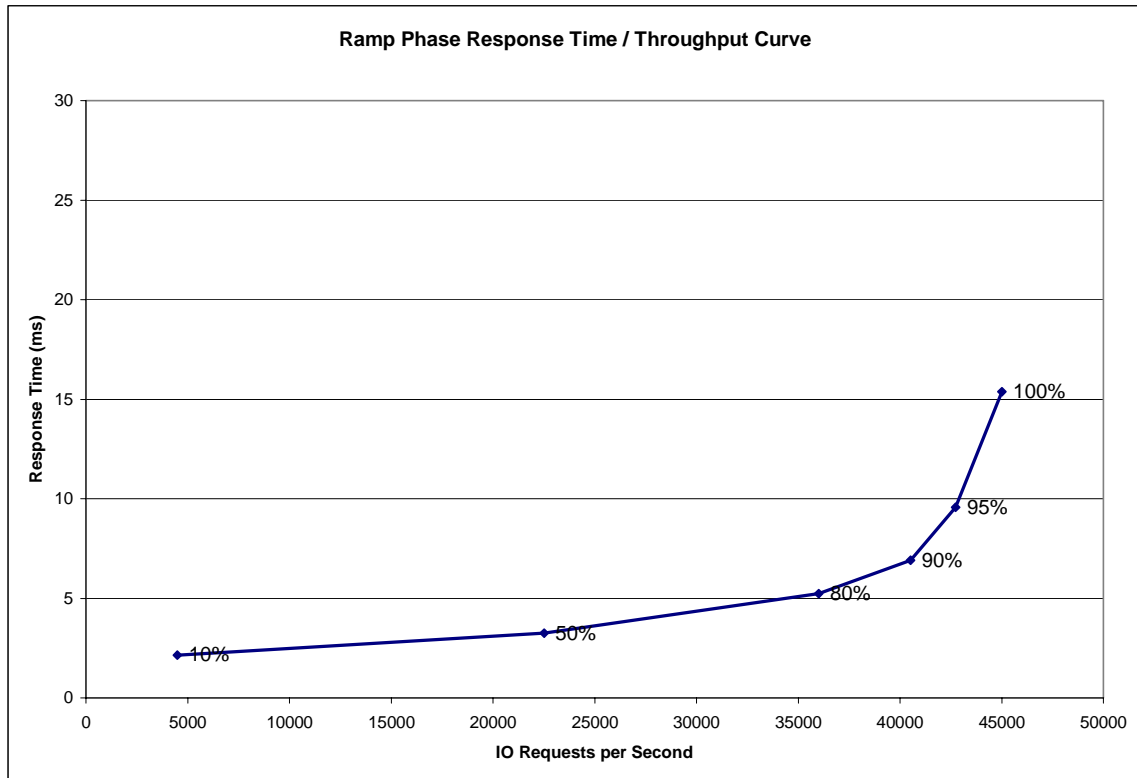
Response Time – Throughput Data

	10% Load	50% Load	80% Load	90% Load	95% Load	100% Load
I/O Request Throughput	4,495.18	22,506.70	36,003.23	40,513.86	42,734.00	45,014.81
Average Response Time (ms):						
All ASUs	2.15	3.26	5.24	6.91	9.56	15.39
ASU-1	2.81	4.16	6.26	7.82	10.16	15.14
ASU-2	3.13	4.89	8.32	10.82	13.83	19.97
ASU-3	0.32	0.63	1.72	3.27	6.41	13.90
Reads	5.02	7.36	10.70	12.58	14.50	17.84
Writes	0.28	0.59	1.68	3.22	6.34	13.79

Tested Storage Configuration Pricing *(Priced Storage Configuration)*

	QTY	list price	extended
1815-82A DS4800 Model 82	1	$53,995	$53,995
2104 DS4000 Host Bus Adapter	16	$1,485	$23,760
2410 SW 4Gbps SFP pairs	6	$998	$5,988
5605 5m Fiber Optic cable	16	$129	$2,064
7700 Windows Host Kit	1	$1,250	$1,250
8870 Eight Storage Partitions	1	$10,000	$10,000
9202 Field Integrate	1	n/c	n/c
9800 Group 1 Power Cords	1	n/c	n/c
warranty upgrade to 24x7x4	1	$3,200	$3,200
1812-81A DS4000 EXP810 Expansion Unit	14	$6,000	$84,000
2410 SW 4Gbps SFP pairs	14	$998	$13,972
5601 1m Fiber Optic cable	28	$79	$2,212
5625 25m Fiber Optic cable	8	$189	$1,512
5413 73GB/15K FC Disk Module	224	$1,679	$376,096
9018 Attach to DS4800	14	n/c	n/c
9800 Group 1 Power Cords	14	n/c	n/c
warranty upgrade to 24x7x4	14	$760	$10,640
2005-B32 IBM TotalStorage SAN32B-2 4Gbps fabric switch with 16	1	$17,750	$17,750
2410 4 Gbps SW SFP Transceiver	32	$150	$4,800
5605 Fibre Cabe LC/LC 5M Multi	16	$105	$1,680
7510 B32 Ports 16-23 Activation	1	$9,000	$9,000
Warranty upgrade for 3 years	1	$5,619	$5,619
			total
			$627,538

The above pricing provides maintenance/support for 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 following are the differences between the TSC and Priced Storage Configuration:

- The priced disk drives have been configured to self-identify as FAStT brand.

- The mounting in each drive is in an IBM drive carrier.

- The 'data scrubbing' option has a default setting of "off" in the TSC, but would need to explicitly set to "off" in the Priced Storage Configuration.

- The IBM TotalStorage SAN Switch 2005-B32 is an IBM relabeled version of the Brocade Silkworm 4100 Switch, which is identical to the component used in the TSC.

The differences listed above, if applied to the TSC, would not have a negative performance impact on the reported SPC-1 performance.

Benchmark Configuration/Tested Storage Configuration Diagram

HS-1   HS-2   HS-3   HS-4

**Brocade Silkworm 4100
4 Gb FC switch**

**IBM TotalStorage®
DS4800**
UID=DS4800-1
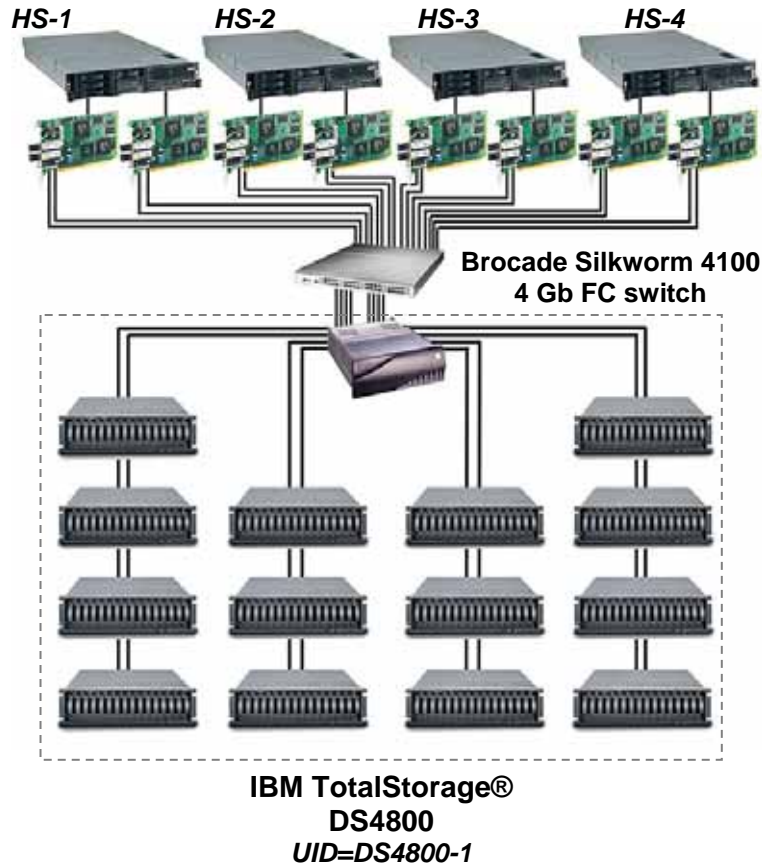
Benchmark Configuration/Tested Storage Configuration Components

Host Systems:	Tested Storage Configuration (TSC)
UID=HS-1, HS-2, HS-3, HS-4:	SANtricity Storage Manager v9.
4 – IBM x346 Servers, each configured with: 2 – 3.2 GHz Xeon CPUs, 1 MB L2/CPU 2 GB main memory Windows 2003 Enterprise Edition PCI-X WG	8 – Qlogic 2342 HBAs (2 per Host System)
	1 – Brocade Silkworm 4100 switch – 32 ports, 4 Gb
	UID=DS4800-1:

	IBM TotalStorage® DS4800 which includes:
	   2 – disk array controllers
	      with 2 GB RAM per controller
	   8 – 4 Gb Fibre Channel host connections
	   8 – 4 Gb Fibre Channel drive connections

	14 – DS4000 EXP810 Expansion Units
	224 – 73 GB 15K RPM Disk Drives

In each of the following sections of this document, the appropriate Full Disclosure Report requirement, from the SPC-1 benchmark specification, is stated in italics followed by the information to fulfill the stated requirement.

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 15** *(Benchmark Configuration/Tested Storage Configuration Diagram).*

Storage Network Configuration

Clause 9.2.4.4.1

…

> 5. *If the TSC contains network storage, the diagram will include the network configuration. If a single diagram is not sufficient to illustrate both the Benchmark Configuration and network configuration in sufficient detail, the Benchmark Configuration diagram will include a high-level network illustration as shown in Figure 9-8. In that case, a separate, detailed network configuration diagram will also be included as described in Clause 9.2.4.4.2.*

Clause 9.2.4.4.2

If a storage network was configured as a part of the Tested Storage Configuration and the Benchmark Configuration diagram described in Clause 9.2.4.4.1 contains a high-level illustration of the network configuration, the Executive Summary will contain a one page topology diagram of the storage network as illustrated in Figure 9-9.

The Benchmark Configuration (BC)/Tested Storage Configuration (TSC) was configured with local storage and, as such, did not employ a storage network.

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 15** *(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. If the parameter name is not self-explanatory to a knowledgeable practitioner, a brief description of the parameter's use must also be included in the FDR entry.

"Appendix B: Customer Tunable Parameters and Options" on page 59 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 BC Configuration Diagram in Clause 9.2.4.4.1 and/or 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.*
- *Listings of scripts used to create the logical representation of the TSC.*
- *If scripts were not used, a description of the process used with sufficient detail to recreate the logical representation of the TSC.*

"Appendix C: Tested Storage Configuration (TSC) Creation" on page 61 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 D: SPC-1 Workload Generator Storage Commands and Parameters" on page 66.

SPC-1 DATA REPOSITORY

This portion of the Full Disclosure Report presents the detailed information that fully documents the various SPC-1 storage capacities and mappings used in the Tested Storage Configuration. "SPC-1 Data Repository Definitions" on page 55 contains definitions of terms specific to the SPC-1 Data Repository.

Storage Capacities and Relationships

Clause 9.2.4.6.1

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)	6,871.277
Addressable Storage Capacity	Gigabytes (GB)	6,871.277
Configured Storage Capacity	Gigabytes (GB)	16,323.057
Physical Storage Capacity	Gigabytes (GB)	16,443.363
Data Protection (Mirroring)	Gigabytes (GB)	8,161.528
Required Storage/Spares	Gigabytes (GB)	0.000
Global Storage Overhead	Gigabytes (GB)	120.306
Total Unused Storage	Gigabytes (GB)	2,580.504

SPC-1 Storage Hierarchy Ratios

	Addressable Storage Capacity	Configured Storage Capacity	Physical Storage Capacity
Total ASU Capacity	100.00%	42.10%	41.79%
Required for Data Protection (Mirroring)		50.00%	49.63%
Addressable Storage Capacity		42.10%	41.79%
Required Storage		0.00%	0.00%
Configured Storage Capacity			99.27%
Global Storage Overhead			0.73%
Unused Storage:			
Addressable	0.00%		
Configured		15.81%	
Physical			0.00%

The Physical Storage Capacity consisted of l6,443.363 GB distributed over 224 disk drives each with a formatted capacity of 68.366 GB. There was 0.00 GB (0.00%) of Unused Storage within the Physical Storage Capacity. Global Storage Overhead consisted of 120.306 GB (0.73%) of Physical Storage Capacity. There was 2,580.5035 GB (15.81%) of Unused Storage within the Configured Storage Capacity. The Total ASU Capacity utilized 100.00% of the Addressable Storage Capacity resulting in 0.000 GB (0.00%) 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).
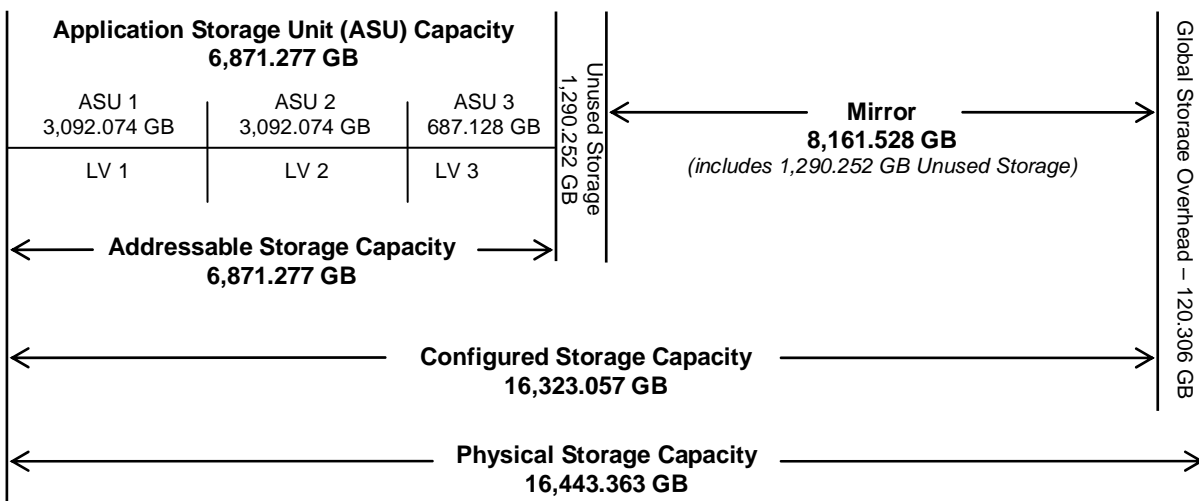
Logical Volume Capacity and ASU Mapping

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 (3,092.074 GB)	ASU-2 (3,092.074 GB)	ASU-3 (687.128 GB)
1 Logical Volume 3,092.074 GB per Logical Volume (3,092.074 GB used per Logical Volume)	1 Logical Volume 3,092.074 GB per Logical Volume (3,092.074 GB used per Logical Volume)	1 Logical Volume 687.128 GB per Logical Volume (687.128 GB used per Logical Volume)

The Data Protection Level used for all Logical Volumes was Mirroring as described on page 12. See "ASU Configuration" in the **IOPS Test Results File** for more detailed configuration information.

SPC-1 BENCHMARK EXECUTION RESULTS

This portion of the Full Disclosure Report documents the results of the various SPC-1 Tests, Test Phases, and Test Runs. "SPC-1 Test Execution Definitions" on page 56 contains definitions of terms specific to the SPC-1 Tests, Test Phases, and Test Runs.

Clause 5.4.3

The Tests must be executed in the following sequence: Primary Metrics, Repeatability, and Data Persistence. That required sequence must be uninterrupted from the start of Primary Metrics to the completion of Persistence Test Run 1. Uninterrupted means the Benchmark Configuration shall not be power cycled, restarted, disturbed, altered, or adjusted during the above measurement sequence. If the required sequence is interrupted other than for the Host System/TSC power cycle between the two Persistence Test Runs, the measurement is invalid.

SPC-1 Tests, Test Phases, and Test Runs

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

- **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**

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

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 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 5.4.4.1.1

The Sustainability Test Phase has exactly one Test Run and shall demonstrate the maximum sustainable I/O Request Throughput within at least a continuous three (3) hour Measurement Interval. This Test Phase also serves to insure that the TSC has reached Steady State prior to reporting the final maximum I/O Request Throughput result (SPC-1 IOPS™).

Clause 5.4.4.1.2

The computed I/O Request Throughput of the Sustainability Test must be within 5% of the reported SPC-1 IOPS™ result.

Clause 5.4.4.1.4

The Average Response Time, as defined in Clause 5.1.1, will be computed and reported for the Sustainability Test Run and cannot exceed 30 milliseconds. If the Average Response time exceeds that 30-milliseconds constraint, the measurement is invalid.

Clause 9.2.4.7.1

For the Sustainability Test Phase the FDR shall contain:

1. *A Data Rate Distribution graph and data table.*
2. *I/O Request Throughput Distribution graph and data table.*
3. *A Response Time Frequency Distribution graph and table.*
4. *An Average Response Time Distribution graph and table.*
5. *The human readable Test Run Results File produced by the Workload Generator (may be included in an appendix).*
6. *A listing or screen image of all input parameters supplied to the Workload Generator (may be included in an appendix).*
7. *The Measured Intensity Multiplier for each I/O stream.*
8. *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, Response Time Ramp, Repeatability, and Persistence Test Runs are documented in "Appendix E: SPC-1 Workload Generator Input Parameters" on Page 67.

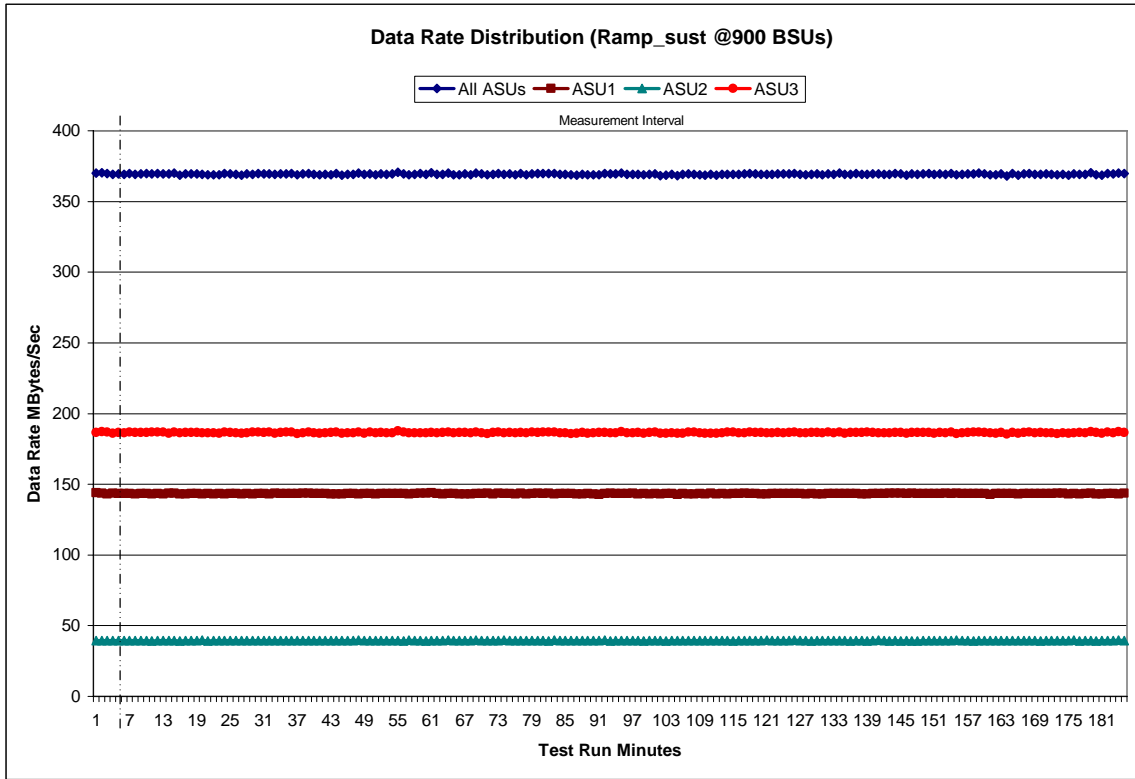### Sustainability Test Results File

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	18:23:48	18:28:48	0-4	0:05:00
Measurement Interval	18:28:48	21:28:48	5-184	3:00:00

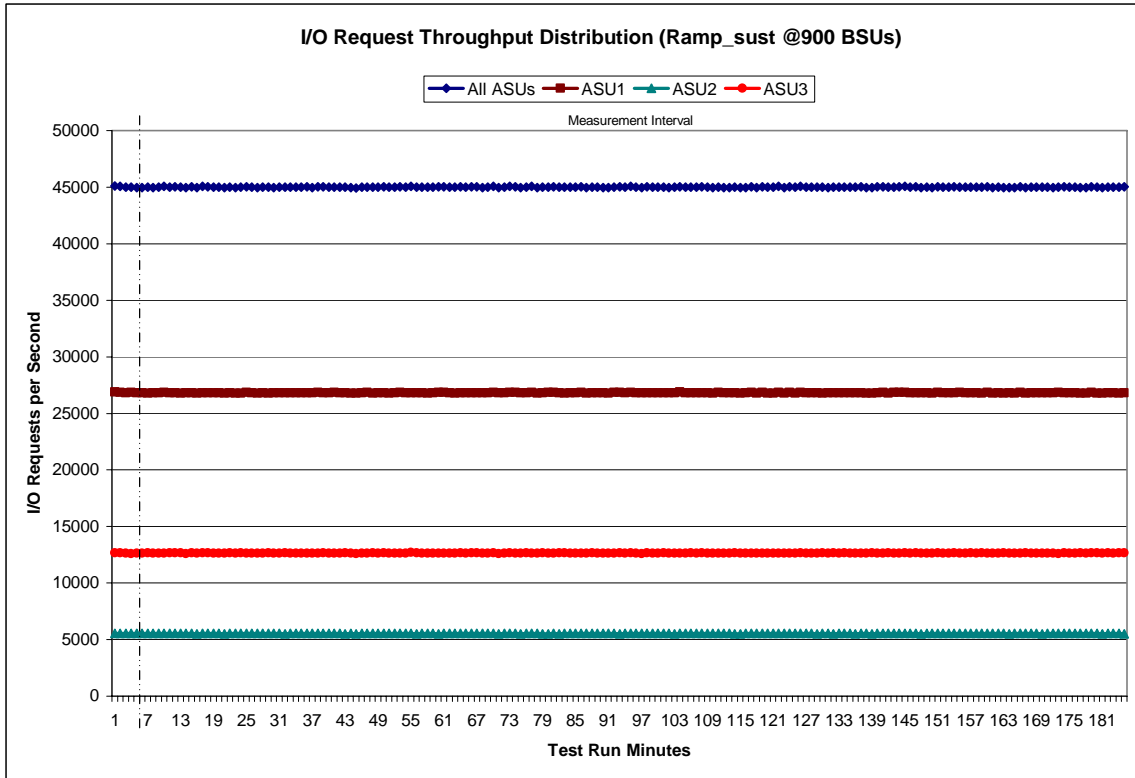| Interval	All ASUs	ASU1	ASU2	ASU3	Interval	All ASUs	ASU1	ASU2	ASU3	Interval	All ASUs	ASU1	ASU2	ASU3
0	369.95	143.88	39.44	186.63	63	370.16	143.55	39.62	186.99	126	369.17	143.36	39.43	186.38
1	370.43	143.81	39.45	187.17	64	368.96	143.38	39.38	186.20	127	368.76	143.16	39.33	186.27
2	369.66	143.23	39.47	186.96	65	368.95	143.06	39.37	186.52	128	369.25	143.46	39.14	186.65
3	369.17	143.67	39.49	186.02	66	369.40	143.27	39.47	186.66	129	369.35	143.16	39.57	186.62
4	369.47	143.51	39.46	186.49	67	368.95	143.22	39.55	186.19	130	369.04	143.22	39.52	186.30
5	369.18	143.27	39.51	186.40	68	369.99	143.45	39.72	186.81	131	369.46	143.27	39.34	186.85
6	369.74	143.39	39.48	186.88	69	369.53	143.54	39.56	186.43	132	369.30	143.35	39.56	186.39
7	369.11	143.19	39.33	186.59	70	368.82	143.60	39.47	185.74	133	369.96	143.48	39.49	186.99
8	369.53	143.46	39.51	186.56	71	369.08	143.19	39.41	186.48	134	369.15	143.51	39.51	186.12
9	369.69	143.48	39.50	186.70	72	369.85	143.78	39.31	186.76	135	369.27	143.48	39.17	186.62
10	369.40	143.21	39.25	186.94	73	369.24	143.32	39.66	186.26	136	369.71	143.52	39.54	186.64
11	369.76	143.36	39.45	186.95	74	369.48	143.44	39.35	186.69	137	369.27	143.12	39.53	186.63
12	369.46	143.01	39.44	187.02	75	368.92	143.22	39.38	186.31	138	369.30	143.11	39.20	187.00
13	369.33	143.62	39.57	186.15	76	369.63	143.81	39.32	186.49	139	369.54	143.49	39.53	186.52
14	369.95	143.57	39.58	186.80	77	368.90	143.04	39.44	186.41	140	369.55	143.49	39.60	186.46
15	368.74	143.22	39.18	186.34	78	369.58	143.49	39.32	186.77	141	369.07	143.32	39.54	186.21
16	369.35	143.18	39.44	186.72	79	369.75	143.77	39.50	186.48	142	369.06	143.58	39.23	186.25
17	369.50	143.37	39.48	186.66	80	369.65	143.52	39.36	186.76	143	369.78	143.73	39.55	186.50
18	369.60	143.55	39.34	186.71	81	369.67	143.62	39.29	186.76	144	369.55	143.77	39.26	186.53
19	369.10	143.22	39.67	186.21	82	369.67	143.09	39.72	186.86	145	368.73	143.29	39.53	185.91
20	368.96	143.29	39.29	186.39	83	369.13	143.29	39.51	186.33	146	369.47	143.58	39.27	186.62
21	368.90	143.18	39.45	186.27	84	369.15	143.44	39.43	186.29	147	369.13	143.32	39.27	186.55
22	368.91	143.33	39.41	186.16	85	368.87	143.51	39.49	185.88	148	369.42	143.30	39.54	186.59
23	369.67	143.11	39.52	187.04	86	368.52	143.07	39.46	185.99	149	369.63	143.37	39.54	186.72
24	369.61	143.52	39.57	186.52	87	369.26	143.23	39.47	186.56	150	369.08	143.47	39.48	186.13
25	369.26	143.43	39.44	186.40	88	368.93	143.34	39.46	186.12	151	369.43	143.50	39.43	186.49
26	368.71	143.07	39.53	186.11	89	368.99	143.16	39.48	186.35	152	369.16	143.57	39.37	186.23
27	369.35	143.54	39.34	186.46	90	368.98	142.95	39.42	186.61	153	369.84	143.36	39.44	187.04
28	369.30	143.06	39.47	186.77	91	369.85	143.50	39.62	186.73	154	369.02	143.60	39.60	185.83
29	369.66	143.32	39.51	186.84	92	369.45	143.77	39.23	186.44	155	369.26	143.39	39.45	186.42
30	369.51	143.45	39.56	186.49	93	369.33	143.51	39.38	186.45	156	369.43	143.42	39.33	186.68
31	369.49	143.17	39.48	186.84	94	370.07	143.40	39.38	187.29	157	369.60	143.49	39.20	186.91
32	369.27	143.69	39.44	186.15	95	369.09	143.48	39.33	186.27	158	369.92	143.40	39.49	187.03
33	369.36	143.46	39.43	186.47	96	369.21	143.64	39.39	186.19	159	369.41	143.37	39.47	186.56
34	369.47	143.33	39.39	186.76	97	369.33	143.09	39.50	186.74	160	368.77	142.97	39.39	186.41
35	369.73	143.43	39.53	186.77	98	368.81	143.47	39.27	186.07	161	369.00	143.45	39.56	185.99
36	368.79	143.49	39.53	185.76	99	369.18	143.25	39.43	186.50	162	369.41	143.39	39.32	186.71
37	369.41	143.65	39.51	186.24	100	369.51	143.28	39.39	186.84	163	368.13	143.31	39.35	185.47
38	369.86	143.69	39.39	186.78	101	368.45	143.10	39.44	185.91	164	369.72	143.41	39.59	186.72
39	369.16	143.42	39.38	186.35	102	368.72	143.40	39.26	186.06	165	368.56	143.18	39.38	186.00
40	369.01	143.44	39.43	186.14	103	369.33	143.39	39.49	186.44	166	369.43	143.30	39.41	186.72
41	369.21	143.40	39.43	186.38	104	368.42	142.98	39.42	186.02	167	369.66	143.33	39.43	186.90
42	369.03	143.15	39.37	186.50	105	369.06	143.38	39.54	186.15	168	369.17	143.50	39.46	186.22
43	369.85	143.23	39.59	187.03	106	369.44	143.17	39.51	186.77	169	369.31	143.37	39.22	186.72
44	368.47	143.09	39.41	185.97	107	369.32	143.05	39.34	186.93	170	369.39	143.43	39.50	186.46
45	369.10	143.42	39.42	186.25	108	369.03	143.40	39.41	186.21	171	369.29	143.49	39.34	186.46
46	369.05	143.38	39.45	186.22	109	368.69	143.11	39.51	186.07	172	368.84	143.61	39.35	185.88
47	369.97	143.26	39.83	186.89	110	369.26	143.71	39.54	186.01	173	369.23	143.59	39.33	186.31
48	369.06	143.46	39.44	186.16	111	368.64	143.06	39.52	186.06	174	368.65	143.25	39.35	186.04
49	369.61	143.35	39.44	186.81	112	369.13	143.48	39.36	186.29	175	369.40	143.32	39.62	186.46
50	368.92	143.11	39.54	186.26	113	369.23	143.16	39.31	186.75	176	369.14	143.20	39.22	186.72
51	369.56	143.36	39.50	186.69	114	369.29	143.28	39.20	186.82	177	369.19	143.42	39.59	186.18
52	369.25	143.47	39.46	186.33	115	369.23	143.27	39.57	186.39	178	370.35	143.63	39.49	187.23
53	369.44	143.42	39.58	186.44	116	369.49	143.56	39.58	186.35	179	368.99	143.15	39.26	186.58
54	370.52	143.38	39.38	187.76	117	369.70	143.39	39.51	186.80	180	368.48	143.04	39.44	186.00
55	369.53	143.39	39.27	186.87	118	369.61	143.52	39.58	186.51	181	369.84	143.34	39.51	186.99
56	369.00	143.00	39.62	186.38	119	369.23	143.12	39.52	186.60	182	369.42	143.48	39.52	186.42
57	369.23	143.28	39.59	186.35	120	369.28	143.19	39.63	186.46	183	370.06	143.19	39.74	187.12
58	369.63	143.80	39.43	186.40	121	369.24	143.54	39.32	186.38	184	369.64	143.67	39.32	186.65
59	369.30	143.83	39.30	186.18	122	369.55	143.48	39.54	186.53					
60	370.28	144.00	39.59	186.69	123	368.93	143.41	39.58	186.38					
61	369.14	143.40	39.46	186.28	124	369.52	143.37	39.42	186.72					
62	369.18	143.13	39.47	186.58	125	369.82	143.32	39.71	186.80					

Sustainability – Data Rate Distribution Graph

Sustainability – I/O Request Throughput Distribution Data

	Start	Stop	Interval	Duration
Ramp-Up/Start-Up	18:23:48	18:28:48	0-4	0:05:00
Measurement Interval	18:28:48	21:28:48	5-184	3:00:00

| Interval	All ASUs	ASU1	ASU2	ASU3	Interval	All ASUs	ASU1	ASU2	ASU3	Interval	All ASUs	ASU1	ASU2	ASU3
0	45,108.33	26,879.62	5,552.18	12,676.53	63	45,035.67	26,834.22	5,532.08	12,669.37	126	44,980.60	26,810.58	5,544.42	12,625.60
1	45,079.58	26,852.37	5,544.40	12,682.82	64	44,989.98	26,824.12	5,535.13	12,630.73	127	44,998.77	26,831.48	5,529.72	12,637.57
2	45,006.13	26,814.70	5,543.07	12,648.37	65	45,018.88	26,828.60	5,530.97	12,659.32	128	44,990.92	26,823.73	5,524.73	12,642.45
3	45,004.32	26,849.30	5,542.02	12,613.00	66	45,025.37	26,826.88	5,539.97	12,658.52	129	45,010.10	26,797.80	5,552.88	12,659.42
4	44,969.12	26,807.67	5,529.42	12,632.03	67	44,975.63	26,806.98	5,543.42	12,625.23	130	44,975.20	26,808.28	5,533.78	12,633.13
5	44,973.00	26,802.50	5,527.73	12,642.77	68	44,988.10	26,809.18	5,534.23	12,644.68	131	44,985.22	26,802.97	5,521.18	12,661.07
6	44,995.37	26,785.17	5,542.92	12,667.28	69	45,053.92	26,842.90	5,557.93	12,653.08	132	44,996.45	26,808.35	5,544.03	12,644.07
7	44,978.07	26,815.70	5,529.08	12,633.28	70	44,950.60	26,822.82	5,523.13	12,604.65	133	45,004.95	26,815.97	5,528.23	12,660.75
8	44,988.65	26,821.55	5,531.35	12,635.75	71	44,985.27	26,821.78	5,531.43	12,632.05	134	45,000.88	26,830.55	5,543.92	12,626.42
9	45,054.67	26,862.33	5,542.73	12,649.60	72	45,085.27	26,863.97	5,542.92	12,678.38	135	44,996.58	26,829.23	5,522.28	12,645.07
10	45,009.30	26,821.85	5,528.15	12,659.30	73	45,026.28	26,836.37	5,555.28	12,634.63	136	45,019.28	26,826.47	5,540.35	12,652.47
11	45,029.13	26,817.38	5,536.23	12,675.52	74	44,967.78	26,817.40	5,509.13	12,641.25	137	44,973.77	26,784.75	5,542.33	12,646.68
12	44,982.83	26,795.75	5,531.75	12,655.33	75	45,007.73	26,811.13	5,537.12	12,659.48	138	44,972.22	26,784.92	5,522.38	12,664.92
13	44,975.20	26,814.93	5,546.42	12,613.85	76	45,050.93	26,858.45	5,540.55	12,651.93	139	45,024.68	26,833.90	5,540.37	12,650.42
14	45,033.77	26,826.27	5,552.07	12,655.43	77	44,960.13	26,787.63	5,536.37	12,636.13	140	45,023.00	26,844.10	5,529.65	12,649.25
15	44,960.45	26,793.60	5,518.25	12,648.60	78	45,013.70	26,826.18	5,518.30	12,669.22	141	44,998.57	26,799.42	5,540.88	12,658.27
16	45,053.97	26,831.68	5,547.77	12,674.52	79	45,004.40	26,843.77	5,524.85	12,635.78	142	45,005.98	26,837.27	5,525.75	12,642.97
17	45,019.93	26,818.70	5,542.65	12,658.58	80	45,032.37	26,849.88	5,531.15	12,651.33	143	45,030.43	26,854.20	5,539.32	12,636.92
18	44,993.93	26,807.10	5,539.52	12,647.32	81	44,998.75	26,820.67	5,524.08	12,654.00	144	45,055.85	26,862.03	5,533.20	12,660.62
19	44,992.80	26,806.97	5,540.40	12,645.43	82	45,007.15	26,785.43	5,545.42	12,676.30	145	45,002.23	26,826.17	5,543.42	12,632.65
20	44,945.17	26,788.13	5,521.80	12,635.23	83	44,997.28	26,822.80	5,532.27	12,642.22	146	45,021.48	26,818.68	5,538.43	12,664.37
21	45,008.22	26,825.32	5,525.67	12,657.23	84	44,995.55	26,825.83	5,535.02	12,634.70	147	44,958.30	26,809.03	5,507.45	12,641.82
22	44,961.15	26,796.83	5,536.62	12,627.70	85	45,014.80	26,846.07	5,545.28	12,623.45	148	45,013.12	26,835.05	5,536.83	12,641.23
23	45,003.13	26,791.60	5,539.90	12,671.63	86	44,963.18	26,792.05	5,544.53	12,626.60	149	44,967.02	26,775.83	5,538.80	12,652.38
24	45,033.70	26,862.82	5,545.15	12,625.73	87	45,004.15	26,811.83	5,531.47	12,660.85	150	45,043.20	26,845.65	5,541.87	12,655.68
25	45,002.10	26,835.65	5,528.58	12,637.87	88	44,994.07	26,810.98	5,536.82	12,646.27	151	45,012.02	26,835.15	5,537.45	12,639.42
26	44,955.38	26,786.33	5,542.08	12,626.97	89	44,956.58	26,802.42	5,529.32	12,624.85	152	44,984.62	26,821.22	5,532.23	12,631.17
27	45,003.27	26,829.85	5,538.20	12,635.22	90	44,960.72	26,779.45	5,534.70	12,646.57	153	45,015.62	26,823.85	5,530.18	12,661.58
28	44,995.00	26,776.03	5,539.58	12,679.38	91	45,012.77	26,839.75	5,538.98	12,634.03	154	45,013.50	26,838.15	5,556.20	12,619.15
29	44,975.92	26,803.30	5,537.08	12,635.53	92	45,026.48	26,842.63	5,522.25	12,661.60	155	44,980.95	26,813.70	5,532.12	12,635.13
30	44,999.98	26,809.93	5,548.85	12,641.20	93	44,984.88	26,813.63	5,528.62	12,642.63	156	45,001.87	26,810.47	5,532.22	12,659.18
31	44,982.92	26,808.67	5,520.02	12,654.23	94	45,057.80	26,845.57	5,539.22	12,673.02	157	44,996.58	26,813.83	5,535.83	12,646.92
32	44,991.65	26,833.18	5,530.98	12,627.48	95	45,004.95	26,820.98	5,538.27	12,645.70	158	44,981.02	26,786.18	5,533.20	12,661.63
33	45,001.65	26,834.00	5,529.85	12,637.80	96	44,976.12	26,814.67	5,544.80	12,616.85	159	45,032.43	26,855.07	5,541.58	12,635.78
34	45,002.62	26,823.03	5,536.17	12,643.42	97	45,030.15	26,827.05	5,546.43	12,656.67	160	44,966.05	26,797.20	5,528.95	12,639.90
35	45,014.98	26,823.95	5,545.05	12,645.98	98	45,001.33	26,825.25	5,536.18	12,639.90	161	44,982.85	26,813.93	5,531.77	12,637.15
36	44,967.98	26,810.45	5,538.58	12,618.95	99	44,985.80	26,807.48	5,526.83	12,651.48	162	44,966.77	26,768.18	5,535.47	12,663.12
37	45,023.83	26,844.62	5,550.33	12,628.88	100	45,005.72	26,822.73	5,526.10	12,656.88	163	44,947.32	26,801.78	5,524.98	12,620.55
38	45,015.58	26,831.33	5,526.97	12,657.28	101	44,967.83	26,806.13	5,531.83	12,629.87	164	44,975.83	26,788.25	5,542.62	12,644.97
39	44,985.15	26,821.87	5,529.43	12,633.85	102	44,989.45	26,835.18	5,515.75	12,638.52	165	45,016.33	26,837.17	5,542.97	12,636.20
40	45,008.60	26,838.52	5,541.52	12,628.57	103	45,044.52	26,852.95	5,529.02	12,641.92	166	44,963.83	26,770.50	5,526.32	12,667.02
41	45,003.90	26,808.48	5,546.88	12,648.53	104	44,979.20	26,803.10	5,537.87	12,638.23	167	45,004.10	26,826.23	5,527.57	12,650.30
42	44,981.38	26,812.52	5,515.67	12,653.20	105	45,009.38	26,809.45	5,541.08	12,658.85	168	44,993.27	26,823.60	5,532.23	12,637.43
43	44,964.80	26,782.47	5,529.78	12,652.55	106	44,994.00	26,799.88	5,542.47	12,651.65	169	45,001.85	26,829.13	5,523.83	12,648.88
44	44,920.45	26,790.88	5,515.05	12,614.52	107	45,028.78	26,819.95	5,540.80	12,668.03	170	45,000.63	26,822.88	5,533.65	12,644.10
45	44,998.83	26,820.15	5,544.43	12,634.25	108	45,000.83	26,813.88	5,540.58	12,646.37	171	44,973.72	26,812.98	5,528.83	12,631.90
46	45,000.12	26,838.28	5,528.30	12,633.53	109	44,971.23	26,797.23	5,543.02	12,630.98	172	44,988.45	26,842.92	5,532.92	12,612.62
47	44,988.40	26,778.88	5,549.68	12,659.83	110	45,009.78	26,841.70	5,548.50	12,619.58	173	45,014.62	26,822.75	5,538.87	12,653.00
48	44,983.25	26,810.37	5,528.90	12,643.98	111	44,976.62	26,811.23	5,539.40	12,625.98	174	44,978.85	26,808.55	5,532.38	12,637.92
49	45,042.70	26,832.13	5,538.12	12,672.45	112	44,970.48	26,806.60	5,526.33	12,637.55	175	44,984.07	26,802.40	5,551.80	12,629.87
50	44,988.83	26,796.93	5,556.78	12,635.12	113	44,997.97	26,815.83	5,520.13	12,662.00	176	44,973.22	26,785.72	5,526.92	12,660.58
51	45,000.52	26,812.18	5,541.78	12,646.55	114	44,973.12	26,795.80	5,524.63	12,652.68	177	44,972.37	26,790.13	5,559.30	12,622.93
52	45,022.33	26,838.38	5,541.07	12,642.88	115	44,966.68	26,809.02	5,536.40	12,621.27	178	45,045.23	26,847.10	5,536.18	12,661.95
53	45,002.87	26,818.20	5,542.58	12,642.08	116	45,023.90	26,859.13	5,536.45	12,628.32	179	44,995.52	26,797.28	5,534.35	12,663.88
54	45,062.55	26,835.65	5,527.98	12,698.92	117	44,944.73	26,787.02	5,529.43	12,628.28	180	44,947.98	26,797.75	5,519.53	12,630.70
55	44,999.88	26,816.68	5,524.95	12,658.25	118	45,024.00	26,843.38	5,540.05	12,640.57	181	45,013.60	26,821.33	5,537.15	12,655.12
56	45,012.10	26,814.50	5,545.28	12,652.32	119	44,988.18	26,798.33	5,538.33	12,651.52	182	44,987.28	26,801.22	5,537.03	12,649.03
57	44,981.80	26,797.07	5,540.88	12,643.85	120	44,996.87	26,797.37	5,546.75	12,652.75	183	44,987.72	26,771.62	5,557.20	12,658.90
58	45,011.38	26,825.73	5,544.53	12,641.12	121	45,053.85	26,870.62	5,534.22	12,649.02	184	45,021.17	26,824.12	5,524.95	12,672.10
59	45,030.25	26,868.28	5,516.55	12,645.42	122	44,963.52	26,799.00	5,531.25	12,633.27	Average	44,998.79	26,817.66	5,535.74	12,645.40
60	45,044.80	26,849.88	5,551.40	12,643.52	123	45,015.92	26,839.82	5,539.40	12,636.70					
61	44,989.28	26,808.62	5,542.72	12,637.95	124	44,985.55	26,794.48	5,541.67	12,649.40					
62	44,978.92	26,789.70	5,546.48	12,642.73	125	45,057.33	26,839.40	5,552.45	12,665.48					

Sustainability – I/O Request Throughput Distribution Graph

Sustainability – Average Response Time (ms) Distribution Data

	Start	Stop	Interval	Duration
Ramp-Up/Start-Up	18:23:48	18:28:48	0-4	0:05:00
Measurement Interval	18:28:48	21:28:48	5-184	3:00:00

Interval	All ASUs	ASU1	ASU2	ASU3	Interval	All ASUs	ASU1	ASU2	ASU3	Interval	All ASUs	ASU1	ASU2	ASU3
0	16.11	15.93	20.37	14.62	63	15.47	15.21	19.96	14.07	126	15.10	14.89	19.56	13.57
1	16.04	15.72	20.45	14.78	64	15.11	14.90	19.63	13.55	127	15.45	15.19	19.94	14.03
2	15.37	15.12	19.89	13.93	65	15.12	14.92	19.58	13.60	128	14.89	14.71	19.35	13.30
3	15.00	14.81	19.51	13.42	66	15.23	15.00	19.70	13.74	129	14.93	14.75	19.38	13.36
4	15.04	14.84	19.53	13.50	67	14.98	14.79	19.50	13.40	130	15.10	14.89	19.57	13.59
5	15.42	15.20	19.83	13.96	68	15.23	14.99	19.79	13.74	131	17.00	16.62	21.42	15.88
6	15.30	15.07	19.77	13.84	69	15.11	14.90	19.61	13.58	132	14.93	14.75	19.39	13.36
7	15.14	14.93	19.62	13.63	70	15.11	14.91	19.63	13.55	133	15.66	15.40	20.10	14.29
8	16.29	15.92	20.77	15.12	71	14.98	14.78	19.49	13.42	134	14.80	14.64	19.30	13.19
9	15.40	15.15	19.88	13.98	72	15.33	15.10	19.81	13.86	135	15.12	14.91	19.61	13.60
10	15.76	15.45	20.21	14.47	73	15.20	14.97	19.71	13.69	136	14.94	14.77	19.42	13.35
11	16.67	16.29	21.08	15.54	74	14.92	14.74	19.37	13.39	137	15.09	14.88	19.53	13.58
12	15.26	15.03	19.70	13.80	75	14.86	14.70	19.36	13.24	138	15.00	14.81	19.47	13.44
13	15.64	15.38	20.16	14.20	76	15.41	15.16	19.89	13.98	139	16.85	16.45	21.26	15.78
14	15.62	15.33	20.08	14.27	77	15.14	14.94	19.58	13.63	140	15.37	15.13	19.88	13.93
15	20.05	19.56	24.47	19.15	78	15.03	14.83	19.48	13.53	141	14.86	14.69	19.35	13.26
16	15.71	15.42	20.16	14.36	79	15.37	15.14	19.83	13.90	142	14.96	14.78	19.40	13.39
17	15.45	15.18	19.98	14.02	80	15.32	15.08	19.76	13.89	143	15.27	15.04	19.71	13.81
18	15.54	15.30	19.99	14.11	81	15.17	14.95	19.67	13.68	144	15.29	15.05	19.78	13.82
19	14.97	14.78	19.46	13.41	82	15.26	15.03	19.70	13.79	145	14.87	14.70	19.32	13.28
20	15.22	15.01	19.71	13.70	83	15.25	15.03	19.72	13.78	146	15.32	15.09	19.78	13.85
21	15.18	14.97	19.66	13.68	84	14.82	14.66	19.30	13.22	147	15.03	14.83	19.52	13.50
22	15.06	14.84	19.60	13.53	85	19.57	19.07	23.96	18.72	148	15.08	14.87	19.52	13.58
23	15.17	14.96	19.62	13.66	86	14.92	14.74	19.41	13.32	149	14.89	14.72	19.37	13.31
24	15.13	14.92	19.64	13.61	87	15.22	15.00	19.67	13.75	150	15.41	15.17	19.88	13.98
25	15.25	15.02	19.73	13.78	88	15.19	14.95	19.70	13.70	151	15.03	14.83	19.48	13.49
26	15.05	14.84	19.55	13.52	89	15.46	15.19	19.96	14.06	152	15.04	14.85	19.53	13.49
27	15.10	14.90	19.62	13.56	90	14.92	14.74	19.45	13.34	153	15.15	14.95	19.64	13.63
28	15.01	14.82	19.50	13.45	91	15.32	15.08	19.82	13.86	154	15.21	14.99	19.69	13.70
29	15.14	14.93	19.65	13.62	92	15.04	14.84	19.53	13.48	155	15.02	14.83	19.52	13.45
30	15.25	15.02	19.73	13.79	93	15.25	15.02	19.80	13.76	156	16.07	15.76	20.49	14.80
31	14.94	14.76	19.46	13.36	94	15.63	15.35	20.15	14.26	157	15.27	15.04	19.75	13.81
32	14.87	14.70	19.37	13.26	95	15.26	15.04	19.73	13.77	158	15.33	15.09	19.82	13.86
33	15.42	15.17	19.90	13.98	96	14.94	14.77	19.39	13.36	159	15.21	14.99	19.72	13.71
34	15.03	14.83	19.55	13.46	97	15.50	15.22	19.96	14.13	160	15.11	14.92	19.57	13.56
35	15.21	15.00	19.68	13.71	98	15.00	14.80	19.51	13.45	161	14.86	14.69	19.34	13.24
36	14.76	14.60	19.29	13.10	99	14.89	14.71	19.37	13.30	162	15.23	15.02	19.69	13.74
37	15.68	15.41	20.16	14.31	100	15.19	14.97	19.68	13.69	163	14.48	14.37	18.95	12.77
38	15.49	15.25	19.93	14.07	101	14.92	14.74	19.43	13.32	164	15.16	14.95	19.62	13.64
39	15.24	15.01	19.74	13.75	102	15.00	14.81	19.53	13.44	165	15.06	14.86	19.54	13.49
40	15.06	14.86	19.56	13.51	103	15.08	14.88	19.60	13.54	166	14.93	14.75	19.43	13.34
41	15.03	14.83	19.48	13.49	104	15.00	14.80	19.47	13.46	167	15.05	14.84	19.59	13.52
42	14.95	14.76	19.46	13.38	105	15.07	14.88	19.50	13.54	168	15.14	14.92	19.58	13.68
43	15.21	14.98	19.65	13.74	106	15.14	14.92	19.59	13.65	169	15.88	15.60	20.28	14.53
44	14.90	14.72	19.41	13.31	107	15.13	14.93	19.56	13.63	170	15.03	14.82	19.56	13.48
45	15.21	14.99	19.71	13.70	108	14.96	14.77	19.47	13.37	171	15.14	14.92	19.62	13.63
46	14.88	14.70	19.35	13.29	109	15.64	15.41	20.09	14.17	172	15.08	14.88	19.62	13.53
47	15.12	14.91	19.56	13.62	110	14.96	14.78	19.42	13.38	173	15.10	14.88	19.63	13.58
48	15.37	15.13	19.82	13.93	111	14.75	14.60	19.30	13.09	174	15.02	14.83	19.54	13.45
49	15.27	15.04	19.77	13.79	112	15.02	14.83	19.52	13.47	175	15.18	14.98	19.56	13.69
50	15.02	14.83	19.48	13.47	113	15.05	14.86	19.53	13.52	176	15.07	14.86	19.55	13.54
51	17.22	16.77	21.61	16.24	114	15.16	14.96	19.62	13.66	177	15.80	15.52	20.26	14.43
52	15.23	15.00	19.74	13.74	115	14.74	14.59	19.25	13.10	178	15.61	15.33	20.08	14.25
53	15.15	14.93	19.65	13.65	116	15.01	14.82	19.50	13.44	179	15.01	14.82	19.45	13.46
54	15.48	15.21	19.95	14.08	117	15.22	15.00	19.71	13.74	180	14.49	14.37	18.98	12.78
55	15.40	15.16	19.84	13.99	118	15.18	14.97	19.64	13.68	181	16.00	15.68	20.42	14.75
56	15.09	14.88	19.54	13.57	119	14.88	14.71	19.41	13.26	182	15.16	14.94	19.67	13.65
57	15.19	14.97	19.70	13.67	120	15.08	14.88	19.55	13.56	183	15.45	15.19	19.94	14.02
58	15.20	14.98	19.68	13.70	121	15.24	15.02	19.73	13.76	184	15.36	15.11	19.89	13.92
59	15.06	14.86	19.57	13.53	122	14.87	14.70	19.33	13.26	Average	15.27	15.04	19.74	13.78
60	15.65	15.36	20.12	14.30	123	15.08	14.87	19.62	13.53					
61	15.09	14.89	19.57	13.57	124	15.19	14.97	19.66	13.69					
62	15.28	15.04	19.72	13.83	125	15.25	15.02	19.78	13.76					

Sustainability – Average Response Time (ms) Distribution Graph
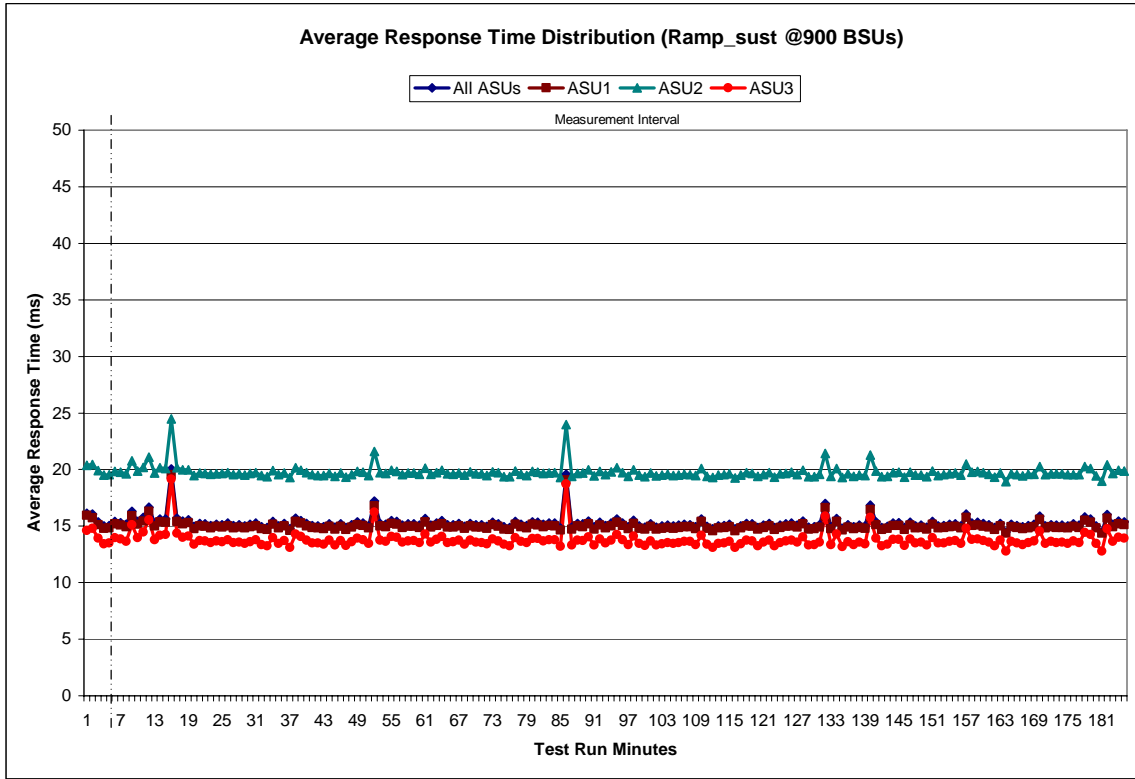
Sustainability – Response Time Frequency Distribution Data

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	8,779	87,779	125,191	135,816	147,288	137,784	106,292	96,231
Write	-	172	1,522	3,989	6,749	8,587	8,077	8,251
All ASUs	8,779	87,951	126,713	139,805	154,037	146,371	114,369	104,482
ASU1	8,268	82,154	117,732	128,987	140,880	132,565	102,978	93,586
ASU2	511	5,738	8,402	9,240	10,268	9,974	7,848	7,253
ASU3	-	59	579	1,578	2,889	3,832	3,543	3,643

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	263,290	220,872	275,783	325,197	757,339	996,081	3,131,975	6,697,196
Write	31,806	40,379	76,211	103,881	301,550	466,212	1,818,490	5,381,128
All ASUs	295,096	261,251	351,994	429,078	1,058,889	1,462,293	4,950,465	12,078,324
ASU1	260,673	227,130	299,677	361,287	871,304	1,176,899	3,836,714	8,773,555
ASU2	20,384	17,501	22,755	27,440	70,832	101,971	373,983	1,033,282
ASU3	14,039	16,620	29,562	40,351	116,753	183,423	739,768	2,271,487

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	8,024,539	12,076,658	11,270,251	58,825,628	35,372,647	19,930,122	11,454,553	21,198,987
Write	8,525,239	17,293,963	19,780,508	148,412,196	72,342,293	15,798,642	2,282,705	1,627,421
All ASUs	16,549,778	29,370,621	31,050,759	207,237,824	107,714,940	35,728,764	13,737,258	22,826,408
ASU1	11,310,258	18,825,573	18,997,388	116,512,663	60,838,436	22,960,307	9,878,401	13,692,869
ASU2	1,550,930	2,906,736	3,183,916	21,948,309	12,178,792	5,073,138	2,770,525	8,446,116
ASU3	3,688,590	7,638,312	8,869,455	68,776,852	34,697,712	7,695,319	1,088,332	687,423

Sustainability – Response Time Frequency Distribution Graph
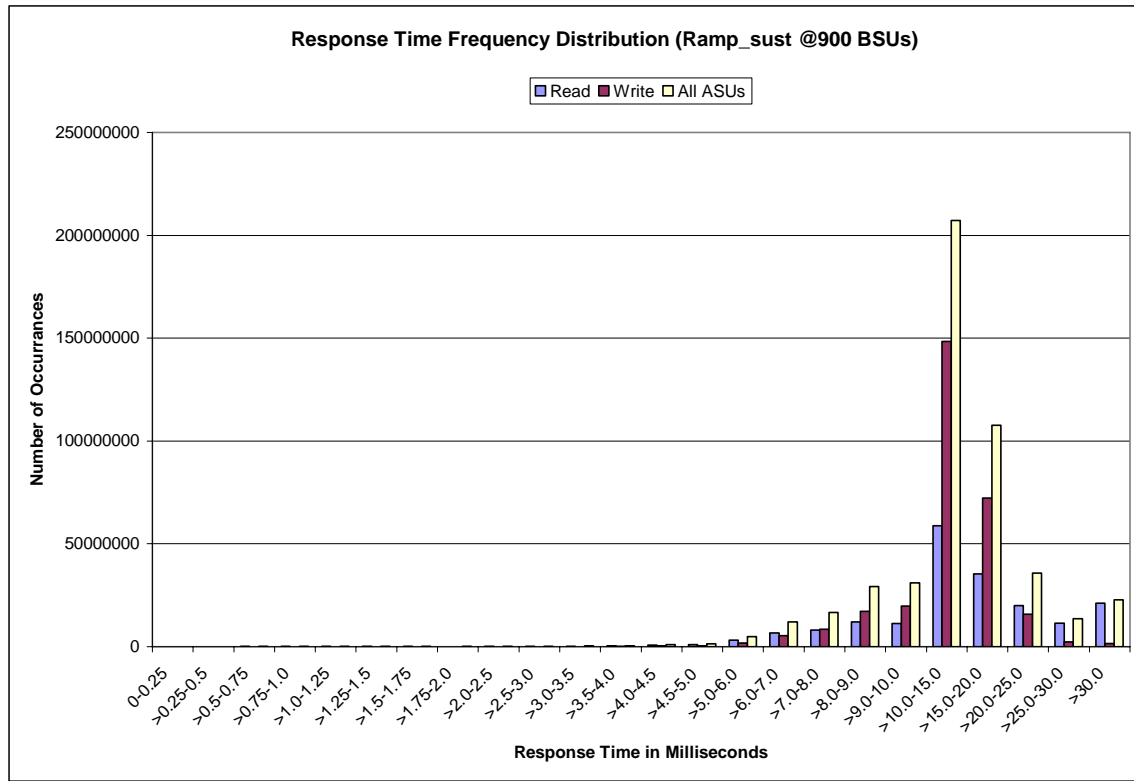
Sustainability – Measured Intensity Multiplier and Coefficient of Variation

	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	0.1405	0.2810	0.2100	0.0180	0.0700	0.0350	0.2810
COV	0.003	0.001	0.002	0.001	0.005	0.002	0.004	0.001

Clause 3.4.3

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.*

Clauses 5.1.0 and 5.3.13.2

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%.*

Clause 5.3.13.3

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, Response Time Ramp, Repeatability, and Persistence Test Runs are documented in "Appendix E: SPC-1 Workload Generator Input Parameters" on Page 67.

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

900 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	21:29:09	21:34:10	0-4	0:05:01
Measurement Interval	21:34:10	21:44:10	5-14	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	44,964.63	26,794.88	5,531.93	12,637.82
1	44,988.53	26,846.43	5,524.60	12,617.50
2	45,037.22	26,839.47	5,542.28	12,655.47
3	45,021.42	26,849.88	5,526.60	12,644.93
4	44,971.55	26,802.47	5,550.50	12,618.58
5	45,001.52	26,829.80	5,541.57	12,630.15
6	44,998.85	26,816.28	5,537.63	12,644.93
7	44,984.93	26,792.67	5,541.78	12,650.48
8	45,010.95	26,817.60	5,536.05	12,657.30
9	45,079.70	26,871.47	5,532.90	12,675.33
10	45,024.90	26,845.90	5,526.03	12,652.97
11	45,000.42	26,844.38	5,525.77	12,630.27
12	45,039.17	26,838.42	5,544.88	12,655.87
13	45,017.77	26,830.35	5,537.17	12,650.25
14	44,989.93	26,824.73	5,528.90	12,636.30
Average	45,014.81	26,831.16	5,535.27	12,648.39

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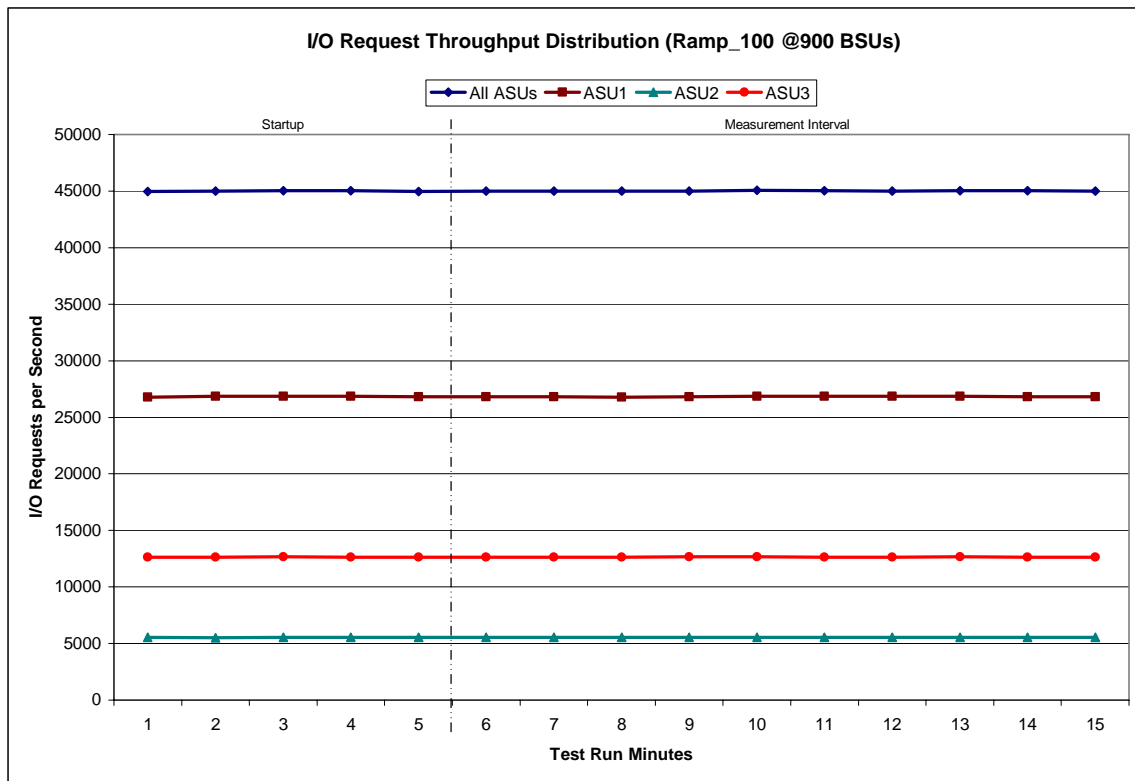
IOPS Test Run – Average Response Time (ms) Distribution Data

900 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	21:29:09	21:34:10	0-4	0:05:01
Measurement Interval	21:34:10	21:44:10	5-14	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	15.99	15.90	20.31	14.30
1	14.99	14.79	19.58	13.40
2	15.36	15.12	19.96	13.86
3	15.28	15.05	19.85	13.76
4	15.25	15.03	19.78	13.74
5	15.17	14.96	19.78	13.59
6	15.08	14.86	19.71	13.50
7	15.16	14.94	19.71	13.63
8	15.24	15.01	19.86	13.70
9	15.48	15.22	20.09	14.01
10	16.63	16.23	21.10	15.53
11	15.16	14.95	19.75	13.61
12	15.73	15.44	20.28	14.33
13	15.25	15.02	19.82	13.75
14	14.99	14.80	19.55	13.39
Average	15.39	15.14	19.97	13.90

## IOPS Test Run – Average Response Time (ms) 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	590	5,501	7,514	7,944	8,878	8,494	6,663	5,751
Write	0	2	46	129	259	283	321	375
All ASUs	590	5,503	7,560	8,073	9,137	8,777	6,984	6,126
ASU1	564	5,175	7,058	7,558	8,482	8,125	6,450	5,543
ASU2	26	328	488	465	559	520	402	409
ASU3	0	0	14	50	96	132	132	174

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	15,430	12,726	16,435	19,451	42,802	55,339	179,426	366,656
Write	1,500	2,301	4,408	6,038	16,571	24,558	100,317	284,071
All ASUs	16,930	15,027	20,843	25,489	59,373	79,897	279,743	650,727
ASU1	15,176	13,122	17,883	21,535	49,037	64,686	217,901	475,961
ASU2	1,108	956	1,258	1,629	3,928	5,523	21,202	55,331
ASU3	646	949	1,702	2,325	6,408	9,688	40,640	119,435

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	452,274	654,461	630,157	3,231,993	1,965,410	1,106,249	637,819	1,212,860
Write	473,974	919,875	1,100,176	8,114,578	4,124,779	939,774	139,524	103,588
All ASUs	926,248	1,574,336	1,730,333	11,346,571	6,090,189	2,046,023	777,343	1,316,448
ASU1	634,868	1,012,790	1,059,749	6,387,871	3,428,107	1,302,143	556,186	792,364
ASU2	86,622	155,276	177,613	1,200,982	686,281	286,676	154,698	478,765
ASU3	204,758	406,270	492,971	3,757,718	1,975,801	457,204	66,459	45,319

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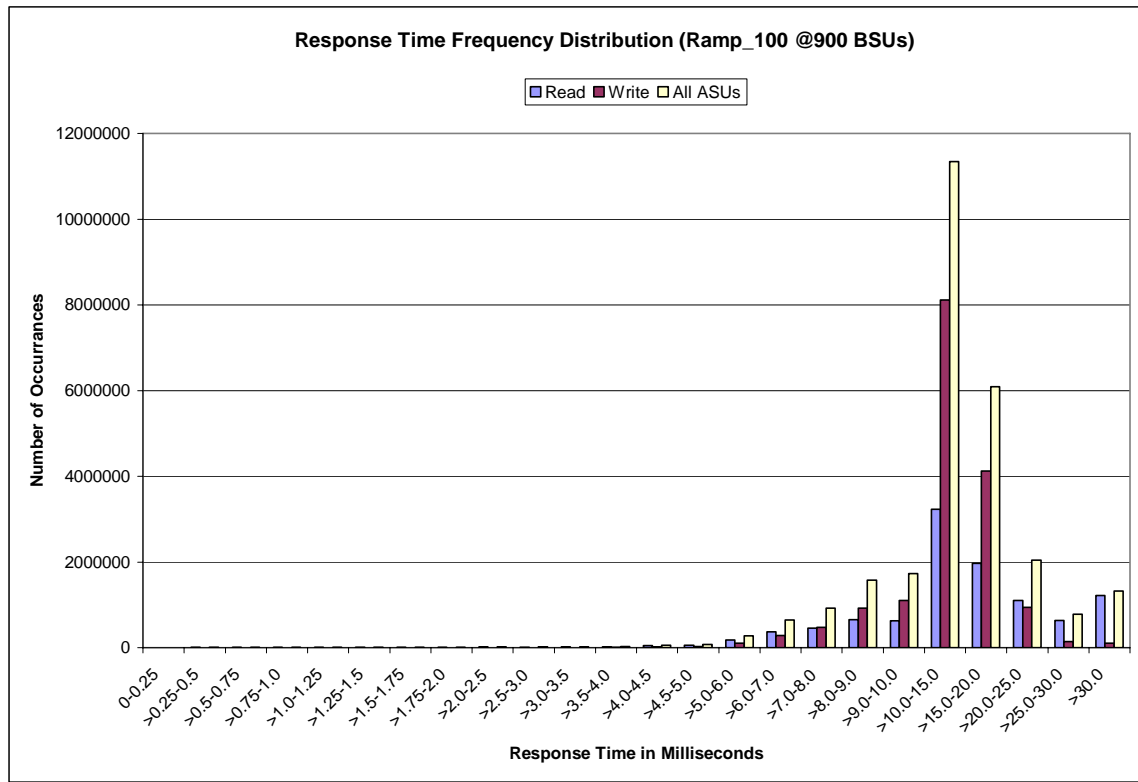
IOPS Test Run – I/O Request Information

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
27,008,270	25,691,822	1,316,448

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	0.0699	0.2100	0.0180	0.0699	0.0350	0.2810
COV	0.002	0.001	0.002	0.001	0.006	0.002	0.003	0.001

Clause 3.4.3

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.*

Clauses 5.1.0 and 5.3.13.2

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%.*

Clause 5.3.13.3

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 13.

In addition, the Average Response Time measured during the 10% Test Run is the value for the SPC-1 LRT™ 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, Response Time Ramp, Repeatability, and Persistence Test Runs are documented in "Appendix E: SPC-1 Workload Generator Input Parameters" on Page 67.

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
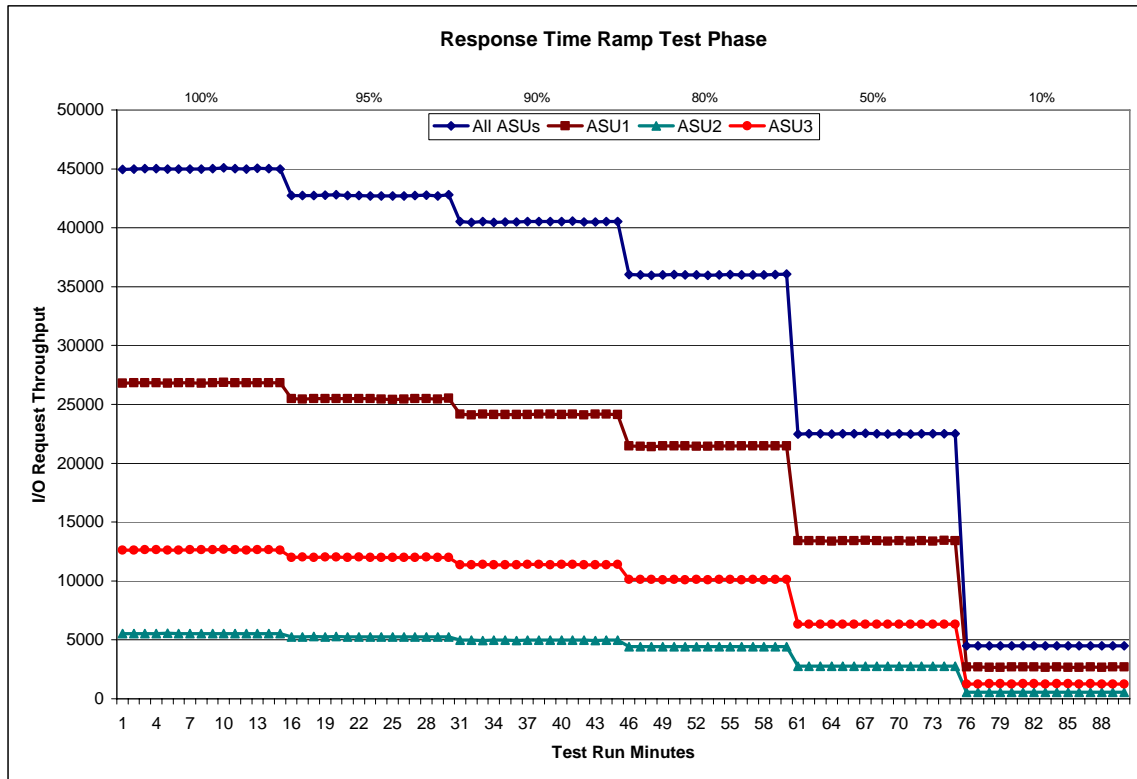
Response Time Ramp Distribution (IOPS) Data

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 - 900 BSUs	Start	Stop	Interval	Duration	95% Load Level - 855 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	21:29:09	21:34:10	0-4	0:05:01	Start-Up/Ramp-Up	21:44:32	21:49:33	0-4	0:05:01
Measurement Interval	21:34:10	21:44:10	5-14	0:10:00	Measurement Interval	21:49:33	21:59:33	5-14	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	44,964.63	26,794.88	5,531.93	12,637.82	0	42,734.90	25,473.70	5,249.62	12,011.58
1	44,988.53	26,846.43	5,524.60	12,617.50	1	42,737.67	25,456.95	5,244.60	12,036.12
2	45,037.22	26,839.47	5,542.28	12,655.47	2	42,751.32	25,488.72	5,274.23	11,988.37
3	45,021.42	26,849.88	5,526.60	12,644.93	3	42,783.52	25,496.83	5,256.47	12,030.22
4	44,971.55	26,802.47	5,550.50	12,618.58	4	42,804.92	25,481.50	5,275.48	12,047.93
5	45,001.52	26,829.80	5,541.57	12,630.15	5	42,724.28	25,474.12	5,240.38	12,009.78
6	44,998.85	26,816.28	5,537.63	12,644.93	6	42,739.53	25,470.45	5,248.80	12,020.28
7	44,984.93	26,792.67	5,541.78	12,650.48	7	42,709.93	25,468.00	5,243.12	11,998.82
8	45,010.95	26,817.60	5,536.05	12,657.30	8	42,714.48	25,445.53	5,262.92	12,006.03
9	45,079.70	26,871.47	5,532.90	12,675.33	9	42,713.57	25,429.83	5,271.43	12,012.30
10	45,024.90	26,845.90	5,526.03	12,652.97	10	42,720.68	25,463.75	5,261.82	11,995.12
11	45,000.42	26,844.38	5,525.77	12,630.27	11	42,741.28	25,489.25	5,248.62	12,003.42
12	45,039.17	26,838.42	5,544.88	12,655.87	12	42,764.42	25,494.17	5,251.55	12,018.70
13	45,017.77	26,830.35	5,537.17	12,650.25	13	42,720.90	25,455.70	5,263.55	12,001.65
14	44,989.93	26,824.73	5,528.90	12,636.30	14	42,790.93	25,514.98	5,266.68	12,009.27
Average	45,014.81	26,831.16	5,535.27	12,648.39	Average	42,734.00	25,470.58	5,255.89	12,007.54

90% Load Level - 810 BSUs	Start	Stop	Interval	Duration	80% Load Level - 720 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	21:59:56	22:04:57	0-4	0:05:01	Start-Up/Ramp-Up	22:15:18	22:20:19	0-4	0:05:01
Measurement Interval	22:04:57	22:14:57	5-14	0:10:00	Measurement Interval	22:20:19	22:30:19	5-14	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	40,523.55	24,172.77	4,981.60	11,369.18	0	36,033.80	21,465.02	4,439.63	10,129.15
1	40,471.38	24,110.60	4,983.17	11,377.62	1	35,989.75	21,422.80	4,442.15	10,124.80
2	40,523.50	24,156.70	4,961.95	11,404.85	2	35,955.47	21,413.22	4,414.30	10,127.95
3	40,469.72	24,118.72	4,984.15	11,366.85	3	36,007.28	21,476.88	4,427.28	10,103.12
4	40,479.88	24,121.73	4,972.18	11,385.97	4	36,031.47	21,473.43	4,429.40	10,128.63
5	40,480.32	24,133.10	4,955.25	11,391.97	5	35,996.40	21,462.27	4,424.52	10,109.62
6	40,528.57	24,142.87	4,983.62	11,402.08	6	35,979.57	21,422.70	4,429.65	10,127.22
7	40,533.70	24,158.33	4,975.23	11,400.13	7	35,963.35	21,447.22	4,416.92	10,099.22
8	40,529.02	24,185.42	4,974.78	11,368.82	8	36,006.42	21,456.08	4,436.17	10,114.17
9	40,518.28	24,135.87	4,985.23	11,397.18	9	36,013.45	21,459.53	4,432.70	10,121.22
10	40,546.82	24,153.40	4,982.65	11,410.77	10	36,002.32	21,464.85	4,435.48	10,101.98
11	40,475.08	24,112.20	4,990.18	11,372.70	11	36,006.35	21,457.12	4,427.93	10,121.30
12	40,500.93	24,155.67	4,957.68	11,387.58	12	35,992.58	21,461.78	4,431.78	10,099.02
13	40,509.45	24,159.90	4,974.72	11,374.83	13	36,023.02	21,478.90	4,418.35	10,125.77
14	40,516.38	24,132.17	4,981.30	11,402.92	14	36,048.82	21,466.22	4,434.33	10,148.27
Average	40,513.86	24,146.89	4,976.07	11,390.90	Average	36,003.23	21,457.67	4,428.78	10,116.78

50% Load Level - 490 BSUs	Start	Stop	Interval	Duration	10% Load Level - 90 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	22:30:37	22:35:38	0-4	0:05:01	Start-Up/Ramp-Up	22:45:55	22:50:56	0-4	0:05:01
Measurement Interval	22:35:38	22:45:38	5-14	0:10:00	Measurement Interval	22:50:56	23:00:56	5-14	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	22,484.70	13,406.98	2,762.83	6,314.88	0	4,503.02	2,684.53	556.90	1,261.58
1	22,511.62	13,407.42	2,763.77	6,340.43	1	4,495.62	2,681.92	551.98	1,261.72
2	22,507.18	13,409.72	2,771.28	6,326.18	2	4,499.92	2,676.97	550.38	1,272.57
3	22,483.53	13,386.52	2,774.97	6,322.05	3	4,490.73	2,673.53	552.08	1,265.12
4	22,500.97	13,418.35	2,761.58	6,321.03	4	4,497.10	2,686.22	549.30	1,261.58
5	22,510.92	13,427.77	2,770.82	6,312.33	5	4,500.88	2,681.70	553.85	1,265.33
6	22,534.80	13,434.10	2,778.05	6,322.65	6	4,503.88	2,683.65	554.62	1,265.62
7	22,503.27	13,418.15	2,760.42	6,324.70	7	4,484.92	2,675.72	553.58	1,255.62
8	22,473.18	13,391.82	2,767.67	6,313.70	8	4,496.55	2,679.97	551.60	1,264.98
9	22,496.68	13,404.62	2,769.27	6,322.80	9	4,496.13	2,675.45	555.38	1,265.30
10	22,491.43	13,396.90	2,770.70	6,323.83	10	4,494.45	2,679.68	554.23	1,260.53
11	22,527.03	13,433.37	2,766.40	6,327.27	11	4,498.32	2,681.45	551.42	1,265.45
12	22,500.02	13,389.40	2,776.82	6,333.80	12	4,480.32	2,672.68	549.78	1,257.85
13	22,519.72	13,449.12	2,756.45	6,314.15	13	4,499.50	2,686.03	551.90	1,261.57
14	22,509.92	13,412.50	2,769.65	6,327.77	14	4,496.88	2,682.42	552.38	1,262.08
Average	22,506.70	13,415.77	2,768.62	6,322.30	Average	4,495.18	2,679.88	552.88	1,262.43

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Response Time Ramp Distribution (IOPS) Graph

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

34 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	22:45:55	22:50:56	0-4	0:05:01
Measurement Interval	22:50:56	23:00:56	5-14	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	2.13	2.78	3.10	0.31
1	2.13	2.79	3.11	0.31
2	2.13	2.80	3.14	0.31
3	2.14	2.81	3.12	0.31
4	2.16	2.83	3.12	0.31
5	2.15	2.82	3.13	0.31
6	2.15	2.81	3.16	0.31
7	2.14	2.80	3.10	0.31
8	2.14	2.79	3.14	0.31
9	2.14	2.80	3.11	0.31
10	2.14	2.80	3.11	0.31
11	2.19	2.85	3.16	0.37
12	2.15	2.81	3.12	0.31
13	2.14	2.80	3.12	0.32
14	2.15	2.82	3.15	0.31
Average	2.15	2.81	3.13	0.32

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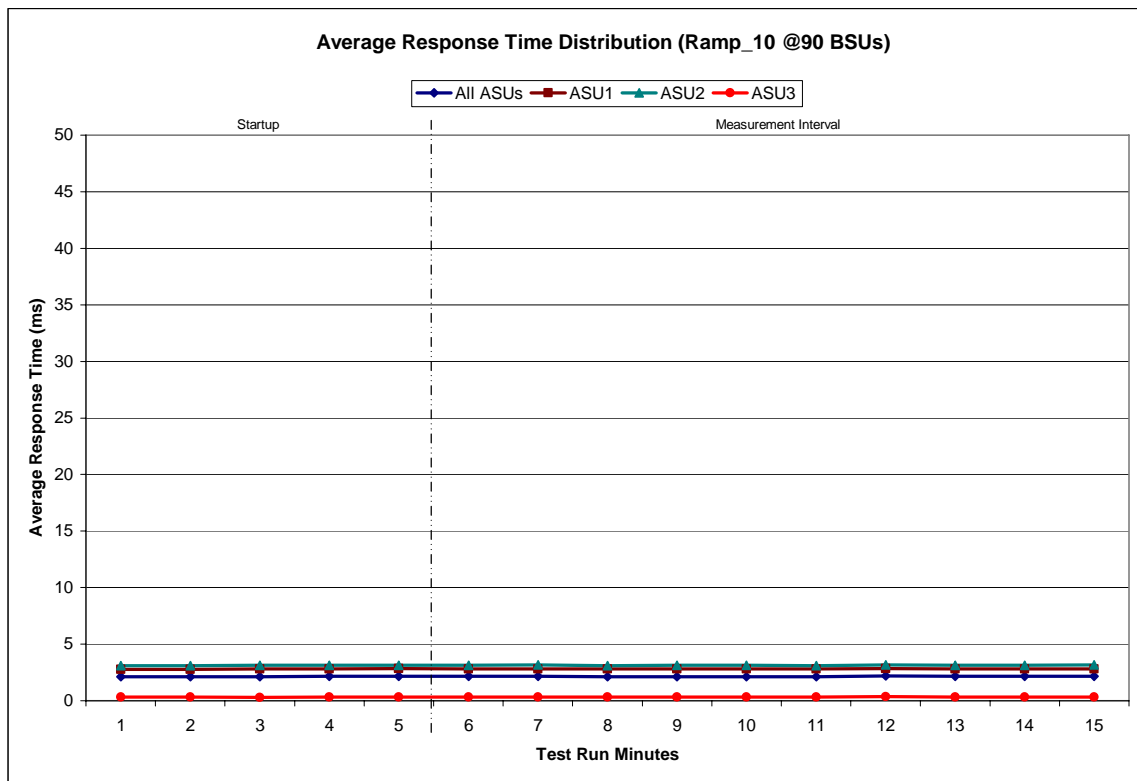
SPC-1 LRT™ (10%) – Measured Intensity Multiplier and Coefficient of Variation

	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	0.0349	0.2808	0.0700	0.2105	0.0180	0.0701	0.0349	0.2808
COV	0.013	0.002	0.007	0.003	0.020	0.006	0.007	0.002

Clause 3.4.3

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.*

Clauses 5.1.0 and 5.3.13.2

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%.*

Clause 5.3.13.3

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

Repeatability Test

Clause 5.4.5

The Repeatability Test demonstrates the repeatability and reproducibility of the SPC-1 IOPS™ primary metric and SPC-1 LRT™ metric 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™ metric. Each Average Response Time value must be less than the SPC-1 LRT™ 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 9.2.4.7.4

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 Repeatability Test.*
2. *An I/O Request Throughput Distribution graph and table.*
3. *An Average Response Time Distribution graph and table.*
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 Sustainability, IOPS, Response Time Ramp, Repeatability, and Persistence Test Runs are documented in "Appendix E: SPC-1 Workload Generator Input Parameters" on Page 67.

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	*45,014.81*	*2.15*
Repeatability Test Phase 1	44,974.17	2.15
Repeatability Test Phase 2	44,989.31	2.15

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

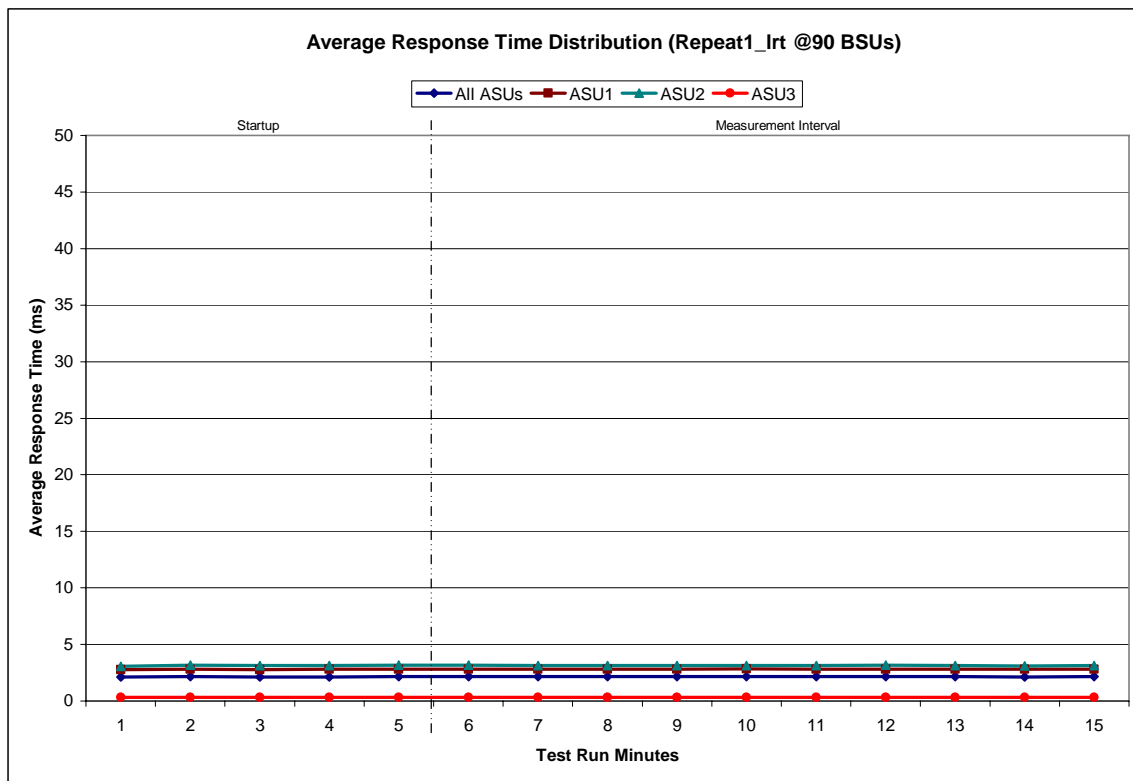| 90 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	23:01:17	23:06:17	0-4	0:05:00
Measurement Interval	23:06:17	23:16:17	5-14	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	4,517.87	2,694.28	557.55	1,266.03
1	4,507.55	2,679.73	557.38	1,270.43
2	4,496.98	2,690.60	549.08	1,257.30
3	4,496.17	2,678.60	549.72	1,267.85
4	4,507.08	2,692.23	548.13	1,266.72
5	4,514.75	2,692.18	553.70	1,268.87
6	4,505.65	2,680.08	557.60	1,267.97
7	4,508.57	2,683.50	557.52	1,267.55
8	4,489.85	2,678.98	554.58	1,256.28
9	4,489.85	2,681.92	553.22	1,254.72
10	4,500.73	2,678.72	554.25	1,267.77
11	4,502.93	2,680.75	555.30	1,266.88
12	4,512.42	2,695.08	554.78	1,262.55
13	4,517.02	2,699.43	552.27	1,265.32
14	4,507.77	2,683.58	560.08	1,264.10
Average	4,504.95	2,685.42	555.33	1,264.20

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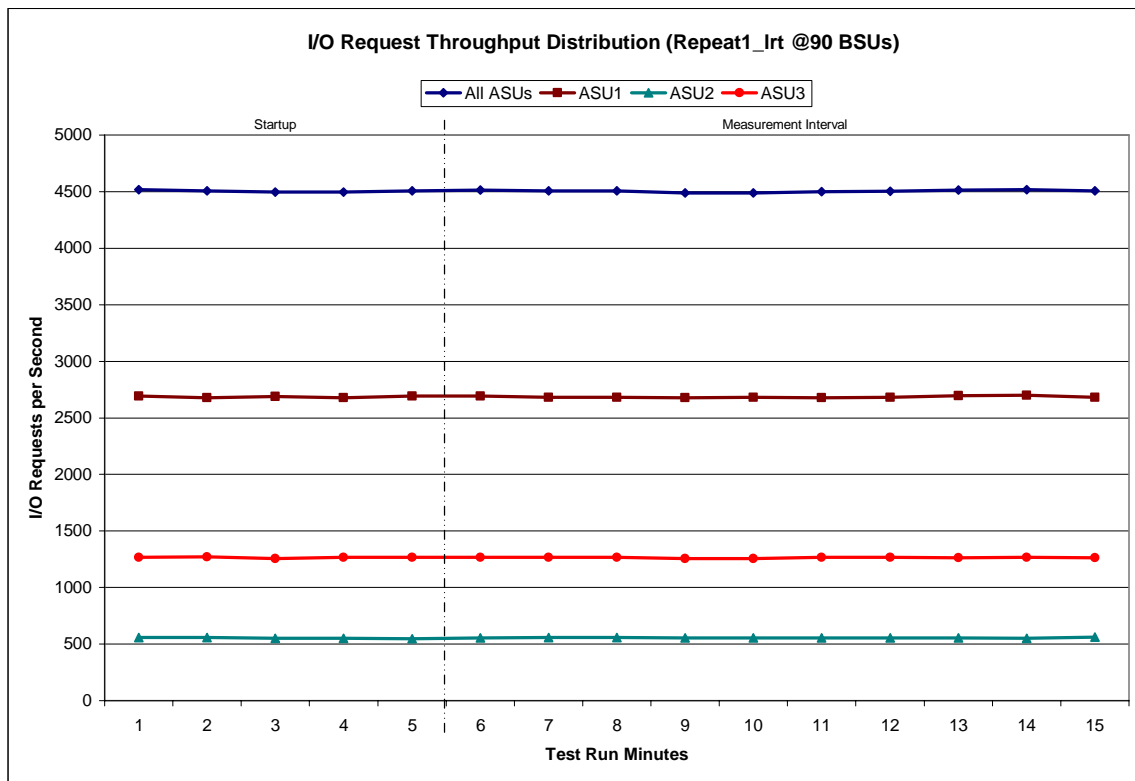
Repeatability 1 LRT –Average Response Time (ms) Distribution Data

90 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	23:01:17	23:06:17	0-4	0:05:00
Measurement Interval	23:06:17	23:16:17	5-14	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	2.12	2.77	3.07	0.32
1	2.16	2.81	3.17	0.32
2	2.14	2.79	3.14	0.31
3	2.14	2.80	3.13	0.31
4	2.16	2.82	3.16	0.33
5	2.15	2.80	3.17	0.32
6	2.15	2.81	3.13	0.32
7	2.15	2.81	3.14	0.32
8	2.16	2.81	3.13	0.33
9	2.17	2.84	3.13	0.31
10	2.14	2.81	3.12	0.31
11	2.16	2.82	3.15	0.32
12	2.14	2.80	3.14	0.32
13	2.14	2.80	3.10	0.31
14	2.14	2.80	3.13	0.31
Average	2.15	2.81	3.13	0.32

Repeatability 1 LRT –Average Response Time (ms) Distribution Graph

Average Response Time Distribution (Repeat1_lrt @90 BSUs)

Repeatability 1 IOPS – I/O Request Throughput Distribution Data

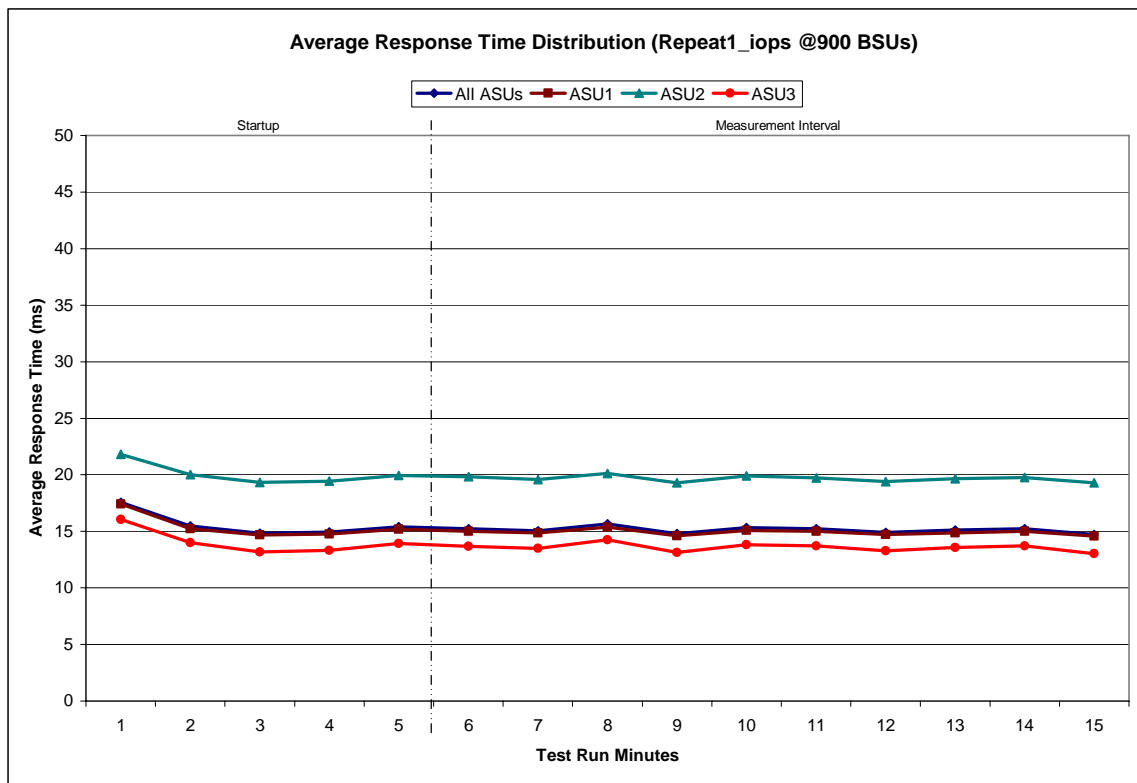| 900 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	23:16:34	23:21:35	0-4	0:05:01
Measurement Interval	23:21:35	23:31:35	5-14	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	45,016.70	26,853.72	5,515.20	12,647.78
1	45,066.50	26,865.75	5,545.70	12,655.05
2	44,946.90	26,818.75	5,523.28	12,604.87
3	45,013.43	26,816.38	5,558.13	12,638.92
4	45,042.78	26,829.83	5,556.48	12,656.47
5	44,989.90	26,817.32	5,542.78	12,629.80
6	44,995.63	26,825.25	5,510.10	12,660.28
7	44,930.25	26,786.55	5,536.07	12,607.63
8	44,947.47	26,778.40	5,534.10	12,634.97
9	44,996.00	26,829.55	5,534.60	12,631.85
10	44,939.80	26,778.38	5,521.63	12,639.78
11	44,977.73	26,826.62	5,527.40	12,623.72
12	44,956.90	26,783.83	5,525.60	12,647.47
13	45,001.15	26,825.42	5,534.57	12,641.17
14	45,006.87	26,806.75	5,541.68	12,658.43
Average	44,974.17	26,805.81	5,530.85	12,637.51

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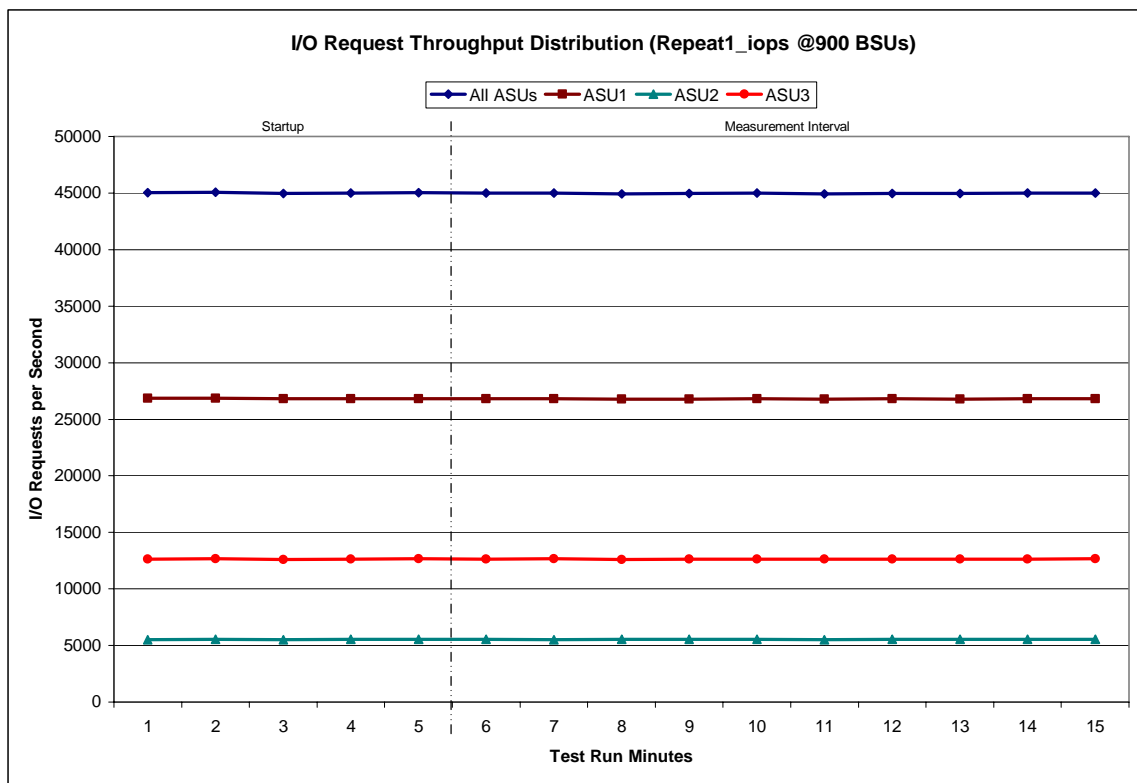
Repeatability 1 IOPS –Average Response Time (ms) Distribution Data

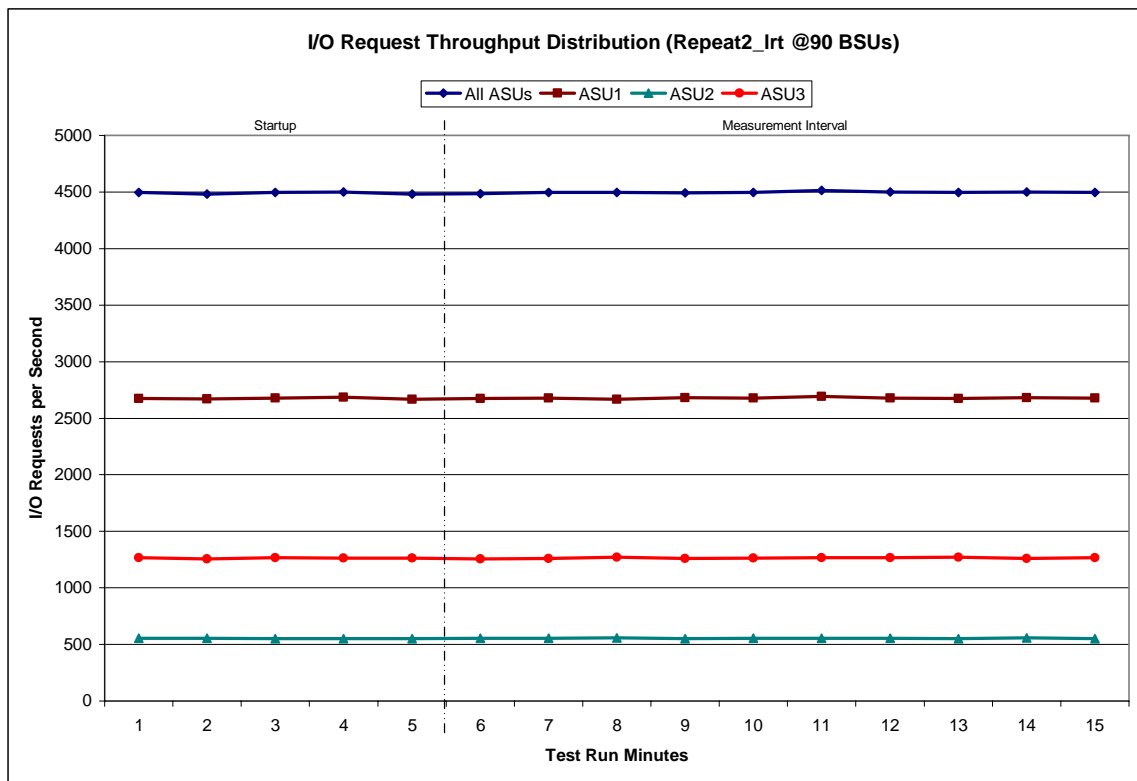| 900 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	23:16:34	23:21:35	0-4	0:05:01
Measurement Interval	23:21:35	23:31:35	5-14	0:10:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	17.58	17.42	21.83	16.07
1	15.48	15.24	20.02	14.01
2	14.83	14.67	19.31	13.19
3	14.93	14.77	19.43	13.31
4	15.41	15.17	19.93	13.92
5	15.24	15.03	19.82	13.69
6	15.06	14.87	19.58	13.49
7	15.65	15.38	20.12	14.27
8	14.78	14.63	19.30	13.13
9	15.33	15.09	19.90	13.82
10	15.22	15.00	19.72	13.72
11	14.89	14.73	19.40	13.28
12	15.11	14.88	19.66	13.59
13	15.23	15.00	19.77	13.71
14	14.72	14.57	19.28	13.05
Average	15.12	14.92	19.65	13.57

Repeatability 1 IOPS –Average Response Time (ms) Distribution Graph

Repeatability 2 LRT – I/O Request Throughput Distribution Data

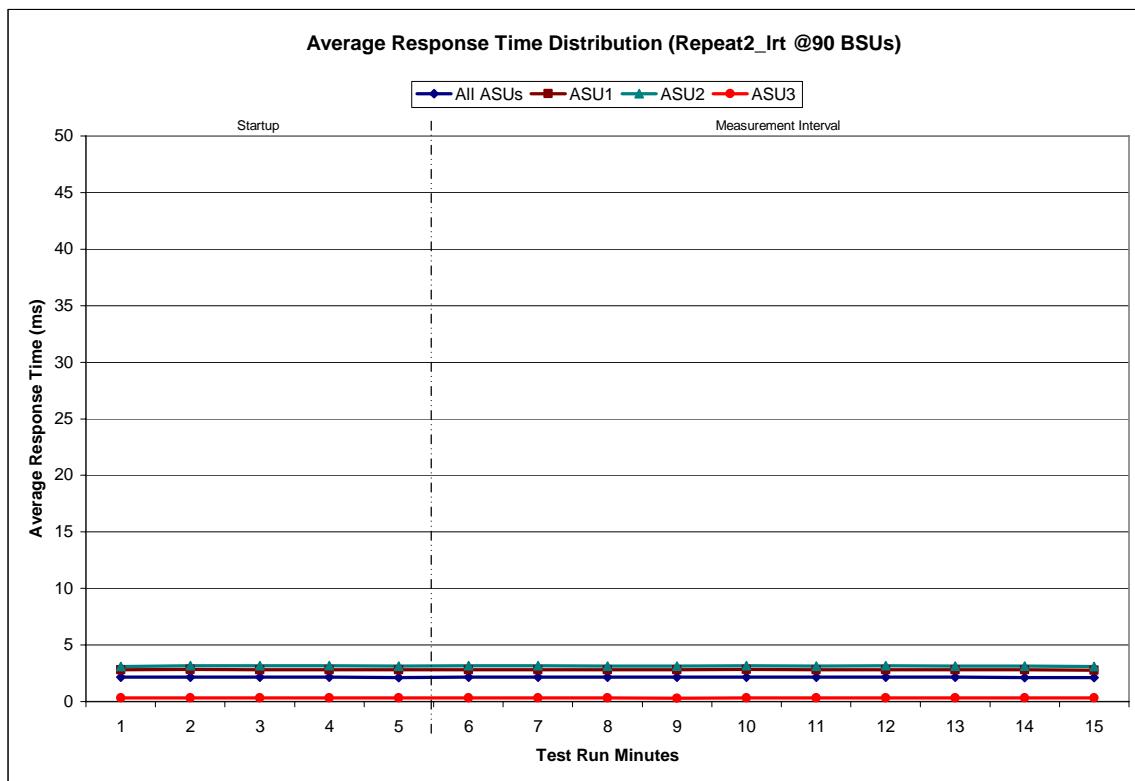| 90 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	23:31:59	23:36:59	0-4	0:05:00
Measurement Interval	23:36:59	23:46:59	5-14	0:10:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	4,495.85	2,673.15	554.75	1,267.95
1	4,479.88	2,671.65	553.43	1,254.80
2	4,497.37	2,679.48	551.78	1,266.10
3	4,499.78	2,684.02	550.60	1,265.17
4	4,482.63	2,667.52	549.93	1,265.18
5	4,484.18	2,674.78	553.17	1,256.23
6	4,494.95	2,677.80	555.65	1,261.50
7	4,496.65	2,668.65	558.07	1,269.93
8	4,492.62	2,682.30	551.52	1,258.80
9	4,496.40	2,678.50	552.65	1,265.25
10	4,513.75	2,694.27	553.32	1,266.17
11	4,500.75	2,679.55	552.82	1,268.38
12	4,495.80	2,674.05	551.60	1,270.15
13	4,500.22	2,682.28	557.30	1,260.63
14	4,495.02	2,676.98	551.67	1,266.37
Average	4,497.03	2,678.92	553.78	1,264.34

Repeatability 2 LRT – I/O Request Throughput Distribution Graph

Repeatability 2 LRT –Average Response Time (ms) Distribution Data

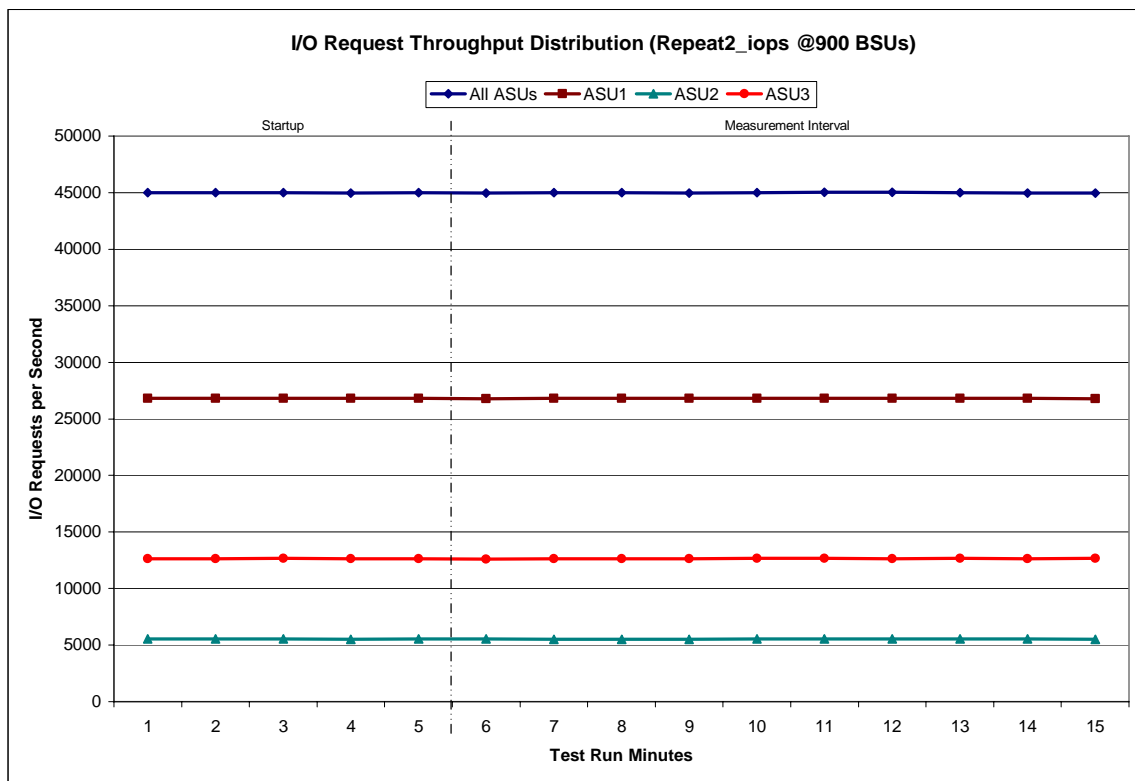| 90 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	23:31:59	23:36:59	0-4	0:05:00
Measurement Interval	23:36:59	23:46:59	5-14	0:10:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	2.15	2.82	3.11	0.33
1	2.17	2.83	3.18	0.31
2	2.15	2.81	3.17	0.31
3	2.16	2.81	3.18	0.32
4	2.13	2.79	3.14	0.31
5	2.15	2.81	3.16	0.31
6	2.15	2.81	3.16	0.32
7	2.15	2.81	3.14	0.31
8	2.14	2.80	3.12	0.30
9	2.17	2.84	3.16	0.31
10	2.14	2.80	3.12	0.31
11	2.14	2.80	3.17	0.31
12	2.15	2.82	3.12	0.31
13	2.14	2.79	3.12	0.31
14	2.13	2.79	3.11	0.31
Average	2.15	2.81	3.14	0.31

Repeatability 2 LRT –Average Response Time (ms) Distribution Graph

Repeatability 2 IOPS – I/O Request Throughput Distribution Data

| 900 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	23:47:18	23:52:19	0-4	0:05:01
Measurement Interval	23:52:19	0:02:19	5-14	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	44,998.30	26,821.60	5,532.18	12,644.52
1	44,985.72	26,813.10	5,525.90	12,646.72
2	45,008.80	26,828.32	5,526.22	12,654.27
3	44,966.57	26,801.17	5,525.53	12,639.87
4	44,979.47	26,822.07	5,535.27	12,622.13
5	44,951.58	26,794.88	5,540.88	12,615.82
6	44,989.25	26,816.68	5,523.97	12,648.60
7	44,981.43	26,820.23	5,514.60	12,646.60
8	44,958.77	26,803.72	5,512.95	12,642.10
9	45,006.72	26,815.55	5,537.57	12,653.60
10	45,050.08	26,828.63	5,556.45	12,665.00
11	45,016.25	26,831.18	5,534.27	12,650.80
12	45,002.20	26,810.97	5,537.50	12,653.73
13	44,962.18	26,812.07	5,528.43	12,621.68
14	44,974.62	26,780.15	5,523.27	12,671.20
Average	44,989.31	26,811.41	5,530.99	12,646.91

Repeatability 2 IOPS – I/O Request Throughput Distribution Graph

Repeatability 2 IOPS –Average Response Time (ms) Distribution Data

900 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	23:47:18	23:52:19	0-4	0:05:01
Measurement Interval	23:52:19	0:02:19	5-14	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	16.63	16.45	20.88	15.17
1	14.99	14.79	19.56	13.41
2	15.19	14.95	19.75	13.70
3	15.32	15.07	19.82	13.88
4	14.80	14.63	19.35	13.15
5	14.96	14.78	19.49	13.36
6	15.16	14.93	19.74	13.64
7	15.98	15.67	20.45	14.70
8	14.97	14.78	19.48	13.41
9	15.01	14.81	19.53	13.44
10	15.58	15.29	20.08	14.21
11	15.06	14.87	19.57	13.51
12	15.28	15.04	19.81	13.79
13	15.20	14.96	19.74	13.72
14	15.26	15.01	19.81	13.80
Average	15.25	15.01	19.77	13.76

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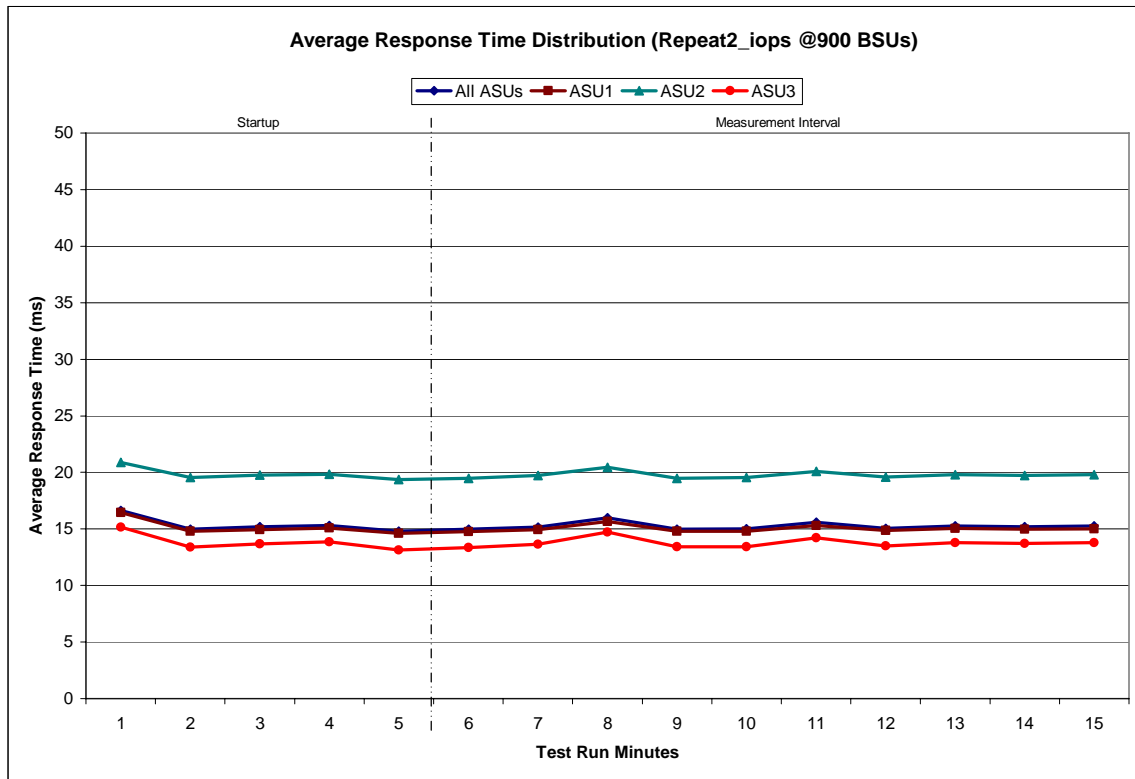
Repeatability 1 (LRT)
Measured Intensity Multiplier and Coefficient of Variation

	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	0.2810	0.0702	0.2099	0.0180	0.0702	0.0351	0.2806
COV	0.009	0.003	0.005	0.002	0.014	0.006	0.008	0.003

Clause 3.4.3

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.*

Clauses 5.1.0 and 5.3.13.2

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%.*

Clause 5.3.13.3

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	0.0350	0.2811	0.0699	0.2100	0.0180	0.0700	0.0350	0.2810
COV	0.004	0.001	0.002	0.001	0.004	0.002	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	0.2807	0.0697	0.2102	0.0180	0.0700	0.0352	0.2812
COV	0.010	0.005	0.009	0.004	0.009	0.005	0.011	0.003

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	0.2810	0.0701	0.2099	0.0180	0.0700	0.0350	0.2811
COV	0.003	0.001	0.002	0.001	0.004	0.003	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 Sustainability, IOPS, Response Time Ramp, Repeatability, and Persistence Test Runs are documented in "Appendix E: SPC-1 Workload Generator Input Parameters" on Page 67.

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	55,579,536
Total Number of Logical Blocks Verified	49,504,320
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 System Storage DS4800 Disk Storage System, as documented in this Full Disclosure Report is currently available for customer purchase and shipment.

PRICING INFORMATION

Clause 9.2.4.11

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

Clause 9.2.4.11.3

A list of all differences between the Tested Storage Configuration (TSC) and Priced Storage Configuration must be included.

Pricing information may found in the Tested Storage Configuration Pricing section on page 14. A list of all differences between the Tested Storage Configuration (TSC) and Priced Storage Configuration may be found in the Executive Summary portion of this document on page 14.

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 System Storage DS4800 Disk Storage System.

<u>APPENDIX A: SPC-1 GLOSSARY</u>

"Decimal" *(powers of ten)* Measurement Units

In the storage industry, the terms "kilo", "mega", "giga", "tera", "peta", and "exa" are commonly used prefixes for computing performance and capacity. For the purposes of the SPC workload definitions, all of the following terms are defined in "powers of ten" measurement units.

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

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

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

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

- A petabyte (PB) is equal to 1,000,000,000,000,000 (10^{15}) bytes

- An exabyte (EB) is equal to 1,000,000,000,000,000,000 (10^{18}) bytes

"Binary" *(powers of two)* Measurement Units

The sizes reported by many operating system components use "powers of two" measurement units rather than "power of ten" units. The following standardized definitions and terms are also valid and may be used in this document.

- A kibibyte (KiB) is equal to 1,024 (2^{10}) bytes.

- A mebibyte (MiB) is equal to 1,048,576 (2^{20}) bytes.

- A gigibyte (GiB) is equal to 1,073,741,824 (2^{30}) bytes.

- A tebibyte (TiB) is equal to 1,099,511,627,776 (2^{40}) bytes.

- A pebibyte (PiB) is equal to 1,125,899,906,842,624 (2^{50}) bytes.

- An exbibyte (EiB) is equal to 1,152,921,504,606,846,967 (2^{60}) bytes.

SPC-1 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 selected level of 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.

SPC-1 Data Protection Levels

RAID5: User data is distributed across the disks in the array. Check data corresponding to user data is distributed across multiple disks in the form of bit-by-bit parity.

Mirroring: Two or more identical copies of user data are maintained on separate disks.

Other Protection Level: Any data protection other than **RAID5** or **Mirroring**.

Unprotected: There is no data protection provided.

SPC-1 Test Execution 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.

Completed I/O Request: An I/O Request with a Start Time and a Completion Time (see "I/O Completion Types" below).

Completion Time: The time recorded by the Workload Generator when an I/O Request is satisfied by the TSC as signaled by System Software.

Data Rate: The data transferred in all Measured I/O Requests in an SPC-1 Test Run divided by the length of the Test Run in seconds.

Expected I/O Count: For any given I/O Stream and Test Phase, the product of 50 times the BSU level, the duration of the Test Phase in seconds, and the Intensity Multiplier for that I/O Stream.

Failed I/O Request: Any I/O Request issued by the Workload Generator that could not be completed or was signaled as failed by System Software. A Failed I/O Request has no Completion Time (see "I/O Completion Types" below).

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.

In-Flight I/O Request: An I/O Request issued by the I/O Command Generator to the TSC that has a recorded Start Time, but does not complete within the Measurement Interval (see "I/O Completion Types" below).

Measured I/O Request: A Completed I/O Request with a Completion Time occurring within the Measurement Interval (see "I/O Completion Types" below).

Measured Intensity Multiplier: The percentage of all Measured I/O Requests that were issued by a given I/O Stream.

Measurement Interval: The finite and contiguous time period, after the 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.

Ramp-Up: The time required for the Benchmark Configuration (BC) to produce Steady State throughput after the Workload Generator begins submitting I/O Requests to the TSC for execution.

Ramp-Down: The time required for the BC to complete all I/O Requests issued by the Workload Generator. The Ramp-Down period begins when the Workload Generator ceases to issue new I/O Requests to the TSC.

Response Time: The Response Time of a Measured I/O Request is its Completion Time minus its Start Time.

Start Time: The time recorded by the Workload Generator when an I/O Request is submitted, by the Workload Generator, to the System Software for execution on the Tested Storage Configuration (TSC).

Start-Up: The period that begins after the Workload Generator starts to submit I/O requests to the TSC and ends at the beginning of the Measurement Interval.

Shut-Down: The period between the end of the Measurement Interval and the time when all I/O Requests issued by the Workload Generator have completed or failed.

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.

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

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
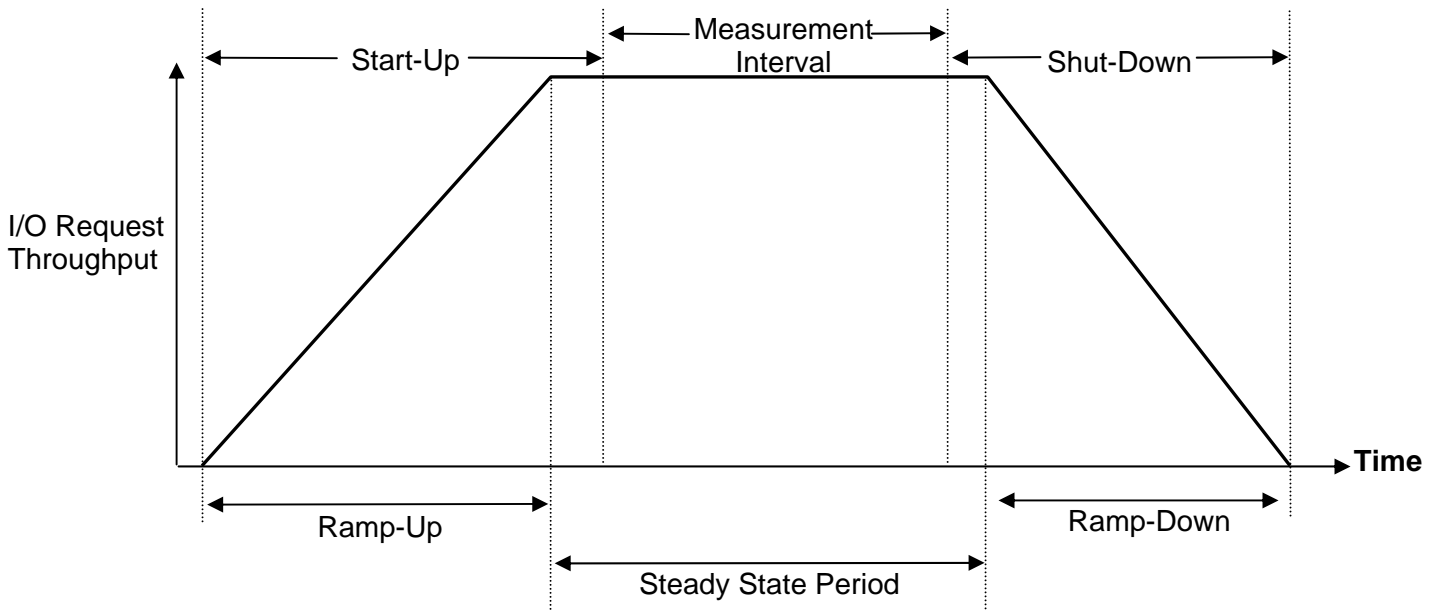
period, Shut-Down period, and Ramp-Down period as illustrated in the "SPC-1 Test Run Components" below. All SPC-1 Test Runs shall have a Steady State period and a Measurement Interval.

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.

I/O Completion Types
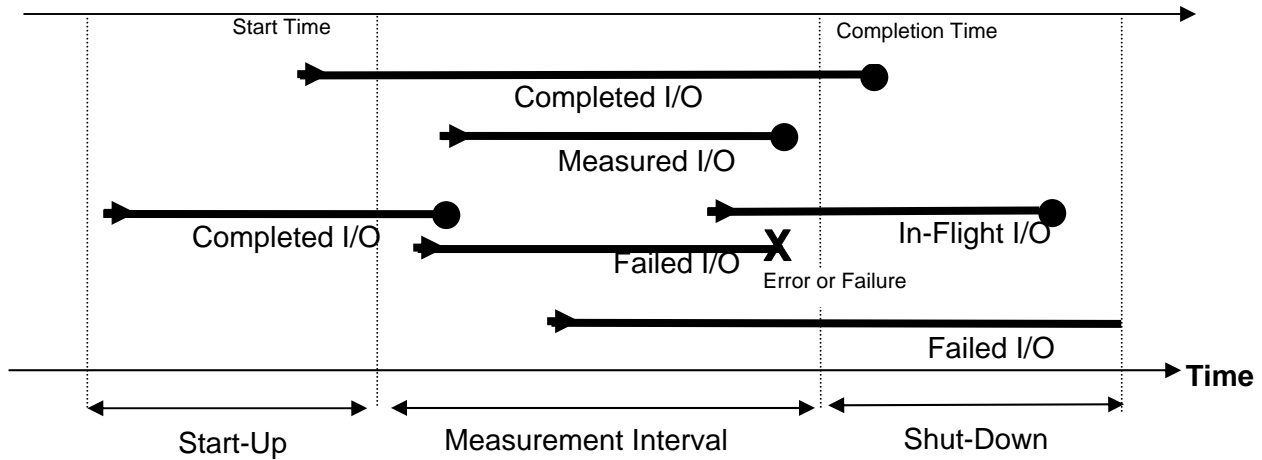
SPC-1 Test Run Components

APPENDIX B: CUSTOMER TUNABLE PARAMETERS AND OPTIONS

Windows 2000 Registry Changes

```
HKEY_LOCAL_MACHINE\SYSTEM\CurrentControlSet\Services\
ql2300\Device\MaximumSGList=0xff
```

```
HKEY_LOCAL_MACHINE\SYSTEM\CurrentControlSet\Services\
ql2300\Device\NumberOfRequests=0xfe
```

```
HKEY_LOCAL_MACHINE\SYSTEM\CurrentControlSet\Services\
Disk\TimeOutValue=0x78
```

```
HKEY_LOCAL_MACHINE\SYSTEM\CurrentControlSet\Services\
ql2300\Device\DriverParameters=UseSameNN=1;BusChange=0;
```

Storage Array Cache Flush Settings

Start Flush: changed from default of 80 to new value of 50

Stop Flush: changed from default

RDAC Failover Options

Host Region	Offset	Default	New Value
3	0x24	1	0
9	0x24	1	0
10	0x24	1	0
11	0x24	1	0
12	0x24	1	0
13	0x24	1	0
14	0x24	1	0

Host Bus Adapter Options

The table below lists the Host Bus Adapter BIOS options that were changed from their default values.

Host Bus Adapter Settings		
Item	**Default**	**New Value**
Adapter Settings:		
Loop Reset Delay	5	8
Adapter Hard Loop ID	Disabled	Enabled
Hard Loop ID (unique for each)	0	Eg. 22
Fibre Channel Tape Support	Enabled	Disabled
Advanced Adapter Settings:		
Execution Throttle	16	255
LUNs per Target	8	0
Login Retry Count	8	30
Port Down Retry Count	8	70
Link Down Timeout	30	60

APPENDIX C: TESTED STORAGE CONFIGURATION (TSC) CREATION

The storage management utility, SANtricity, was used to create sixteen volume groups on the storage subsystem, each volume group contains a single volume. The SANtricity script is listed below. These sixteen volumes are visible by each of the attached hosts. There are four hosts used in this benchmark. One host is the "master", and is not configured to issue IO to the storage subsystem. The other three "slave" hosts, configured with three JVM's each, perform the IO for the benchmark. The steps that follow are required to define the Windows partitions, volumes, and stripe sets that will be used by the SPC-1 benchmark. Steps 1-8 below are performed on only one of the hosts

(1)   Use diskpar.exe to set the starting offset for each of the storage system volumes. Starting offset is 65536. Use all of the remaining capacity in the partition.

(2)   Start Windows Disk Administrator.

(3)   Convert all of the storage system volumes to Dynamic Disks.

(4)   Create a Windows Striped (RAID 0) volume using all sixteen 32MB volumes.

(5)   Delete the large volume on each of the Dynamic Disks.

(6)   Create a Windows Striped (RAID 0) volume for ASU 3.

      a.   Select all sixteen volumes.

      b.   Set capacity to 40956MB.

      c.   Assign drive letter "N" to the volume. Do not format the volume.

(7)   Create the Windows Striped (RAID0) volume for ASU 1.

      a.   Select all sixteen volumes.

      b.   Set capacity to 184302MB.

      c.   Assign drive letter "L" to the volume. Do not format the volume.

(8)   Create the Windows Striped (RAID 0) volume for ASU 2.

      a.   Select all sixteen volumes.

      b.   Set capacity to 184302MB.

      c.   Assign drive letter "M" to the volume. Do not format the volume.

(9)   Reboot all four host systems.

(10)   After reboot completes, start Disk Administrator on each of the host systems.

(11)   Import foreign disks, or reactive the Windows stripe sets as necessary. On each host, assign drive letters to the stripe sets as they were assigned in steps 6, 7, and 8.

SANtricity Volume Creation Script

```
create volume drives[ 10,1 10,2 30,1 30,2  10,3 10,4  30,3  30,4  10,5  30,5
10,6  30,6  10,7  10,8  ]
RAIDLevel=1
segmentSize=128
userLabel="LUN_0"
owner = A;

create volume drives[ 30,7 30,8 10,9 10,10 30,9 30,10 10,11 10,12 30,11
30,12 10,13 10,14 10,15 10,16 ]
RAIDLevel=1
segmentSize=128
userLabel="LUN_1"
owner = A;

create volume drives[ 11,1 11,2 31,1 31,2  11,3 11,4  31,3  31,4  11,5  11,6
31,5  31,6  11,7  11,8  ]
RAIDLevel=1
segmentSize=128
userLabel="LUN_2"
owner = A;

create volume drives[ 31,7 31,8 11,9 11,10 31,9 31,10 11,11 11,12 31,11
31,12 11,13 11,14 11,15 11,16 ]
RAIDLevel=1
segmentSize=128
userLabel="LUN_3"
owner = A;

create volume drives[ 12,1 12,2 32,1 32,2  12,3 12,4  32,3  32,4  12,5  12,6
32,5  32,6  12,7  12,8  ]
RAIDLevel=1
segmentSize=128
userLabel="LUN_4"
owner = A;

create volume drives[ 32,7 32,8 12,9 12,10 32,9 32,10 12,11 12,12 32,11
32,12 12,13 12,14 12,15 12,16 ]
RAIDLevel=1
segmentSize=128
userLabel="LUN_5"
owner = A;

create volume drives[ 13,1  13,2  30,13 30,14 13,3  13,4  30,15 30,16 13,5
13,6  31,13 31,14 13,7  13,8  ]
RAIDLevel=1
segmentSize=128
userLabel="LUN_6"
owner = A;
```

```
create volume drives[ 31,15 31,16 13,9  13,10 32,13 32,14 13,11 13,12 32,15
32,16 13,13 13,14 13,15 13,16 ]
RAIDLevel=1
segmentSize=128
userLabel="LUN_7"
owner = A;

create volume drives[ 20,1 20,2 40,1 40,2  20,3 20,4  40,3  40,4  20,5  20,6
40,5  40,6  20,7  20,8 ]
RAIDLevel=1
segmentSize=128
userLabel="LUN_8"
owner = b;

create volume drives[ 40,7 40,8 20,9 20,10 40,9 40,10 20,11 20,12 40,11
40,12 40,13 40,14 40,15 40,16 ]
RAIDLevel=1
segmentSize=128
userLabel="LUN_9"
owner = b;

create volume drives[ 21,1 21,2 41,1 41,2  21,3 21,4  41,3  41,4  21,5  21,6
41,5  41,6  21,7  21,8  ]
RAIDLevel=1
segmentSize=128
userLabel="LUN_10"
owner = b;

create volume drives[ 41,7 41,8 21,9 21,10 41,9 41,10 21,11 21,12 41,11
41,12 41,13 41,14 41,15 41,16 ]
RAIDLevel=1
segmentSize=128
userLabel="LUN_11"
owner = b;

create volume drives[ 22,1 22,2 42,1 42,2  22,3 22,4  42,3  42,4  22,5  22,6
42,5  42,6  22,7  22,8  ]
RAIDLevel=1
segmentSize=128
userLabel="LUN_12"
owner = b;

create volume drives[ 42,7 42,8 22,9 22,10 42,9 42,10 22,11 22,12 42,11
42,12 42,13 42,14 42,15 42,16 ]
RAIDLevel=1
segmentSize=128
userLabel="LUN_13"
owner = b;

create volume drives[ 43,1  43,2  20,13 20,14 43,3  43,4  20,15 20,16 43,5
43,6  21,13 21,14 43,7  43,8  ]
RAIDLevel=1
segmentSize=128
userLabel="LUN_14"
owner = b;
```

```
create volume drives[ 21,15 21,16 43,9  43,10 22,13 22,14 43,11 43,12 22,15
22,16 43,13 43,14 43,15 43,16 ]
RAIDLevel=1
segmentSize=128
userLabel="LUN_15"
owner = b;

set volume["LUN_0"]  mirrorEnabled = True writeCacheEnabled = True
cacheWithoutBatteryEnabled = True readAheadMultiplier = 0;
set volume["LUN_1"]  mirrorEnabled = True writeCacheEnabled = True
cacheWithoutBatteryEnabled = True readAheadMultiplier = 0;
set volume["LUN_2"]  mirrorEnabled = True writeCacheEnabled = True
cacheWithoutBatteryEnabled = True readAheadMultiplier = 0;
set volume["LUN_3"]  mirrorEnabled = True writeCacheEnabled = True
cacheWithoutBatteryEnabled = True readAheadMultiplier = 0;
set volume["LUN_4"]  mirrorEnabled = True writeCacheEnabled = True
cacheWithoutBatteryEnabled = True readAheadMultiplier = 0;
set volume["LUN_5"]  mirrorEnabled = True writeCacheEnabled = True
cacheWithoutBatteryEnabled = True readAheadMultiplier = 0;
set volume["LUN_6"]  mirrorEnabled = True writeCacheEnabled = True
cacheWithoutBatteryEnabled = True readAheadMultiplier = 0;
set volume["LUN_7"]  mirrorEnabled = True writeCacheEnabled = True
cacheWithoutBatteryEnabled = True readAheadMultiplier = 0;
set volume["LUN_8"]  mirrorEnabled = True writeCacheEnabled = True
cacheWithoutBatteryEnabled = True readAheadMultiplier = 0;
set volume["LUN_9"]  mirrorEnabled = True writeCacheEnabled = True
cacheWithoutBatteryEnabled = True readAheadMultiplier = 0;
set volume["LUN_10"] mirrorEnabled = True writeCacheEnabled = True
cacheWithoutBatteryEnabled = True readAheadMultiplier = 0;
set volume["LUN_11"] mirrorEnabled = True writeCacheEnabled = True
cacheWithoutBatteryEnabled = True readAheadMultiplier = 0;
set volume["LUN_12"] mirrorEnabled = True writeCacheEnabled = True
cacheWithoutBatteryEnabled = True readAheadMultiplier = 0;
set volume["LUN_13"] mirrorEnabled = True writeCacheEnabled = True
cacheWithoutBatteryEnabled = True readAheadMultiplier = 0;
set volume["LUN_14"] mirrorEnabled = True writeCacheEnabled = True
cacheWithoutBatteryEnabled = True readAheadMultiplier = 0;
set volume["LUN_15"] mirrorEnabled = True writeCacheEnabled = True
cacheWithoutBatteryEnabled = True readAheadMultiplier = 0;

set storageArray cacheBlockSize  = 4;
set storageArray cacheFlushStart = 50 cacheFlushStop  = 50;

set storageArray defaultHostType = "Windows 2000/Server 2003 Non-Clustered";

set controller[a] HostNVSRAMByte[0x01, 0x17]=0x01;
set controller[b] HostNVSRAMByte[0x01, 0x17]=0x01;

/* Setup for RDAC failover environment */

set controller[a] HostNVSRAMByte[0x00, 0x24]=0x00;
set controller[a] HostNVSRAMByte[0x01, 0x24]=0x00;
set controller[a] HostNVSRAMByte[0x02, 0x24]=0x00;
set controller[a] HostNVSRAMByte[0x03, 0x24]=0x00;
set controller[a] HostNVSRAMByte[0x04, 0x24]=0x00;
set controller[a] HostNVSRAMByte[0x05, 0x24]=0x00;
```

```
set controller[a] HostNVSRAMByte[0x06, 0x24]=0x00;
set controller[a] HostNVSRAMByte[0x07, 0x24]=0x00;
set controller[a] HostNVSRAMByte[0x08, 0x24]=0x00;
set controller[a] HostNVSRAMByte[0x09, 0x24]=0x00;
set controller[a] HostNVSRAMByte[0x0a, 0x24]=0x00;
set controller[a] HostNVSRAMByte[0x0b, 0x24]=0x00;
set controller[a] HostNVSRAMByte[0x0c, 0x24]=0x00;
set controller[a] HostNVSRAMByte[0x0d, 0x24]=0x00;
set controller[a] HostNVSRAMByte[0x0e, 0x24]=0x00;
set controller[a] HostNVSRAMByte[0x0f, 0x24]=0x00;

set controller[b] HostNVSRAMByte[0x00, 0x24]=0x00;
set controller[b] HostNVSRAMByte[0x01, 0x24]=0x00;
set controller[b] HostNVSRAMByte[0x02, 0x24]=0x00;
set controller[b] HostNVSRAMByte[0x03, 0x24]=0x00;
set controller[b] HostNVSRAMByte[0x04, 0x24]=0x00;
set controller[b] HostNVSRAMByte[0x05, 0x24]=0x00;
set controller[b] HostNVSRAMByte[0x06, 0x24]=0x00;
set controller[b] HostNVSRAMByte[0x07, 0x24]=0x00;
set controller[b] HostNVSRAMByte[0x08, 0x24]=0x00;
set controller[b] HostNVSRAMByte[0x09, 0x24]=0x00;
set controller[b] HostNVSRAMByte[0x0a, 0x24]=0x00;
set controller[b] HostNVSRAMByte[0x0b, 0x24]=0x00;
set controller[b] HostNVSRAMByte[0x0c, 0x24]=0x00;
set controller[b] HostNVSRAMByte[0x0d, 0x24]=0x00;
set controller[b] HostNVSRAMByte[0x0e, 0x24]=0x00;
set controller[b] HostNVSRAMByte[0x0f, 0x24]=0x00;
```

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

The contents of the SPC-1 Workload Generator command and parameter files are listed below.

Master Host System

```
* spc1.cfg

host=master
slaves=(bmex346b_s1,bmex346b_s2,bmex346b_s3,bmex346d_s1,bmex346d_s2,bmex34
6d_s3,bmex346e_s1,bmex346e_s2,bmex346e_s3)

javaparms="-Xmx256m -Xms256m"

sd=asu1_1,lun=\\.\L:,size=3092074463232
sd=asu2_1,lun=\\.\M:,size=3092074463232
sd=asu3_1,lun=\\.\N:,size=687127658496

eof
```

Slave Host Systems

Each file for the Slave Host Systems were identical with the exception of the "host=" value, which varied dependent upon the system.

```
*slave1.parm

host=bmex346b_s1
master=bmex346c

sd=asu1_1,lun=\\.\L:,size=3092074463232
sd=asu2_1,lun=\\.\M:,size=3092074463232
sd=asu3_1,lun=\\.\N:,size=687127658496

eof
```

Persistence Test

The following SPC-1 Workload Generator command and parameter file was used for the Persistence Test.

```
* spc1_persist.cfg

javaparms="-Xmx512m -Xms512m"

sd=asu1_1,lun=\\.\L:,size=3092074463232
sd=asu2_1,lun=\\.\M:,size=3092074463232
sd=asu3_1,lun=\\.\N:,size=687127658496

eof
```

APPENDIX E: SPC-1 WORKLOAD GENERATOR INPUT PARAMETERS

The following script was used to execute the Primary Metric Test *(Sustainability Test Phase, IOPS Test Phase, and Response Time Ramp Test Phase)*, **Repeatability Test** *(Repeatability Test Phase 1 and Repeatability Test Phase 2)*, **and Persistence Test Run 1.**

```
copy spc1_iops.cfg spc1.cfg

java -Xmx256m -Xms256m metrics -b 900 -s 300

java -Xmx256m -Xms256m repeat1 -b 900 -s 300

java -Xmx256m -Xms256m repeat2 -b 900 -s 300

copy spc1_persist.cfg spc1.cfg

java -Xmx512m -Xms512m persist1 -b 900
```

The following script was used to execute Persistence Test Run 2.

```
rem java -Xmx512m -Xms512m persist1 -b 900

java -Xmx512m -Xms512m persist2
```