SPC Benchmark 1™
Full Disclosure Report

IBM Corporation
IBM System Storage® DS3524 Express

SPC-1 V1.12

Submitted for Review: December 31, 2010
Submission Identifier: A00101

First Edition – December 2010

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SPC BENCHMARK 1™ V1.12   FULL DISCLOSURE REPORT   Submission Identifier: A00101
IBM Corporation   Submitted for Review: DECEMBER 31, 2010
IBM System Storage® DS3524 Express

AUDIT CERTIFICATION

Storage Performance Council

Gradient SYSTEMS

Bruce McNutt
IBM Corporation
650 Harry Road C2 500
San Jose, CA 95120

December 30, 2010

The SPC Benchmark 1™ results listed below for the IBM System Storage® DS3524 Express were produced in compliance with the SPC Benchmark 1™ 1.12 Remote Audit requirements.

SPC Benchmark 1™ 1.12 Results	
Tested Storage Configuration (TSC) Name: IBM System Storage® DS3524 Express	
Metric	**Reported Result**
SPC-1 IOPS™	14,797.26
SPC-1 Price-Performance	$3.26/SPC-1 IOPS™
Total ASU Capacity	6,706.440 GB
Data Protection Level	Protected *(Mirroring)*
Total TSC Price (including three-year maintenance)	$48,310.00

The following SPC Benchmark 1™ Remote Audit requirements were reviewed and found compliant with 1.12 of the SPC Benchmark 1™ specification:

- A Letter of Good Faith, signed by a senior executive.
- The following Data Repository storage items, based on 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).
- Listings and commands to configure the Benchmark Configuration/Tested Storage Configuration, including customer tunable parameters that were changed from default values.
- SPC-1 Workload Generator commands and parameters used for the audited SPC Test Runs.

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® DS3524 Express   Page 2
SPC-1 Audit Certification

- The following Host System requirements, based on information supplied by IBM Corporation:

  - ✓ The type of Host System including the number of processors and main memory.
  - ✓ The presence and version number of the SPC-1 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 and Priced Storage Configuration were documented and, if applied to the Tested Storage Configuration, would not have an impact on the audited benchmark measurements.

- 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.

- This successfully audited SPC measurement is not subject to an SPC Confidential Review.

Audit Notes:

There were no audit notes or exceptions.

Respectfully,
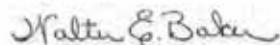
Walter E. Baker
SPC Auditor

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LETTER OF GOOD FAITH

IBM

Vice President and Disk Storage Business Line Executive

IBM Technology & Systems Group
3039 Cornwallis Road,
Research Triangle Park, NC 27709

Phone 1-919-543-6345
Fax: 1-919-543-2856

October 7, 2010

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 DS3500 Express.

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,

Doug Balog

EXECUTIVE SUMMARY

Test Sponsor and Contact Information

Test Sponsor and Contact Information	
Test Sponsor Primary Contact	IBM Corporation – http://www.ibm.com Bruce McNutt – bmcnutt@us.ibm.com 650 Harry Road C2 500 San Jose, CA 95120 Phone: (408) 927-2717 FAX: 0086 28 62905793
Test Sponsor Alternate Contact	IBM Corporation – http://www.ibm.com Vernon Miller – millerv@us.ibm.com KBV/9062-2 9000 South Rita Road Tucson, AZ 85744 Phone: (520) 799-4849 FAX: (520) 799-5550
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	V1.12
SPC-1 Workload Generator revision number	V2.1.0
Date Results were first used publicly	December 31, 2010
Date the FDR was submitted to the SPC	December 31, 2010
Date the priced storage configuration is available for shipment to customers	currently available
Date the TSC completed audit certification	December 30, 2010

Tested Storage Product (TSP) Description

The IBM System Storage DS3500 Express Storage Systems and EXP3500 Express Expansion Units are the newest addition to the IBM System Storage DS3000 series family of entry disk storage systems. The DS3500 delivers affordable, entry-level configurations for small and medium businesses in compact 2U, 19-inch rack mount enclosures, with the flexibility to scale in capacity, performance, host interfaces, and functions as your business grows or requirements change.

Summary of Results

SPC-1 Results	
Tested Storage Configuration (TSC) Name: IBM System Storage® DS3524 Express	
Metric	**Reported Result**
SPC-1 IOPS™	14,797.26
SPC-1 Price-Performance	$3.26/SPC-1 IOPS™
Total ASU Capacity	6,706.440 GB
Data Protection Level	Protected *(Mirroring)*
Total TSC Price (including three-year maintenance)	$48,310.00

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 **Protected** using *Mirroring* configures two or more identical copies of user data.

Storage Capacities, Relationships, and Utilization

The following diagram and table document the various storage capacities, used in this benchmark, and their relationships, as well as the storage utilization values required to be reported.
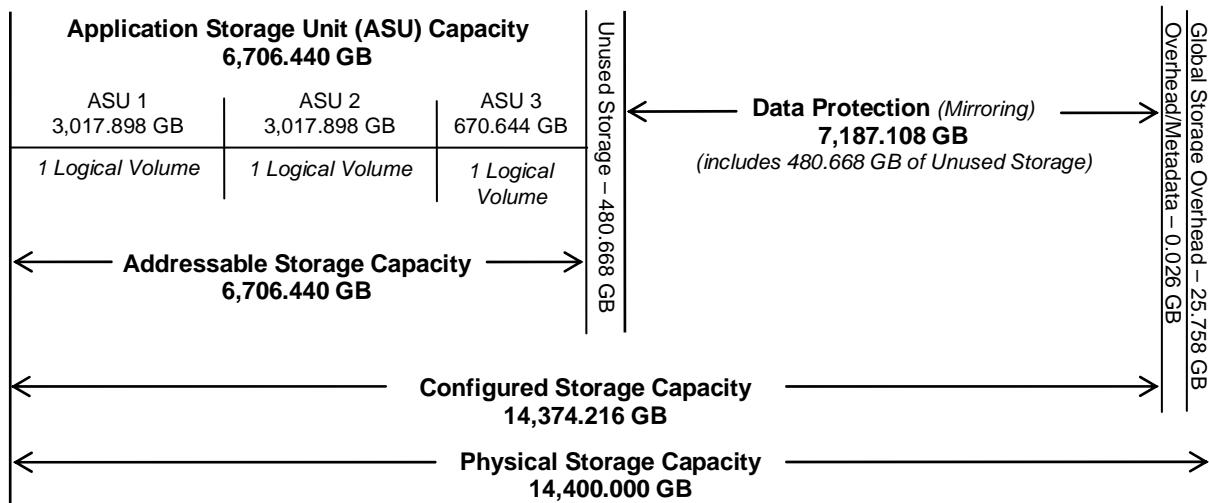
SPC-1 Storage Capacity Utilization	
Application Utilization	46.57%
Protected Application Utilization	93.15%
Unused Storage Ratio	6.68%

Application Utilization: Total ASU Capacity *(6,706.440 GB)* divided by Physical Storage Capacity *(14,440.000 GB)*

Protected Application Utilization: (Total ASU Capacity *(6,706.440 GB)* plus total Data Protection Capacity *(7,187.108 GB)* minus unused Data Protection Capacity *(480.668 GB)* divided by Physical Storage Capacity *(14,440.000 GB)*

Unused Storage Ratio: Total Unused Capacity *(961.335 GB)* divided by Physical Storage Capacity *(14,440.000 GB)* and may not exceed 45%.

Detailed information for the various storage capacities and utilizations is available on pages 19-20 in the Full Disclosure Report.

Response Time – Throughput Curve

The Response Time-Throughput Curve illustrates the Average Response Time (milliseconds) and I/O Request Throughput at 100%, 95%, 90%, 80%, 50%, and 10% of the workload level used to generate the SPC-1 IOPS™ metric.

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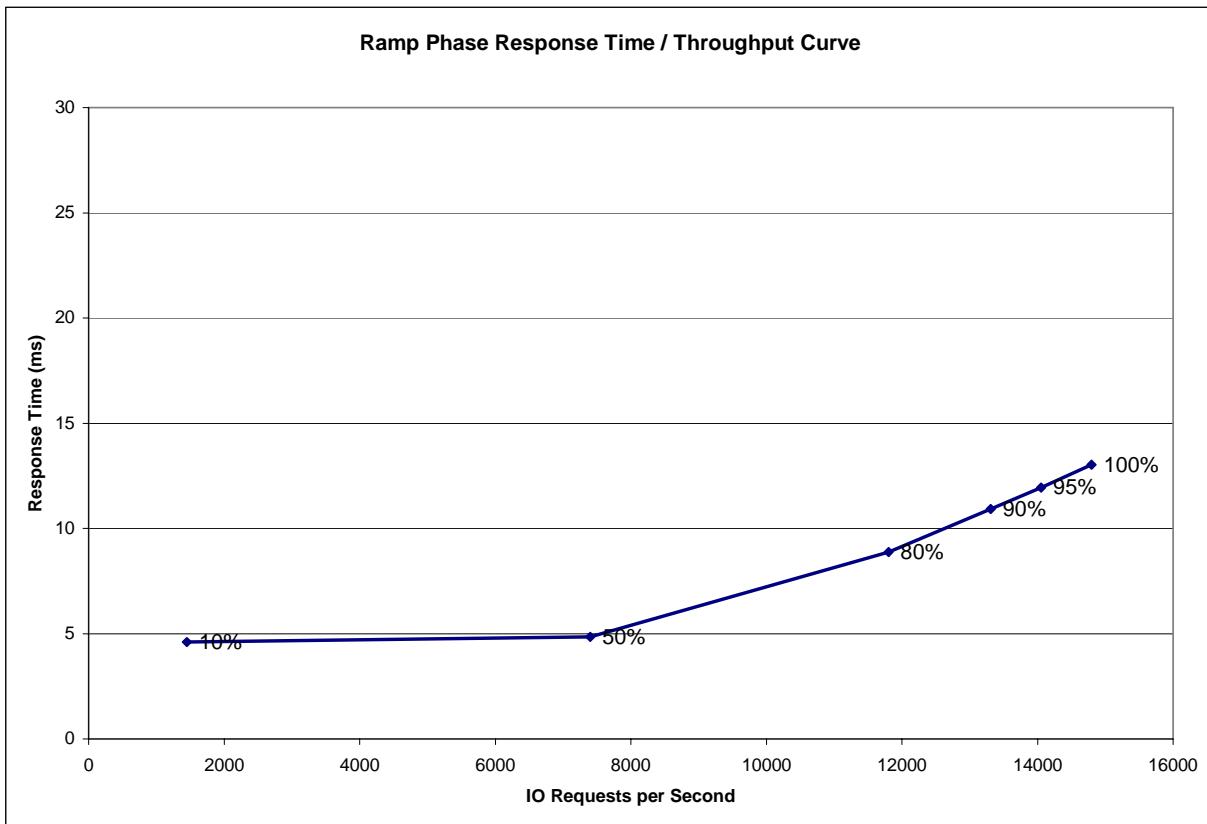
Response Time – Throughput Data

	10% Load	50% Load	80% Load	90% Load	95% Load	100% Load
I/O Request Throughput	1,451.32	7,401.76	11,800.50	13,308.46	14,057.16	14,797.26
Average Response Time (ms):						
All ASUs	4.61	4.84	8.87	10.93	11.95	13.02
ASU-1	4.49	6.44	10.98	13.09	14.15	15.27
ASU-2	6.03	6.78	17.06	23.38	26.42	29.60
ASU-3	4.25	0.59	0.81	0.89	0.94	0.98
Reads	6.69	11.41	21.27	26.35	28.87	31.51
Writes	3.26	0.57	0.79	0.87	0.92	0.97

Priced Storage Configuration Pricing

Item	IBM Description	Feature Code (4 digits) or Part Number (7 digits)	Qty	Unit Price (usd)	Total (usd)
HBA	IBM 6Gb SAS HBA	46M0907	2	$ 199.00	$ 398.00
Storage System	IBM System Storage DS3524 Express Dual Controller	2812	1	$ 9,299.00	$ 9,299.00
Memory	2 GB cache upgrade	3630	2	$ 2,499.00	$ 4,998.00
Expansion Unit	IBM System Storage EXP3524 Express	2822	1	$ 3,999.00	$ 3,999.00
Drives	300GB 10,000 rpm 6Gb SAS 2.5" HDD	5210	48	$ 549.00	$ 26,352.00
Cables	1m SAS Cable	3708	6	$ 119.00	$ 714.00
Maintenance and Warranty	DS3524 3 Year Onsite Repair 24x7 4 Hour Response	67567DT	1	$ 1,350.00	$ 1,350.00
Maintenance and Warranty	EXP3524 3 Year Onsite Repair 24x7 4 Hour Response	67567F3	1	$ 1,200.00	$ 1,200.00
				Total Price List (usd)	$ 48,310.00

The above pricing includes hardware maintenance and software support for three years, 7 days per week, 24 hours per day. The hardware maintenance and software support provides the following:

- Acknowledgement of new and existing problems with four (4) hours.

- Onsite present of a qualified maintenance engineer or provision of a customer replaceable part within four (4) hours of the above acknowledgement for any hardware failure that results in an inoperative Price Storage Configuration that can be remedied by the repair or replacement of a Priced Storage Configuration component.

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

The difference between the Tested Storage Configuration and Priced Storage Configuration is that the priced disk drives are mounted in an IBM drive carrier and each disk drive is configured to self-identify as a DS3000 brand. That difference, if applied to the TSC, would not have a negative impact on the reported SPC-1 performance.

Priced Storage Configuration Diagram

2 – IBM 6 Gb SAS HBAs

**IBM System Storage®
DS3524 Express
Dual Controller**

**24 – 300 GB 10K RPM
SAS disk drives**

**IBM System Storage®
EXP3524 Express
Expansion Enclosure**

**24 – 300 GB 10K RPM
SAS disk drives**
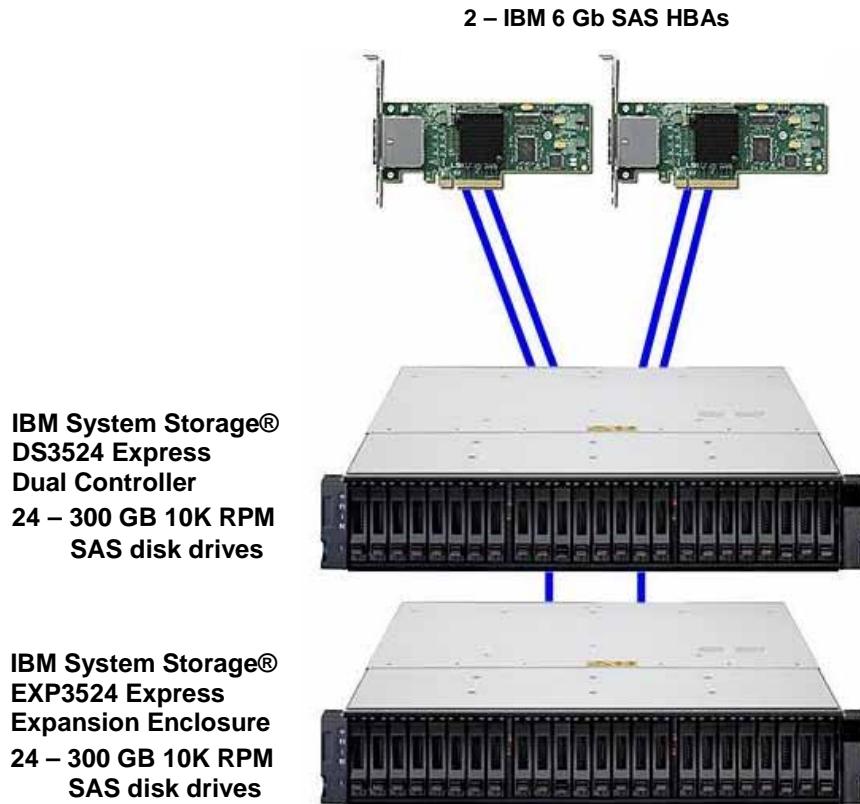
Priced Storage Configuration Components

Priced Storage Configuration
2 – IBM 6 Gb dual-ported SAS HBAs

IBM System Storage® DS3524 Express
IBM System Storage® DS3524 Express dual controller with:
    2 GB cache per controller *(4 GB total)*
    2 – 6 Gb SAS host connections per controller
        (4 total, 4 used)
    1 – 6 Gb SAS drive connections per controller
        (2 total, 2 used)

6 – 1m SAS cables
1 – IBM System Storage® EXP3524 Express expansion unit

48 – 300 GB 10K RPM SAS disk drives
    24 disk drives in the base unit
    24 disk drives in the expansion enclosure

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 9.4.3.4.1

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

The Benchmark Configuration (BC)/Tested Storage Configuration (TSC) is illustrated on page 17 *(Benchmark Configuration/Tested Storage Configuration Diagram).*

Storage Network Configuration

Clause 9.4.3.4.1

…

> 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 9.4.3.4.2.*

Clause 9.4.3.4.2

If a storage network was configured as a part of the Tested Storage Configuration and the Benchmark Configuration diagram described in Clause 9.4.3.4.1 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 storage network configuration is illustrated on page 17 *(Benchmark Configuration/Tested Storage Configuration Diagram).*

Host System and Tested Storage Configuration (TSC) Table of Components

Clause 9.4.3.4.3

The FDR will contain a table that lists the major components of each Host System and the Tested Storage Configuration (TSC). Table 9-10 specifies the content, format, and appearance of the table.

The Host System and TSC table of components may be found on page 17 *(Host System(s) and Tested Storage Configuration Components).*

Benchmark Configuration/Tested Storage Configuration Diagram

IBM System x3650 M2

LSI SAS 9200-8e   **LSI SAS 9200-8e**

**LSI Dual-Active
2600 Storage System**
**24 – 300 GB 10K RPM
SAS disk drives**

**LSI DE5600
Expansion Enclosure**
**24 – 300 GB 10K RPM
SAS disk drives**
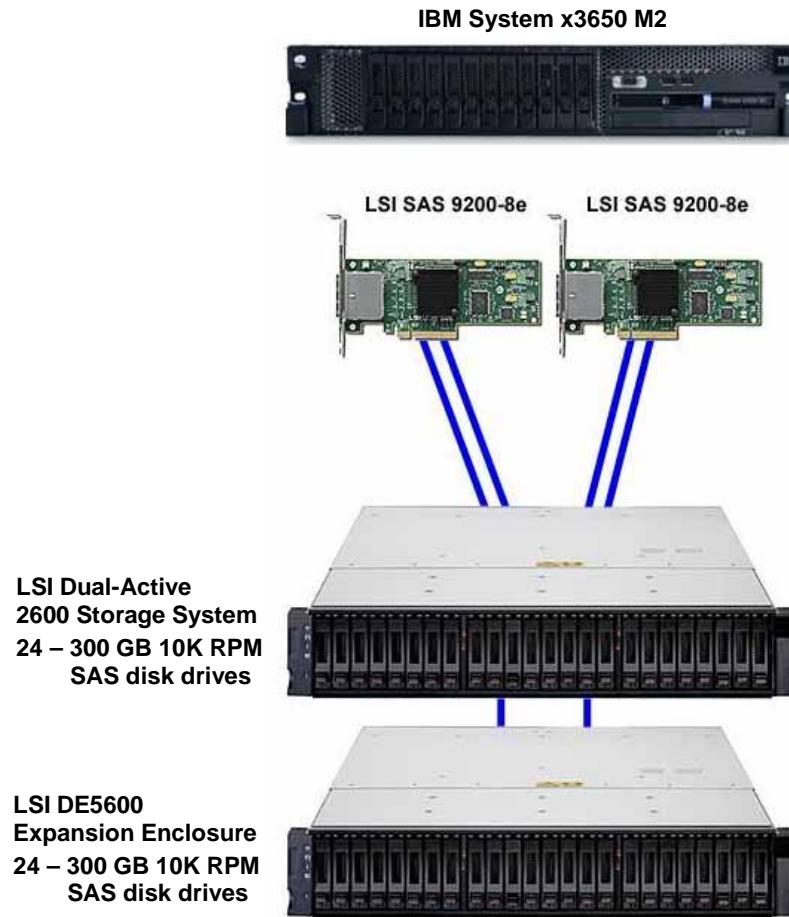
Host System(s) and Tested Storage Configuration Components

Host System:	Tested Storage Configuration (TSC):
IBM System x3650 M2	2 – LSI 9200-8e 6Gb SAS HBAs *(dual-ported)*

2 – 2.8 GHz Dual Xeon Processors
    with 8 MB L2 cache/CPU
	LSI 26000 Storage System
	  2 – LSI 2660 SAS dual-active controllers with:
	    2 GB cache per controller *(4 GB total)*

12 GB main memory	2 – 6 Gb SAS host connections per controller *(4 total, 4 used)*
Windows Server 2003 Enterprise Edition with SP2	1 – 6 Gb SAS drive connections per controller *(2 total, 2 used)*
PCIe	
	6 – 1m SAS cables
	1 – LSI DE5600 24-slot expansion unit

	48 – 300 GB 10K RPM SAS disk drives
	    24 disk drives in the base unit
	    24 disk drives in the expansion enclosure

Customer Tunable Parameters and Options

Clause 9.4.3.5.1

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 61 contains the customer tunable parameters and options that have been altered from their default values for this benchmark.

Tested Storage Configuration (TSC) Description

Clause 9.4.3.5.2

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 62 contains the detailed information that describes how to create and configure the logical TSC.

SPC-1 Workload Generator Storage Configuration

Clause 9.4.3.5.3

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 57 contains definitions of terms specific to the SPC-1 Data Repository.

Storage Capacities and Relationships

Clause 9.4.3.6.1

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)	6,706.440
Addressable Storage Capacity	Gigabytes (GB)	6,706.440
Configured Storage Capacity	Gigabytes (GB)	14,374.216
Physical Storage Capacity	Gigabytes (GB)	14,400.000
Data Protection *(Mirroring)*	Gigabytes (GB)	7,187.108
Required Storage	Gigabytes (GB)	0.026
Global Storage Overhead	Gigabytes (GB)	25.758
Total Unused Storage	Gigabytes (GB)	961.335

SPC-1 Storage Hierarchy Ratios

	Addressable Storage Capacity	Configured Storage Capacity	Physical Storage Capacity
Total ASU Capacity	100.00%	46.66%	46.57%
Required for Data Protection *(Mirrored)*		50.00%	49.91%
Addressable Storage Capacity		46.66%	46.57%
Required Storage		0.00%	0.00%
Configured Storage Capacity			99.82%
Global Storage Overhead			0.18%
Unused Storage:			
Addressable	0.00%		
Configured		6.69%	
Physical			0.00%

The Physical Storage Capacity consisted of 14,400.00 GB distributed over 48 disk drives each with a formatted capacity of 300.00 GB. There was 0.000 GB (0.00%) of Unused Storage within the Physical Storage Capacity. Global Storage Overhead consisted of 25.758 GB (0.18%) of Physical Storage Capacity. There was 961.335 GB (6.69%) 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. The Data Protection *(mirroring)* capacity was 7,187.108 GB of which 6,706.440 GB was utilized. The total Unused Storage was 961.335 GB.

SPC-1 Storage Capacities and Relationships Illustration

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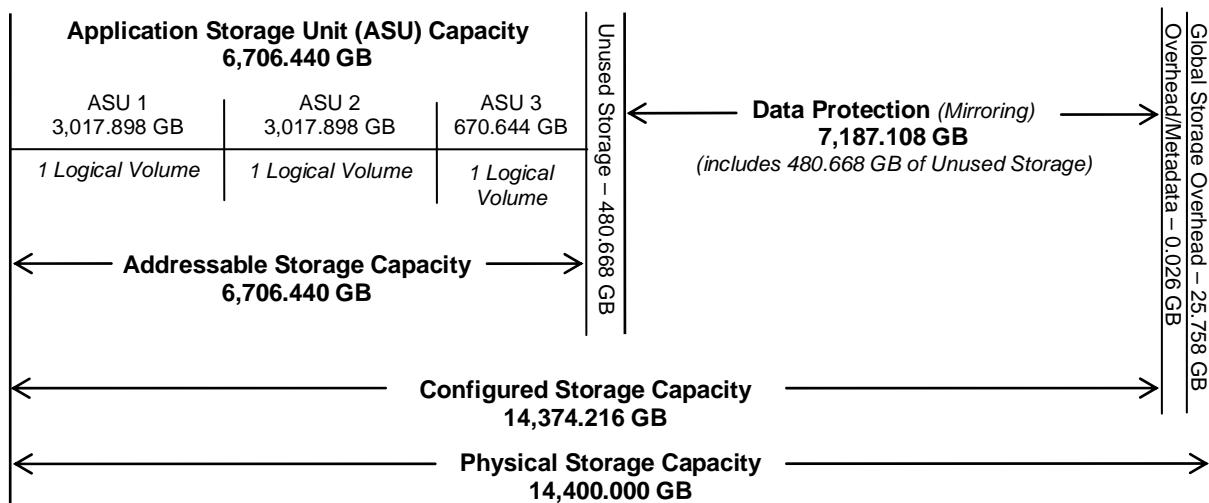
Logical Volume Capacity and ASU Mapping

Clause 9.4.3.6.3

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 (3,017.898 GB)	**ASU-2 (3,017.898 GB)**	**ASU-3 (670.644 GB)**
1 Logical Volume 3,017.898 GB per Logical Volume (3,017.898 GB used per Logical Volume)	1 Logical Volume 3,017.898 GB per Logical Volume (3,017.898 GB used per Logical Volume)	1 Logical Volume 670.644 GB per Logical Volume (670.644 GB used per Logical Volume)

The Data Protection Level used for all Logical Volumes was "Mirrored" as described on page 11. See "ASU Configuration" in the **IOPS Test Results File** for more detailed configuration information.

Storage Capacity Utilization

Clause 9.4.3.6.2

The FDR will include a table illustrating the storage capacity utilization values defined for Application Utilization (Clause 2.8.1), Protected Application Utilization (Clause 2.8.2), and Unused Storage Ratio (Clause 2.8.3).

Clause 2,8.1

Application Utilization is defined as Total ASU Capacity divided by Physical Storage Capacity.

Clause 2,8.2

Protected Application Utilization is defined as (Total ASU Capacity plus total Data Protection Capacity minus unused Data Protection Capacity) divided by Physical Storage Capacity.

Clause 2,8.3

Unused Storage Ratio is defined as Total Unused Capacity divided by Physical Storage Capacity and may not exceed 45%.

SPC-1 Storage Capacity Utilization	
Application Utilization	46.57%
Protected Application Utilization	93.15%
Unused Storage Ratio	6.68%

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 58 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
    - 95% of IOPS Test Run
    - 90% of IOPS Test Run
    - 80% of IOPS Test Run
    - 50% of IOPS Test Run
    - 10% of IOPS Test Run (LRT)

- **Repeatability Test**
  - Repeatability Test Phase 1
    - 10% of IOPS Test Run (LRT)
    - IOPS Test Run
  - Repeatability Test Phase 2
    - 10% of IOPS Test Run (LRT)
    - 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 9.4.3.7.1

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	14:12:35	14:17:35	0-4	0:05:00
Measurement Interval	14:17:35	17:17:35	4-184	3:00:00

Interval	All ASUs	ASU1	ASU2	ASU3	Interval	All ASUs	ASU1	ASU2	ASU3	Interval	All ASUs	ASU1	ASU2	ASU3
0	121.27	47.03	12.95	61.29	63	121.60	47.21	13.00	61.39	126	121.50	47.17	13.01	61.32
1	121.62	47.17	12.92	61.54	64	121.41	47.18	12.94	61.29	127	121.25	47.01	12.90	61.33
2	121.35	47.10	12.98	61.27	65	121.54	47.18	12.98	61.38	128	121.52	47.23	13.10	61.19
3	121.68	47.23	12.98	61.47	66	121.31	47.12	12.94	61.25	129	121.16	47.12	13.14	60.90
4	121.37	47.02	12.96	61.39	67	121.70	47.32	12.97	61.41	130	121.15	47.15	13.11	60.89
5	121.00	47.01	12.86	61.13	68	121.64	47.32	13.06	61.26	131	121.63	47.14	13.03	61.47
6	121.69	47.23	13.01	61.45	69	121.59	47.16	13.12	61.32	132	121.53	47.06	13.02	61.45
7	121.26	47.07	13.10	61.10	70	121.86	47.25	13.06	61.56	133	121.42	47.17	13.00	61.25
8	121.66	47.23	12.97	61.46	71	121.50	47.12	13.04	61.34	134	121.85	47.12	13.06	61.66
9	121.23	47.20	12.84	61.19	72	121.31	47.10	12.94	61.27	135	121.53	47.31	12.92	61.30
10	121.46	47.13	12.94	61.38	73	121.47	47.00	13.00	61.47	136	121.25	46.98	12.93	61.34
11	121.59	47.00	12.96	61.62	74	121.42	47.31	12.94	61.16	137	121.67	47.13	13.09	61.44
12	121.21	47.20	12.94	61.07	75	121.53	47.19	12.98	61.36	138	121.03	47.02	12.90	61.10
13	121.50	47.19	13.02	61.28	76	121.44	47.09	12.97	61.37	139	121.39	47.16	12.98	61.25
14	121.62	47.10	12.88	61.63	77	121.73	47.25	12.97	61.51	140	121.55	47.18	13.01	61.36
15	121.36	47.17	12.82	61.36	78	121.40	47.21	12.83	61.35	141	121.40	47.17	12.99	61.25
16	121.43	47.08	13.00	61.35	79	121.29	46.94	13.09	61.27	142	121.28	47.21	12.96	61.11
17	121.69	47.22	12.94	61.53	80	121.29	47.27	13.00	61.02	143	121.44	47.12	12.86	61.46
18	121.49	47.13	13.00	61.36	81	121.37	47.30	12.95	61.12	144	121.46	47.14	13.05	61.27
19	121.53	47.10	13.06	61.37	82	121.21	47.13	12.96	61.12	145	121.74	47.45	12.97	61.32
20	121.24	47.09	12.92	61.22	83	121.26	47.06	12.86	61.34	146	121.44	47.18	12.79	61.46
21	121.46	47.18	13.02	61.25	84	121.31	47.07	13.04	61.20	147	121.31	47.15	12.98	61.17
22	121.39	47.14	12.94	61.30	85	121.55	47.24	13.05	61.26	148	121.65	47.41	12.95	61.30
23	121.45	47.05	13.08	61.32	86	121.48	47.20	13.06	61.22	149	121.11	47.21	12.85	61.05
24	121.57	47.01	13.05	61.51	87	121.28	47.19	12.87	61.21	150	121.13	46.96	12.98	61.19
25	121.48	47.10	12.82	61.56	88	121.48	47.12	12.99	61.37	151	121.46	47.38	12.96	61.11
26	121.42	47.25	12.91	61.25	89	121.70	47.16	12.97	61.57	152	121.43	47.04	12.84	61.55
27	121.42	47.25	13.01	61.16	90	121.36	47.20	12.96	61.21	153	121.30	47.23	13.00	61.07
28	121.44	47.11	12.91	61.42	91	121.58	47.22	13.02	61.34	154	121.39	47.22	12.88	61.28
29	121.32	47.20	12.90	61.22	92	121.46	47.14	13.12	61.20	155	121.45	47.08	13.07	61.30
30	121.31	47.19	12.95	61.17	93	121.69	47.26	13.04	61.39	156	121.30	47.20	12.91	61.19
31	121.82	47.20	12.99	61.62	94	121.09	46.96	12.99	61.15	157	121.53	47.23	13.02	61.28
32	121.22	47.06	12.85	61.31	95	121.84	47.11	12.97	61.76	158	121.41	47.20	12.99	61.23
33	121.47	47.33	13.04	61.10	96	121.35	47.14	12.85	61.37	159	121.74	47.11	12.99	61.64
34	121.75	47.17	13.12	61.46	97	121.51	47.15	13.10	61.27	160	121.51	47.07	12.90	61.55
35	121.76	47.11	13.02	61.63	98	121.13	47.18	12.99	60.97	161	121.63	47.05	13.03	61.54
36	121.44	47.30	12.93	61.21	99	121.43	47.18	12.85	61.39	162	121.60	47.40	12.95	61.25
37	121.20	47.25	12.87	61.09	100	121.45	47.27	13.02	61.16	163	121.42	47.23	12.99	61.20
38	121.46	46.98	13.10	61.38	101	121.71	47.11	12.95	61.65	164	121.74	47.03	12.95	61.76
39	121.46	47.15	12.91	61.40	102	121.85	47.14	13.01	61.70	165	121.19	47.18	12.95	61.05
40	121.35	47.07	12.98	61.30	103	121.45	47.14	13.09	61.22	166	121.28	47.11	12.88	61.29
41	121.26	47.27	12.97	61.03	104	121.27	47.28	12.92	61.07	167	121.65	47.21	12.95	61.49
42	121.67	47.19	13.00	61.49	105	121.70	47.19	13.00	61.51	168	120.85	47.04	12.95	60.86
43	121.35	47.12	12.98	61.24	106	121.39	47.12	12.99	61.28	169	121.55	47.06	12.95	61.54
44	121.54	47.09	12.94	61.51	107	121.48	47.30	12.89	61.29	170	121.32	47.12	12.87	61.33
45	121.56	47.11	13.06	61.40	108	121.68	47.17	12.98	61.54	171	120.70	47.05	12.90	60.75
46	121.97	47.31	13.05	61.61	109	121.68	46.98	13.05	61.65	172	121.39	46.93	12.92	61.54
47	121.22	47.15	12.99	61.08	110	121.52	47.18	12.94	61.41	173	121.52	47.19	12.93	61.41
48	121.40	47.15	13.06	61.18	111	120.89	47.11	12.87	60.92	174	121.22	47.11	12.99	61.11
49	121.49	47.12	13.02	61.36	112	121.06	47.00	13.08	60.98	175	121.23	47.26	12.89	61.08
50	121.59	47.28	12.94	61.37	113	121.41	47.32	12.84	61.25	176	121.91	47.19	13.00	61.73
51	121.40	47.06	12.91	61.43	114	121.17	47.12	12.77	61.28	177	121.33	47.14	13.02	61.17
52	121.64	47.31	12.86	61.47	115	121.24	47.03	12.97	61.23	178	121.75	47.21	13.08	61.46
53	121.36	47.01	12.99	61.36	116	121.08	47.03	12.90	61.15	179	121.81	47.21	12.96	61.63
54	121.17	47.19	12.96	61.03	117	121.61	47.21	13.00	61.40	180	121.58	47.27	13.06	61.26
55	121.49	47.22	12.87	61.41	118	121.51	47.09	12.82	61.59	181	121.21	47.18	12.87	61.16
56	121.15	47.08	12.94	61.13	119	121.21	47.10	12.95	61.16	182	121.81	47.31	13.03	61.47
57	121.05	47.13	12.85	61.07	120	121.27	47.04	12.89	61.34	183	121.65	47.04	12.91	61.70
58	121.56	47.18	13.01	61.37	121	121.47	47.16	12.97	61.33	184	121.63	47.38	12.96	61.30
59	121.52	47.33	12.85	61.34	122	121.29	47.21	12.94	61.13					
60	121.34	46.97	12.99	61.38	123	121.11	47.06	13.03	61.02					
61	121.62	47.28	13.05	61.29	124	121.33	47.17	12.85	61.31					
62	121.65	47.26	12.94	61.45	125	121.51	47.06	12.92	61.54					

Sustainability – Data Rate Distribution Graph

Sustainability – I/O Request Throughput Distribution Data

	Start	Stop	Interval	Duration
Ramp-Up/Start-Up	14:12:35	14:17:35	0-4	0:05:00
Measurement Interval	14:17:35	17:17:35	5-184	3:00:00

Interval	All ASUs	ASU1	ASU2	ASU3	Interval	All ASUs	ASU1	ASU2	ASU3	Interval	All ASUs	ASU1	ASU2	ASU3
0	14,798.65	8,815.93	1,825.08	4,157.63	63	14,814.55	8,822.65	1,820.73	4,171.17	126	14,797.98	8,819.37	1,822.28	4,156.33
1	14,819.53	8,838.52	1,818.93	4,162.08	64	14,806.87	8,824.48	1,818.65	4,163.73	127	14,814.32	8,821.35	1,827.72	4,165.25
2	14,799.97	8,812.48	1,820.12	4,167.37	65	14,798.25	8,816.53	1,824.82	4,156.90	128	14,805.23	8,820.67	1,820.20	4,164.37
3	14,819.55	8,837.17	1,824.48	4,157.90	66	14,801.33	8,820.68	1,824.08	4,156.57	129	14,800.15	8,815.55	1,824.23	4,160.37
4	14,795.00	8,818.20	1,816.53	4,160.27	67	14,825.27	8,836.60	1,820.50	4,168.17	130	14,781.27	8,812.53	1,824.57	4,144.17
5	14,795.08	8,823.95	1,819.13	4,152.00	68	14,807.13	8,822.25	1,825.57	4,159.32	131	14,793.37	8,819.80	1,817.77	4,155.80
6	14,824.20	8,827.23	1,822.97	4,174.00	69	14,806.37	8,815.93	1,830.20	4,160.23	132	14,788.02	8,806.52	1,817.12	4,164.38
7	14,783.03	8,803.85	1,824.12	4,155.07	70	14,819.47	8,829.55	1,825.62	4,164.30	133	14,814.27	8,831.05	1,822.95	4,160.27
8	14,809.00	8,832.25	1,814.90	4,161.85	71	14,819.40	8,821.97	1,830.73	4,166.70	134	14,789.90	8,803.17	1,824.78	4,161.95
9	14,760.68	8,797.48	1,809.67	4,153.53	72	14,776.47	8,812.00	1,810.05	4,154.42	135	14,802.95	8,828.28	1,813.85	4,160.82
10	14,795.05	8,819.27	1,815.22	4,160.57	73	14,785.88	8,800.53	1,820.22	4,165.13	136	14,776.03	8,809.12	1,814.93	4,151.98
11	14,800.33	8,807.12	1,820.00	4,173.22	74	14,800.82	8,834.47	1,819.83	4,146.52	137	14,814.32	8,808.95	1,834.58	4,170.78
12	14,801.18	8,823.77	1,823.42	4,154.00	75	14,793.97	8,806.22	1,825.68	4,162.07	138	14,774.17	8,819.58	1,806.08	4,148.50
13	14,802.45	8,832.98	1,823.08	4,146.38	76	14,766.85	8,803.60	1,815.27	4,147.98	139	14,793.50	8,816.22	1,818.12	4,159.17
14	14,788.35	8,803.43	1,816.55	4,168.37	77	14,805.03	8,826.98	1,816.12	4,161.93	140	14,778.78	8,808.73	1,816.97	4,153.08
15	14,784.82	8,796.28	1,813.50	4,175.03	78	14,806.63	8,822.32	1,820.15	4,164.17	141	14,781.48	8,806.07	1,825.13	4,150.28
16	14,797.63	8,813.42	1,819.78	4,164.43	79	14,770.02	8,798.83	1,820.42	4,150.77	142	14,798.95	8,828.83	1,821.27	4,148.85
17	14,793.40	8,810.93	1,816.80	4,165.67	80	14,802.20	8,819.70	1,823.25	4,159.25	143	14,804.58	8,817.67	1,823.42	4,163.50
18	14,803.82	8,827.23	1,818.82	4,157.77	81	14,811.90	8,835.23	1,817.93	4,158.73	144	14,792.57	8,811.85	1,818.93	4,161.78
19	14,798.57	8,805.38	1,822.50	4,170.68	82	14,783.13	8,812.38	1,819.27	4,151.48	145	14,827.47	8,846.03	1,824.62	4,156.82
20	14,790.40	8,823.87	1,811.50	4,155.03	83	14,778.27	8,808.65	1,803.98	4,165.63	146	14,801.23	8,831.30	1,819.92	4,150.02
21	14,801.25	8,830.15	1,824.97	4,146.13	84	14,781.12	8,812.58	1,822.53	4,146.00	147	14,796.07	8,825.52	1,825.85	4,144.70
22	14,802.45	8,826.20	1,823.47	4,152.78	85	14,770.65	8,789.82	1,820.83	4,160.00	148	14,786.47	8,822.10	1,814.12	4,150.25
23	14,774.02	8,802.30	1,822.35	4,149.37	86	14,794.68	8,818.33	1,822.85	4,153.50	149	14,795.48	8,822.30	1,818.03	4,155.15
24	14,813.45	8,812.77	1,832.60	4,168.08	87	14,806.00	8,835.18	1,816.05	4,154.77	150	14,816.12	8,829.90	1,824.42	4,161.80
25	14,774.43	8,802.85	1,812.17	4,159.42	88	14,809.78	8,829.20	1,817.62	4,162.97	151	14,809.78	8,845.23	1,816.27	4,148.28
26	14,816.02	8,837.50	1,819.43	4,159.08	89	14,794.60	8,821.48	1,821.90	4,151.22	152	14,783.50	8,814.43	1,802.60	4,166.47
27	14,801.85	8,831.65	1,813.50	4,156.70	90	14,784.22	8,824.82	1,810.60	4,148.80	153	14,813.27	8,825.63	1,822.53	4,165.10
28	14,806.48	8,812.88	1,819.93	4,173.67	91	14,807.87	8,825.57	1,823.77	4,158.53	154	14,783.08	8,806.70	1,818.60	4,157.78
29	14,812.68	8,825.70	1,821.07	4,165.92	92	14,799.88	8,820.13	1,828.95	4,150.80	155	14,809.38	8,822.90	1,829.83	4,156.65
30	14,789.02	8,826.50	1,815.93	4,146.58	93	14,813.08	8,828.90	1,827.37	4,156.82	156	14,787.93	8,819.67	1,820.72	4,147.55
31	14,797.77	8,809.25	1,821.37	4,167.15	94	14,773.98	8,800.50	1,825.05	4,148.43	157	14,807.62	8,827.53	1,823.43	4,156.65
32	14,796.20	8,823.82	1,813.53	4,158.85	95	14,818.77	8,829.50	1,825.83	4,163.43	158	14,785.83	8,815.77	1,819.78	4,150.28
33	14,799.25	8,828.37	1,829.12	4,141.77	96	14,801.18	8,815.27	1,815.12	4,170.80	159	14,811.15	8,815.35	1,820.78	4,175.02
34	14,823.70	8,834.70	1,827.95	4,161.05	97	14,823.48	8,838.13	1,826.55	4,158.80	160	14,786.37	8,812.13	1,820.97	4,153.27
35	14,786.12	8,805.22	1,823.42	4,157.48	98	14,788.98	8,831.70	1,819.65	4,137.63	161	14,798.45	8,809.27	1,821.73	4,167.45
36	14,806.75	8,825.23	1,814.75	4,166.77	99	14,795.30	8,810.13	1,816.57	4,168.60	162	14,821.05	8,839.62	1,821.58	4,159.85
37	14,812.43	8,842.50	1,816.85	4,153.08	100	14,796.80	8,829.18	1,816.93	4,150.68	163	14,794.50	8,817.23	1,822.70	4,154.57
38	14,807.93	8,803.58	1,827.95	4,176.40	101	14,808.37	8,821.82	1,819.58	4,166.97	164	14,797.07	8,802.40	1,826.30	4,168.37
39	14,792.38	8,810.72	1,822.23	4,159.43	102	14,823.85	8,831.40	1,814.55	4,177.90	165	14,794.65	8,812.78	1,819.75	4,162.12
40	14,784.75	8,802.65	1,820.57	4,161.53	103	14,806.57	8,821.28	1,826.52	4,158.77	166	14,788.35	8,819.88	1,820.30	4,148.17
41	14,758.80	8,807.98	1,810.30	4,140.52	104	14,801.20	8,832.90	1,819.70	4,148.60	167	14,828.25	8,836.47	1,821.65	4,170.13
42	14,828.22	8,838.43	1,832.95	4,156.83	105	14,813.92	8,817.58	1,828.13	4,168.20	168	14,763.60	8,798.85	1,815.93	4,148.82
43	14,807.15	8,825.92	1,821.95	4,159.28	106	14,810.12	8,823.22	1,826.10	4,160.80	169	14,782.50	8,806.93	1,820.35	4,155.22
44	14,809.73	8,823.60	1,821.80	4,164.33	107	14,817.93	8,841.68	1,816.53	4,159.72	170	14,790.87	8,818.05	1,815.83	4,156.98
45	14,810.40	8,823.18	1,832.03	4,155.18	108	14,811.25	8,816.20	1,822.65	4,172.40	171	14,791.95	8,824.55	1,816.95	4,150.45
46	14,806.95	8,822.93	1,828.42	4,155.60	109	14,789.67	8,806.05	1,823.73	4,159.88	172	14,793.85	8,810.03	1,822.47	4,161.35
47	14,782.20	8,820.73	1,814.12	4,147.35	110	14,790.67	8,817.78	1,823.62	4,149.27	173	14,791.38	8,816.73	1,810.05	4,164.60
48	14,792.45	8,814.23	1,823.87	4,154.35	111	14,774.42	8,807.28	1,817.38	4,149.95	174	14,793.83	8,821.12	1,819.55	4,153.17
49	14,804.75	8,831.12	1,815.57	4,158.07	112	14,794.53	8,818.28	1,827.12	4,149.13	175	14,823.72	8,854.80	1,817.55	4,151.37
50	14,817.18	8,844.23	1,809.83	4,163.12	113	14,794.55	8,817.20	1,812.10	4,165.25	176	14,808.02	8,823.37	1,819.70	4,164.95
51	14,785.80	8,804.70	1,814.25	4,166.85	114	14,780.95	8,821.30	1,801.40	4,158.25	177	14,771.53	8,807.15	1,820.07	4,144.32
52	14,820.03	8,854.33	1,810.07	4,155.63	115	14,800.70	8,818.15	1,823.12	4,159.43	178	14,813.42	8,836.30	1,819.13	4,157.98
53	14,795.15	8,813.88	1,822.17	4,159.10	116	14,791.50	8,816.38	1,817.87	4,157.25	179	14,808.25	8,817.67	1,821.60	4,168.98
54	14,790.80	8,817.77	1,823.35	4,149.68	117	14,786.48	8,810.87	1,813.12	4,162.50	180	14,810.03	8,841.08	1,821.13	4,147.82
55	14,786.20	8,820.75	1,814.92	4,150.53	118	14,764.87	8,798.90	1,809.10	4,156.87	181	14,802.47	8,820.40	1,817.62	4,164.45
56	14,797.87	8,825.42	1,815.40	4,157.05	119	14,763.02	8,796.12	1,820.93	4,145.97	182	14,827.02	8,842.47	1,817.42	4,167.13
57	14,795.30	8,828.30	1,810.78	4,156.22	120	14,814.47	8,823.88	1,825.10	4,165.48	183	14,807.55	8,811.10	1,827.23	4,169.22
58	14,782.62	8,819.33	1,817.02	4,146.27	121	14,791.58	8,809.75	1,820.75	4,161.08	184	14,800.35	8,827.87	1,816.20	4,156.28
59	14,810.13	8,846.95	1,810.08	4,153.10	122	14,790.40	8,822.78	1,824.83	4,142.78	Average	14,798.19	8,819.86	1,820.04	4,158.30
60	14,780.32	8,797.43	1,824.52	4,158.37	123	14,814.58	8,831.58	1,822.20	4,160.80					
61	14,804.45	8,809.72	1,832.97	4,161.77	124	14,795.22	8,818.75	1,814.75	4,161.72					
62	14,807.77	8,824.58	1,822.22	4,160.97	125	14,796.72	8,818.83	1,810.75	4,167.13					

## Sustainability – I/O Request Throughput Distribution Graph

Sustainability – Average Response Time (ms) Distribution Data

	Start	Stop	Interval	Duration
Ramp-Up/Start-Up	14:12:35	14:17:35	0-4	0:05:00
Measurement Interval	14:17:35	17:17:35	4-184	3:00:00

Interval	All ASUs	ASU1	ASU2	ASU3	Interval	All ASUs	ASU1	ASU2	ASU3	Interval	All ASUs	ASU1	ASU2	ASU3
0	13.16	15.02	27.78	2.80	63	12.93	15.16	29.50	0.97	126	12.89	15.16	29.07	0.98
1	13.03	15.24	29.71	1.04	64	13.04	15.19	30.27	0.96	127	12.91	15.10	29.57	0.97
2	12.91	15.11	29.59	0.97	65	12.85	15.07	29.25	0.95	128	12.96	15.16	29.68	0.99
3	12.94	15.20	29.23	0.99	66	12.89	15.16	29.07	0.97	129	12.91	15.13	29.27	1.03
4	12.78	14.94	29.23	1.00	67	12.98	15.20	29.63	0.98	130	12.88	15.08	29.23	1.00
5	12.83	15.00	29.37	0.98	68	13.07	15.29	29.98	0.94	131	12.87	15.07	29.37	0.99
6	12.95	15.14	29.68	0.99	69	13.03	15.28	29.60	0.98	132	12.95	15.17	29.58	0.99
7	12.86	15.03	29.47	0.96	70	12.91	15.15	29.29	0.98	133	12.86	15.09	29.11	1.00
8	13.05	15.24	29.98	1.01	71	13.07	15.33	29.65	1.00	134	12.90	15.12	29.44	0.95
9	12.82	15.01	29.42	0.96	72	12.83	15.10	29.02	0.97	135	12.93	15.16	29.50	0.97
10	12.82	15.01	29.40	0.95	73	12.92	15.19	29.19	0.99	136	12.82	15.01	29.22	1.00
11	12.91	15.11	29.66	0.97	74	12.87	15.03	29.53	0.97	137	12.84	15.12	28.90	0.95
12	12.89	15.13	29.13	1.00	75	13.03	15.24	29.77	1.01	138	12.91	15.13	29.46	0.97
13	12.96	15.18	29.48	0.99	76	12.87	15.08	29.40	0.94	139	12.95	15.24	29.35	0.91
14	12.83	15.06	29.17	0.99	77	12.86	15.06	29.46	0.96	140	12.79	15.08	28.72	0.98
15	12.86	15.14	29.18	0.96	78	12.90	15.17	29.12	0.99	141	12.91	15.13	29.17	1.04
16	12.94	15.21	29.38	0.96	79	12.83	15.03	29.09	1.04	142	12.86	15.09	29.10	0.98
17	12.80	14.97	29.37	0.99	80	12.89	15.10	29.23	1.03	143	12.99	15.26	29.35	1.02
18	12.91	15.09	29.60	0.98	81	12.94	15.18	29.32	1.00	144	12.88	15.07	29.47	0.97
19	12.91	15.14	29.56	0.94	82	12.83	15.09	29.01	0.96	145	12.98	15.18	29.57	1.03
20	12.93	15.17	29.39	0.98	83	12.89	15.14	29.34	1.00	146	12.78	15.06	28.64	0.98
21	12.91	15.04	29.77	0.94	84	12.93	15.14	29.43	0.99	147	12.86	15.07	29.19	0.97
22	12.87	15.07	29.37	0.96	85	12.82	15.06	29.11	0.98	148	12.87	15.10	29.23	0.96
23	12.90	15.16	29.22	0.96	86	12.97	15.17	29.77	0.94	149	12.81	15.09	28.82	0.97
24	13.01	15.22	29.75	0.97	87	12.83	15.10	28.96	0.95	150	12.84	15.10	29.07	0.93
25	12.87	15.13	29.16	0.96	88	12.89	15.09	29.54	0.95	151	13.05	15.33	29.47	0.99
26	12.99	15.24	29.55	0.98	89	12.97	15.17	29.55	1.01	152	12.77	14.99	29.14	0.99
27	12.87	15.08	29.39	0.98	90	12.81	15.02	29.17	0.97	153	12.81	15.06	28.94	0.98
28	12.90	15.19	29.18	0.96	91	12.88	15.11	29.20	1.00	154	12.93	15.21	29.17	0.99
29	12.99	15.19	29.80	0.99	92	12.87	15.12	29.03	0.99	155	12.85	15.04	29.27	0.97
30	13.10	15.34	29.84	0.99	93	12.85	15.10	29.05	0.95	156	12.86	15.04	29.28	1.03
31	12.98	15.25	29.51	0.96	94	12.79	15.03	28.91	0.97	157	13.02	15.22	29.71	1.02
32	12.86	15.07	29.37	0.99	95	13.00	15.23	29.48	1.03	158	12.94	15.11	29.74	0.96
33	12.97	15.25	29.13	0.99	96	12.72	14.92	29.04	0.97	159	12.92	15.19	29.28	0.99
34	13.08	15.29	29.93	0.98	97	13.05	15.26	29.80	1.00	160	12.84	15.08	29.04	0.99
35	12.95	15.23	29.25	0.99	98	12.88	15.10	29.30	0.93	161	12.86	15.08	29.34	0.98
36	12.83	15.09	29.02	0.99	99	13.00	15.24	29.65	1.02	162	12.92	15.17	29.23	0.98
37	12.92	15.13	29.42	1.01	100	12.97	15.23	29.38	0.97	163	12.75	15.00	28.70	0.99
38	12.95	15.18	29.60	0.97	101	12.93	15.12	29.70	0.95	164	12.81	15.02	29.14	0.99
39	12.87	15.16	28.99	0.96	102	12.85	15.05	29.47	0.98	165	12.84	15.06	29.26	0.94
40	12.93	15.22	29.20	0.97	103	12.97	15.20	29.56	0.96	166	12.87	15.13	28.94	1.02
41	12.90	15.09	29.42	1.02	104	12.88	15.09	29.25	0.97	167	13.18	15.52	29.81	0.98
42	13.09	15.31	29.84	0.97	105	12.88	15.13	29.27	0.95	168	12.76	15.00	28.80	0.97
43	12.90	15.12	29.36	0.99	106	12.91	15.05	29.77	0.96	169	12.87	15.14	29.12	0.96
44	12.87	15.11	29.20	0.96	107	12.84	15.09	28.92	1.03	170	12.78	14.99	29.06	0.96
45	12.94	15.14	29.50	0.98	108	12.89	15.11	29.36	0.99	171	12.83	15.04	29.23	0.95
46	12.95	15.19	29.35	0.97	109	13.02	15.22	29.84	0.97	172	12.84	15.05	29.21	0.98
47	12.89	15.06	29.50	1.00	110	12.88	15.16	28.88	0.99	173	12.82	15.08	29.10	0.97
48	12.92	15.11	29.52	1.00	111	12.77	15.00	28.83	1.01	174	13.04	15.35	29.38	1.00
49	12.98	15.20	29.71	0.97	112	12.89	15.06	29.44	0.99	175	13.00	15.24	29.53	0.98
50	13.01	15.27	29.56	1.02	113	12.94	15.18	29.35	1.06	176	12.98	15.21	29.60	0.99
51	12.84	15.02	29.54	0.97	114	13.00	15.29	29.25	0.95	177	12.86	15.10	29.10	0.98
52	12.98	15.19	29.68	1.01	115	12.88	15.09	29.25	1.00	178	12.91	15.17	29.16	0.99
53	12.80	14.99	29.24	0.98	116	12.82	15.04	29.04	1.00	179	12.97	15.23	29.53	0.94
54	13.14	15.43	29.86	0.93	117	12.89	15.13	29.39	0.97	180	12.88	15.08	29.16	1.03
55	12.87	15.10	29.20	0.99	118	12.93	15.17	29.56	0.98	181	12.81	15.03	29.12	1.00
56	12.92	15.14	29.45	0.98	119	12.91	15.17	29.15	0.97	182	13.00	15.23	29.74	0.96
57	13.05	15.30	29.70	1.03	120	12.81	15.03	29.05	0.98	183	12.90	15.15	29.28	0.97
58	13.03	15.26	29.69	0.99	121	12.91	15.16	29.52	1.00	184	12.95	15.17	29.52	0.97
59	13.04	15.24	30.00	0.98	122	12.96	15.16	29.52	0.96	Average	12.91	15.14	29.35	0.98
60	12.84	15.15	28.74	0.99	123	12.93	15.19	29.27	1.00					
61	12.91	15.14	29.28	0.99	124	12.79	15.03	29.03	0.98					
62	13.03	15.28	29.61	0.98	125	12.85	15.10	29.22	0.98					

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	464,426	2,040,176	2,496,549	1,106,736	352,365	303,765	191,829	170,041
Write	3,990	5,645,212	24,930,078	32,229,371	17,674,587	11,003,196	3,601,013	1,016,320
All ASUs	468,416	7,685,388	27,426,627	33,336,107	18,026,952	11,306,961	3,792,842	1,186,361
ASU1	427,123	4,601,518	13,747,102	14,872,057	7,527,786	4,234,568	1,319,393	461,429
ASU2	40,872	1,216,356	3,451,435	3,584,042	1,792,602	1,007,359	306,425	91,019
ASU3	421	1,867,514	10,228,090	14,880,008	8,706,564	6,065,034	2,167,024	633,913

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	288,042	536,157	597,126	758,651	759,542	1,113,221	2,298,956	2,465,408
Write	302,084	146,156	46,361	40,899	19,095	21,416	24,812	12,136
All ASUs	590,126	682,313	643,487	799,550	778,637	1,134,637	2,323,768	2,477,544
ASU1	360,678	548,368	574,994	727,832	722,103	1,049,324	2,142,238	2,273,394
ASU2	44,760	50,283	44,512	51,853	47,010	74,812	169,981	198,624
ASU3	184,688	83,662	23,981	19,865	9,524	10,501	11,549	5,526

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	2,496,259	2,346,066	2,093,419	8,453,052	5,559,700	4,154,688	3,107,511	18,867,233
Write	8,940	5,205	5,267	14,434	6,185	5,201	4,450	32,962
All ASUs	2,505,199	2,351,271	2,098,686	8,467,486	5,565,885	4,159,889	3,111,961	18,900,195
ASU1	2,293,543	2,143,613	1,903,244	7,583,885	4,916,216	3,631,662	2,691,642	14,500,629
ASU2	208,085	205,696	193,651	879,541	649,449	528,173	420,305	4,399,510
ASU3	3,571	1,962	1,791	4,060	220	54	14	56

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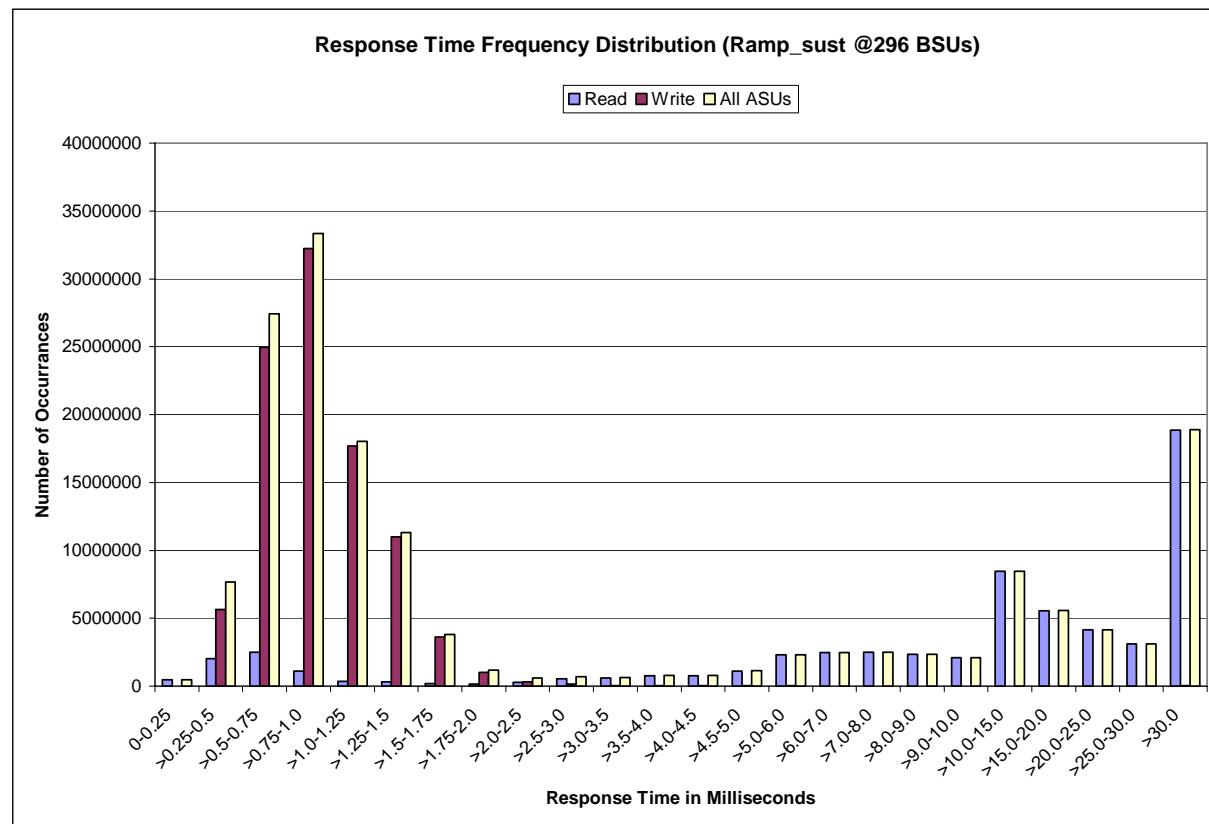
Sustainability – Measured Intensity Multiplier and Coefficient of Variation

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 5.1.10 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.*

	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	0.0700	0.2100	0.0180	0.0700	0.0350	0.2810
COV	0.006	0.002	0.004	0.002	0.008	0.004	0.006	0.002

Primary Metrics Test – IOPS Test Phase

Clause 5.4.4.2

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 9.4.3.7.2

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

296 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	17:17:37	17:22:38	0-4	0:05:01
Measurement Interval	17:22:38	17:32:38	3-14	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	14,823.27	8,828.60	1,824.60	4,170.07
1	14,774.25	8,809.90	1,817.32	4,147.03
2	14,806.23	8,821.10	1,821.37	4,163.77
3	14,792.00	8,800.13	1,820.67	4,171.20
4	14,791.37	8,815.30	1,825.05	4,151.02
5	14,795.67	8,819.22	1,823.93	4,152.52
6	14,810.13	8,831.22	1,813.38	4,165.53
7	14,800.83	8,825.22	1,816.37	4,159.25
8	14,800.25	8,814.98	1,823.02	4,162.25
9	14,797.25	8,818.58	1,815.65	4,163.02
10	14,802.92	8,829.82	1,827.40	4,145.70
11	14,785.53	8,807.53	1,817.83	4,160.17
12	14,800.68	8,818.93	1,822.33	4,159.42
13	14,795.98	8,811.63	1,824.58	4,159.77
14	14,783.30	8,815.08	1,815.23	4,152.98
Average	*14,797.26*	*8,819.22*	*1,819.97*	*4,158.06*

IOPS Test Run – I/O Request Throughput Distribution Graph
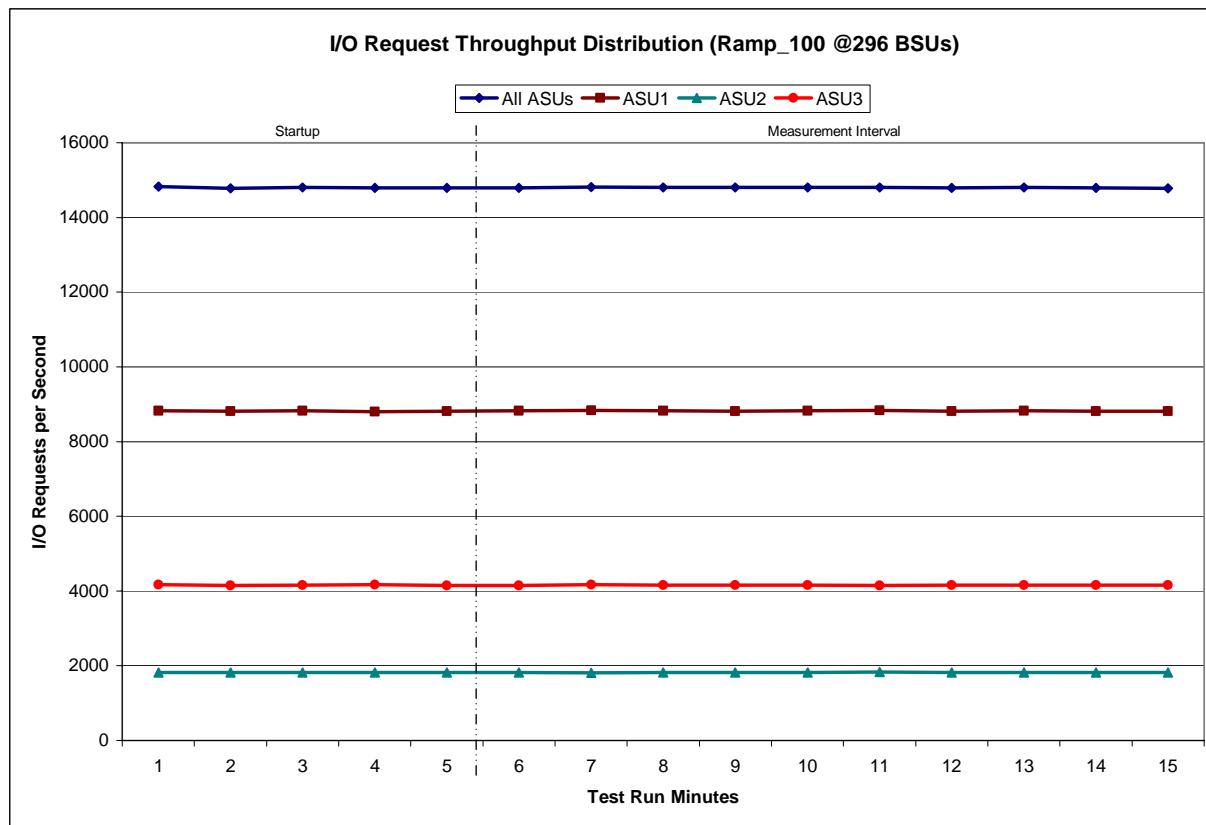
SPC BENCHMARK 1™ V1.12   FULL DISCLOSURE REPORT   Submission Identifier: A00101
IBM Corporation   Submitted for Review: DECEMBER 31, 2010
IBM System Storage® DS3524 Express

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

296 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	17:17:37	17:22:38	0-4	0:05:01
Measurement Interval	17:22:38	17:32:38	3-14	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	20.15	20.59	37.17	11.76
1	12.93	15.16	29.43	0.97
2	13.02	15.27	29.67	0.96
3	13.20	15.53	29.95	0.99
4	13.05	15.29	29.65	0.98
5	13.01	15.27	29.36	1.00
6	13.01	15.27	29.54	1.03
7	13.09	15.34	29.84	0.99
8	12.98	15.18	29.77	0.98
9	12.87	15.12	29.28	0.96
10	13.05	15.26	29.74	0.96
11	13.02	15.30	29.57	0.96
12	13.04	15.29	29.61	0.99
13	13.02	15.28	29.61	0.96
14	13.09	15.38	29.64	1.00
Average	*13.02*	*15.27*	*29.60*	*0.98*

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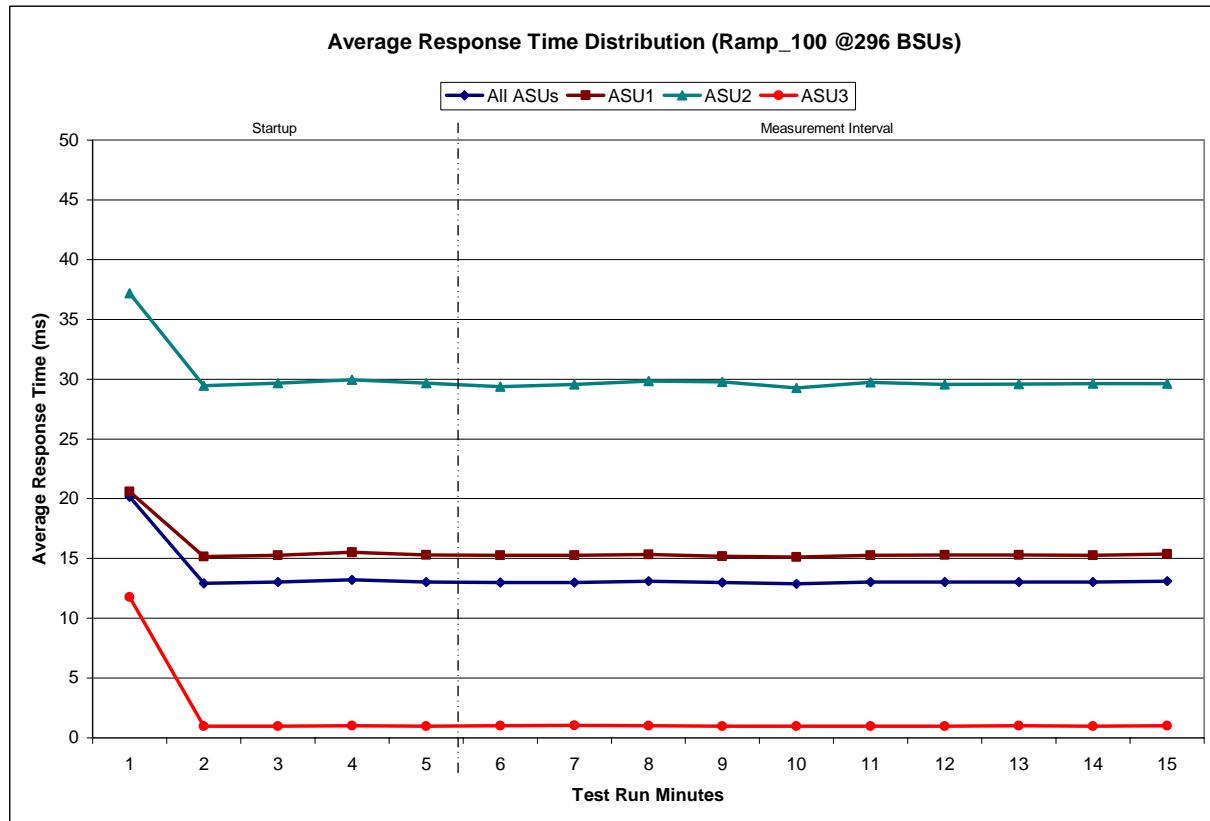
IOPS Test Run – Response Time Frequency Distribution Data

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	26971	113,151	137,574	61,612	19,543	16,860	10,645	9,475
Write	208	308,958	1,377,673	1,783,169	993,224	619,039	201,399	55,697
All ASUs	27179	422,109	1,515,247	1,844,781	1,012,767	635,899	212,044	65,172
ASU1	24864	253,292	759,927	823,548	423,359	238,129	73,541	25,063
ASU2	2299	66,593	191,075	197,976	101,095	56,861	17,110	4,881
ASU3	16	102,224	564,245	823,257	488,313	340,909	121,393	35,228

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	16,110	29,458	33,055	42,036	41,432	61,610	127,817	137,323
Write	15,353	7,955	2,679	2,406	1,116	1,172	1,278	575
All ASUs	31,463	37,413	35,734	44,442	42,548	62,782	129,095	137,898
ASU1	19,603	30,131	31,815	40,397	39,471	58,139	119,071	126,723
ASU2	2,368	2,791	2,531	2,864	2,530	4,062	9,415	10,919
ASU3	9,492	4,491	1,388	1,181	547	581	609	256

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	138,560	130,460	116,115	467,972	306,622	229,155	172,239	1,055,644
Write	505	289	214	823	401	284	287	2,015
All ASUs	139,065	130,749	116,329	468,795	307,023	229,439	172,526	1,057,659
ASU1	127,336	119,234	105,335	419,423	270,769	200,179	149,045	812,981
ASU2	11,512	11,407	10,933	49,146	36,206	29,251	23,471	244,653
ASU3	217	108	61	226	48	9	10	25

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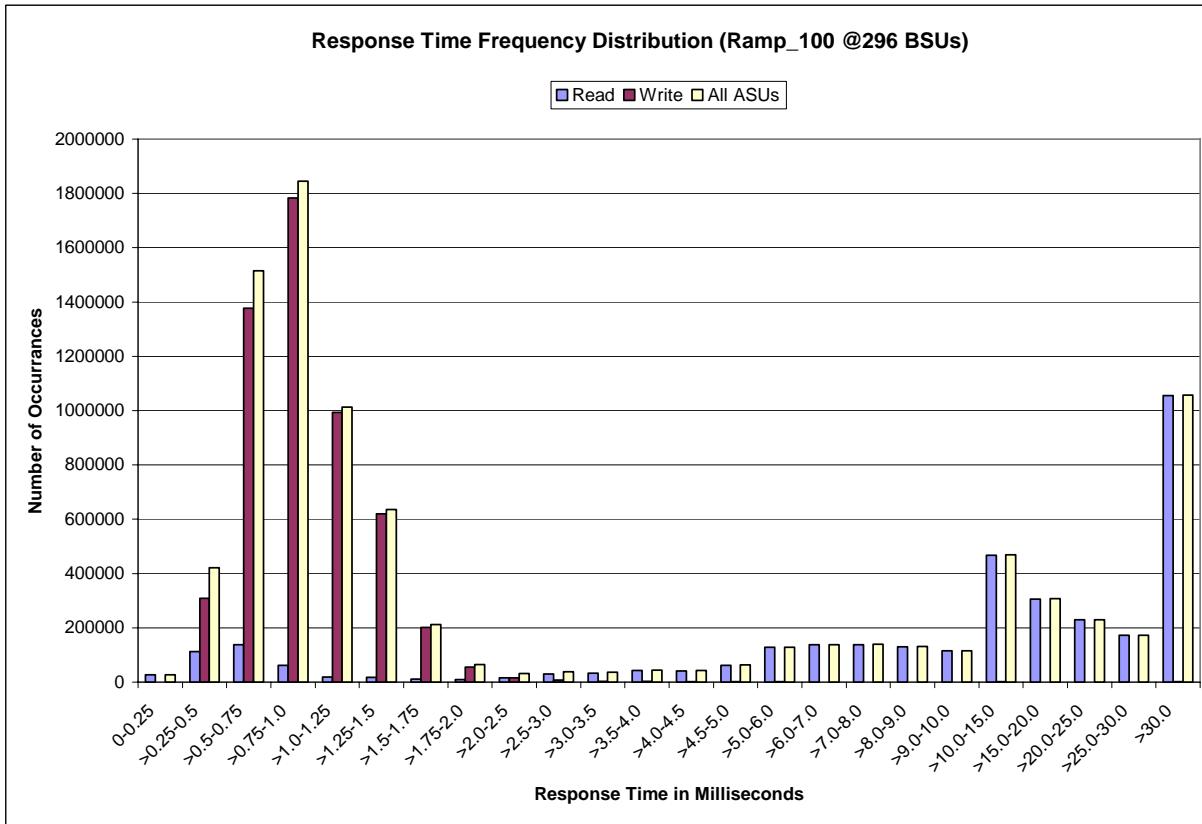
IOPS Test Run – I/O Request Information

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
8,878,158	7,820,499	1,057,659

IOPS Test Run – Measured Intensity Multiplier and Coefficient of Variation

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 5.1.10 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.*

	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	0.2808	0.0701	0.2101	0.0180	0.0700	0.0350	0.2810
COV	0.005	0.001	0.004	0.001	0.008	0.003	0.005	0.001

Primary Metrics Test – Response Time Ramp Test Phase

Clause 5.4.4.3

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 9.4.3.7.3

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 - 296 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	17:17:37	17:22:38	0-4	0:05:01
Measurement Interval	17:22:38	17:32:38	5-14	0:10:00
(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3
0	14,823.27	8,828.60	1,824.60	4,170.07
1	14,774.25	8,809.90	1,817.32	4,147.03
2	14,806.23	8,821.10	1,821.37	4,163.77
3	14,792.00	8,800.13	1,820.67	4,171.20
4	14,791.37	8,815.30	1,825.05	4,151.02
5	14,795.67	8,819.22	1,823.93	4,152.52
6	14,810.13	8,831.22	1,813.38	4,165.53
7	14,800.83	8,825.22	1,816.37	4,159.25
8	14,800.25	8,814.98	1,823.02	4,162.25
9	14,797.25	8,818.58	1,815.65	4,163.02
10	14,802.92	8,829.82	1,827.40	4,145.70
11	14,785.53	8,807.53	1,817.83	4,160.17
12	14,800.68	8,818.93	1,822.33	4,159.42
13	14,795.98	8,811.63	1,824.58	4,159.77
14	14,783.30	8,815.08	1,815.23	4,152.98
Average	14,797.26	8,819.22	1,819.97	4,158.06

95% Load Level - 281 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	17:32:39	17:37:40	0-4	0:05:01
Measurement Interval	17:37:40	17:47:40	5-14	0:10:00
(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3
0	14,036.15	8,360.23	1,734.40	3,941.52
1	14,056.23	8,364.92	1,731.93	3,959.38
2	14,053.00	8,375.65	1,726.35	3,951.00
3	14,053.78	8,384.92	1,721.10	3,947.77
4	14,085.08	8,394.10	1,737.15	3,953.83
5	14,069.18	8,385.43	1,732.40	3,951.35
6	14,054.58	8,388.67	1,725.78	3,940.13
7	14,028.30	8,355.17	1,719.72	3,953.42
8	14,036.25	8,348.08	1,735.77	3,952.40
9	14,067.95	8,387.25	1,726.48	3,954.22
10	14,039.65	8,367.02	1,725.25	3,947.38
11	14,076.13	8,390.70	1,735.07	3,950.37
12	14,062.70	8,375.92	1,730.08	3,956.70
13	14,080.38	8,398.63	1,727.83	3,953.92
14	14,056.47	8,381.38	1,729.55	3,945.53
Average	14,057.16	8,377.83	1,728.79	3,950.54

90% Load Level - 266 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	17:47:41	17:52:42	0-4	0:05:01
Measurement Interval	17:52:42	18:02:42	5-14	0:10:00
(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3
0	13,322.35	7,931.50	1,636.38	3,754.47
1	13,264.98	7,905.62	1,631.03	3,728.33
2	13,322.30	7,933.38	1,644.90	3,744.02
3	13,317.78	7,935.17	1,635.62	3,747.00
4	13,324.98	7,949.97	1,631.47	3,743.55
5	13,319.73	7,929.87	1,638.23	3,751.63
6	13,304.08	7,915.93	1,639.35	3,748.80
7	13,305.30	7,921.60	1,643.85	3,739.85
8	13,291.95	7,919.52	1,628.77	3,743.67
9	13,308.15	7,927.37	1,639.12	3,741.67
10	13,287.13	7,918.32	1,631.43	3,737.38
11	13,302.40	7,921.17	1,639.28	3,741.95
12	13,314.37	7,944.27	1,640.62	3,729.48
13	13,311.92	7,932.60	1,635.92	3,743.40
14	13,339.55	7,957.62	1,635.77	3,746.17
Average	13,308.46	7,928.83	1,637.23	3,742.40

80% Load Level - 236 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	18:02:43	18:07:44	0-4	0:05:01
Measurement Interval	18:07:44	18:17:44	5-14	0:10:00
(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3
0	11,793.87	7,034.15	1,444.65	3,315.07
1	11,796.55	7,029.20	1,453.48	3,313.87
2	11,783.73	7,027.48	1,452.75	3,303.50
3	11,812.53	7,039.42	1,449.43	3,323.68
4	11,775.28	7,014.50	1,447.70	3,313.08
5	11,808.47	7,046.82	1,444.70	3,316.95
6	11,812.23	7,042.13	1,454.83	3,315.27
7	11,797.48	7,041.57	1,450.95	3,304.97
8	11,782.58	7,011.47	1,455.80	3,315.32
9	11,829.50	7,050.42	1,452.02	3,327.07
10	11,786.70	7,028.13	1,453.75	3,304.82
11	11,793.88	7,031.73	1,451.23	3,310.92
12	11,812.98	7,031.52	1,458.68	3,322.78
13	11,801.83	7,031.88	1,452.57	3,317.38
14	11,779.30	7,028.22	1,436.40	3,314.68
Average	11,800.50	7,034.39	1,451.09	3,315.02

50% Load Level - 148 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	18:17:45	18:22:46	0-4	0:05:01
Measurement Interval	18:22:46	18:32:46	5-14	0:10:00
(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3
0	7,393.65	4,395.48	914.97	2,083.20
1	7,391.75	4,407.02	907.48	2,077.25
2	7,390.42	4,404.03	908.38	2,078.00
3	7,407.52	4,417.40	910.78	2,079.33
4	7,409.50	4,415.52	907.87	2,086.12
5	7,383.95	4,397.75	908.25	2,077.95
6	7,409.78	4,413.63	904.53	2,091.62
7	7,419.47	4,430.95	908.77	2,079.75
8	7,390.03	4,405.15	912.92	2,071.97
9	7,420.82	4,428.33	908.87	2,083.62
10	7,407.12	4,417.62	910.20	2,079.30
11	7,390.85	4,403.42	912.27	2,075.17
12	7,399.18	4,404.52	918.27	2,076.40
13	7,396.25	4,414.03	908.73	2,073.48
14	7,400.13	4,409.63	913.50	2,077.00
Average	7,401.76	4,412.50	910.63	2,078.63

10% Load Level - 29 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	18:32:47	18:37:48	0-4	0:05:01
Measurement Interval	18:37:48	18:47:48	5-14	0:10:00
(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3
0	1,446.75	862.73	177.30	406.72
1	1,446.30	864.05	177.07	405.18
2	1,448.68	865.98	179.33	403.37
3	1,450.43	863.63	180.83	405.97
4	1,440.28	858.95	175.42	405.92
5	1,463.00	870.45	180.80	411.75
6	1,453.13	867.28	178.30	407.55
7	1,446.97	862.50	177.35	407.12
8	1,443.87	855.72	179.37	408.78
9	1,457.05	869.35	179.45	408.25
10	1,445.87	861.47	176.85	407.55
11	1,448.90	861.22	177.68	410.00
12	1,454.37	869.48	176.42	408.47
13	1,448.28	861.50	179.93	406.85
14	1,451.78	866.20	178.70	406.88
Average	1,451.32	864.52	178.49	408.32

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Response Time Ramp Distribution (IOPS) Graph

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

29 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	18:32:47	18:37:48	0-4	0:05:01
Measurement Interval	18:37:48	18:47:48	5-14	0:10:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	5.43	5.61	8.19	3.85
1	5.16	4.89	6.91	4.97
2	4.50	4.27	5.24	4.67
3	4.02	4.11	5.08	3.36
4	5.79	4.82	6.56	7.50
5	5.62	4.86	8.01	6.16
6	5.95	5.13	7.64	6.94
7	4.10	4.16	5.20	3.49
8	5.76	4.95	7.57	6.67
9	3.38	4.17	4.48	1.21
10	3.82	3.99	5.63	2.68
11	6.15	5.37	7.86	7.05
12	2.92	3.66	3.81	0.98
13	4.69	4.53	5.69	4.58
14	3.72	4.04	4.43	2.72
Average	*4.61*	*4.49*	*6.03*	*4.25*

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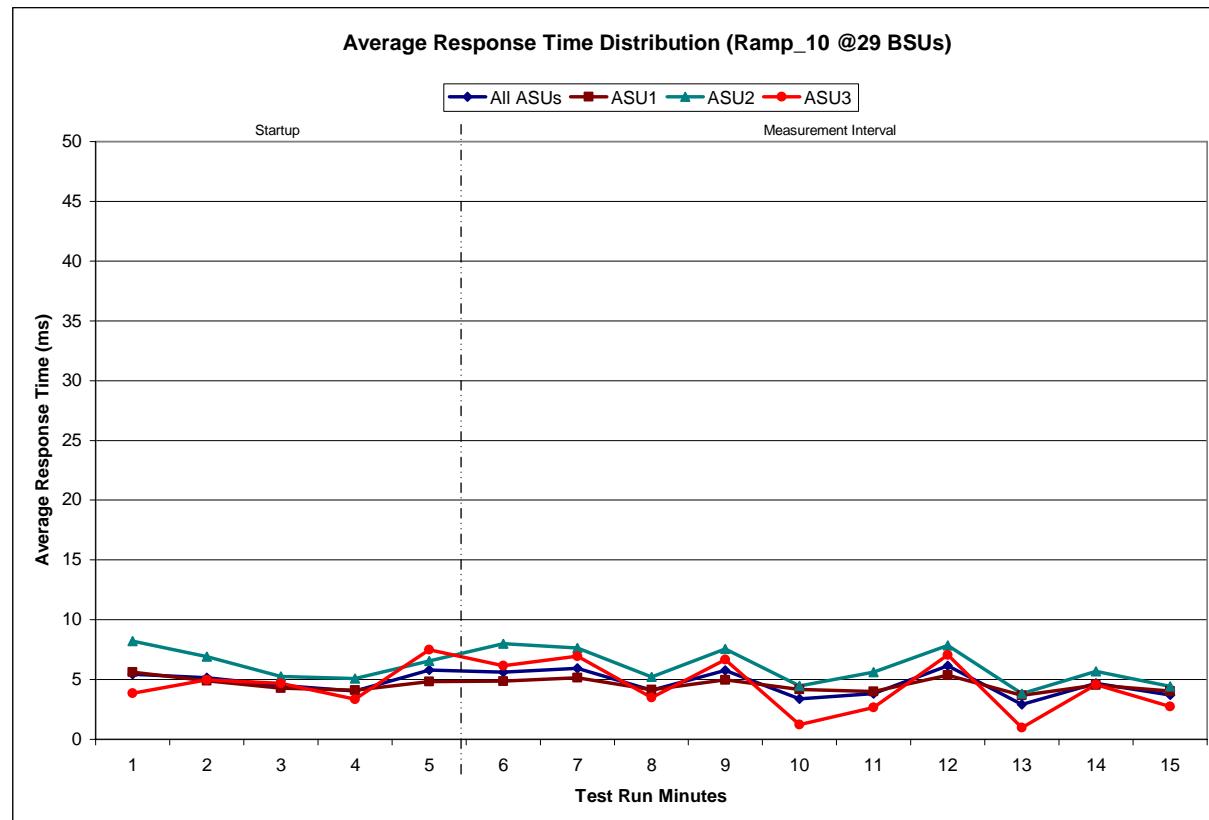
SPC-1 LRT™ (10%) – Measured Intensity Multiplier and Coefficient of Variation

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 5.1.10 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.*

	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	0.2814	0.0701	0.2093	0.0180	0.0700	0.0349	0.2813
COV	0.020	0.008	0.011	0.008	0.017	0.008	0.017	0.004

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% or less than the SPC-1 LRT™ metric plus one (1) millisecond (ms).

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 9.4.3.7.4

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 in the tables below.

	SPC-1 IOPS™
Primary Metrics	*14,797.26*
Repeatability Test Phase 1	14,794.01
Repeatability Test Phase 2	14,801.64

The SPC-1 IOPS™ values in the above table were generated using 100% of the specified Business Scaling Unit (BSU) load level. Each of the Repeatability Test Phase values for SPC-1 IOPS™ must greater than 95% of the reported SPC-1 IOPS™ Primary Metric.

	SPC-1 LRT™
Primary Metrics	*4.61 ms*
Repeatability Test Phase 1	4.28 ms
Repeatability Test Phase 2	4.79 ms

The average response time values in the SPC-1 LRT™ column were generated using 10% of the specified Business Scaling Unit (BSU) load level. Each of the Repeatability Test Phase values for SPC-1 LRT™ must be less than 105% of the reported SPC-1 LRT™ Primary Metric or less than the reported SPC-1 LRT™ Primary Metric minus one (1) millisecond (ms).

A link to the test result file generated from each Repeatability Test Run 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

| 29 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	18:47:51	18:52:51	0-4	0:05:00
Measurement Interval	18:52:51	19:02:51	3-14	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	1,452.50	865.55	179.25	407.70
1	1,448.60	867.33	176.40	404.87
2	1,447.33	859.03	180.58	407.72
3	1,456.63	868.10	179.83	408.70
4	1,448.22	862.75	180.60	404.87
5	1,449.48	863.12	177.65	408.72
6	1,455.02	865.72	178.35	410.95
7	1,450.12	866.27	175.57	408.28
8	1,454.15	868.03	177.98	408.13
9	1,452.33	867.50	176.63	408.20
10	1,453.07	862.37	182.30	408.40
11	1,444.65	861.35	177.52	405.78
12	1,444.45	859.93	179.05	405.47
13	1,453.48	865.73	179.93	407.82
14	1,457.10	872.00	179.47	405.63
Average	*1,451.39*	*865.20*	*178.45*	*407.74*

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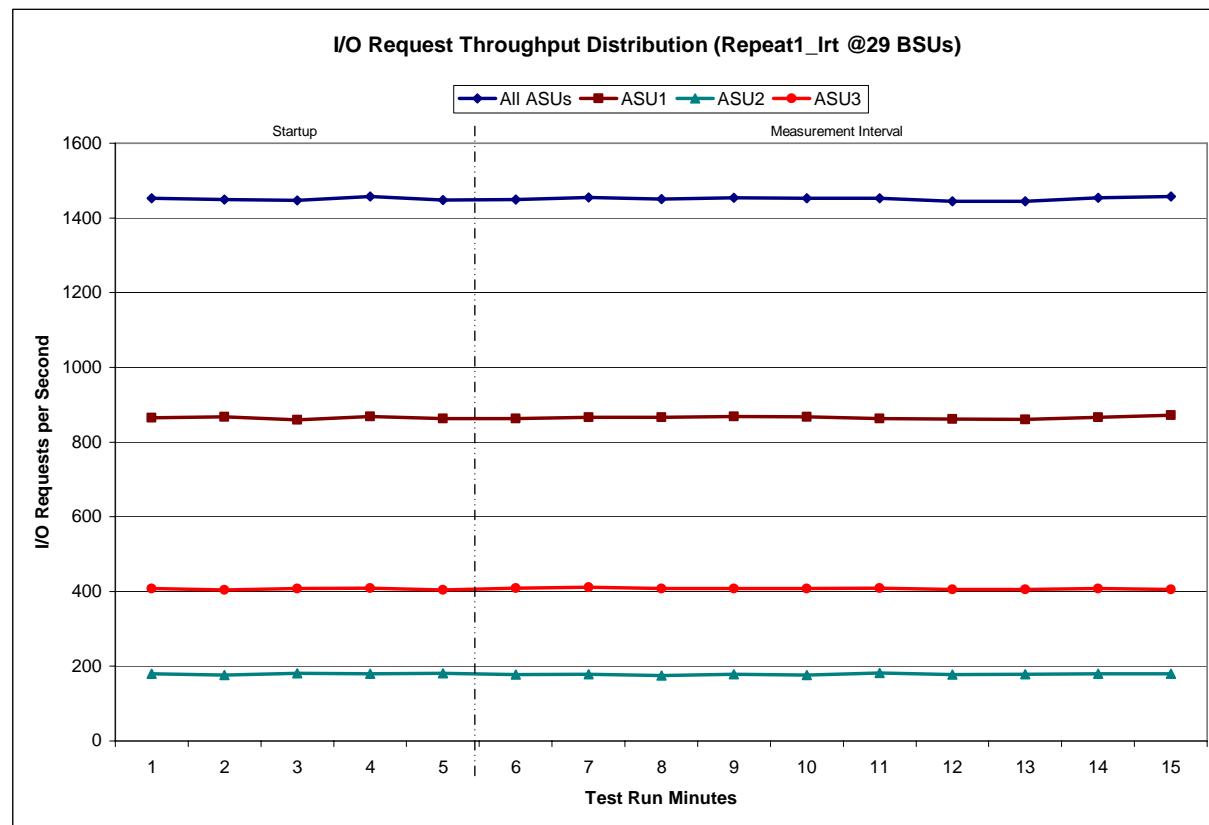
Repeatability 1 LRT –Average Response Time (ms) Distribution Data

29 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	18:47:51	18:52:51	0-4	0:05:00
Measurement Interval	18:52:51	19:02:51	3-14	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	5.54	4.97	6.67	6.25
1	2.95	3.78	3.96	0.74
2	4.57	4.60	5.32	4.16
3	4.93	4.35	6.16	5.63
4	7.66	6.01	8.96	10.59
5	4.44	4.32	6.05	4.01
6	2.98	3.67	3.46	1.32
7	3.02	3.77	3.95	1.02
8	4.96	4.66	6.46	4.92
9	3.22	3.86	3.99	1.53
10	5.12	4.39	5.98	6.28
11	6.09	5.07	8.68	7.13
12	2.87	3.62	3.67	0.92
13	5.94	5.26	6.80	7.00
14	4.18	4.16	5.38	3.68
Average	*4.28*	*4.28*	*5.44*	*3.78*

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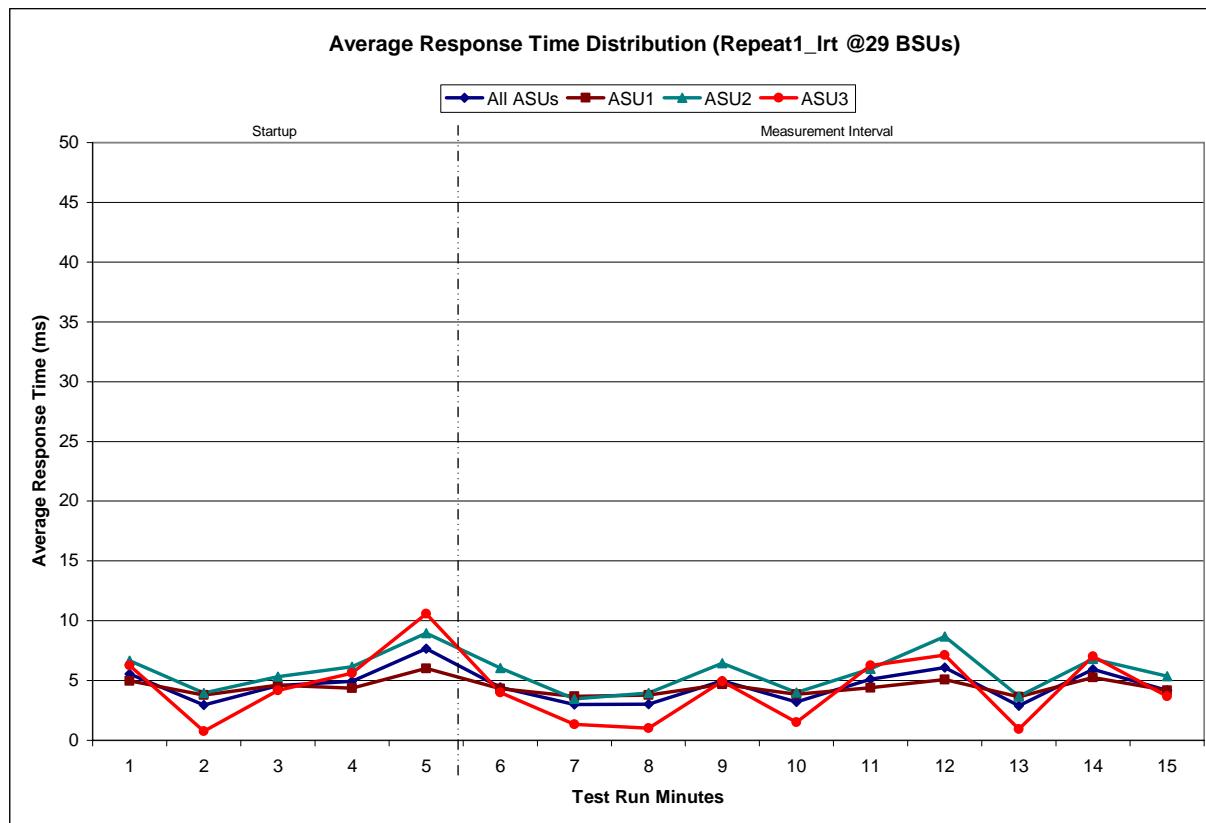
Repeatability 1 IOPS – I/O Request Throughput Distribution Data

296 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	19:02:52	19:07:53	0-4	0:05:01
Measurement Interval	19:07:53	19:17:53	3-14	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	14,793.17	8,821.48	1,820.53	4,151.15
1	14,796.02	8,824.17	1,816.75	4,155.10
2	14,765.58	8,803.13	1,810.83	4,151.62
3	14,802.78	8,829.87	1,819.15	4,153.77
4	14,817.38	8,835.28	1,818.32	4,163.78
5	14,744.92	8,782.87	1,811.55	4,150.50
6	14,837.85	8,841.43	1,827.00	4,169.42
7	14,784.67	8,803.20	1,821.53	4,159.93
8	14,794.48	8,815.22	1,819.00	4,160.27
9	14,782.60	8,812.98	1,820.32	4,149.30
10	14,799.95	8,803.93	1,820.72	4,175.30
11	14,817.20	8,833.22	1,831.47	4,152.52
12	14,812.52	8,833.18	1,822.68	4,156.65
13	14,760.53	8,795.18	1,819.30	4,146.05
14	14,805.38	8,818.30	1,820.12	4,166.97
Average	*14,794.01*	*8,813.95*	*1,821.37*	*4,158.69*

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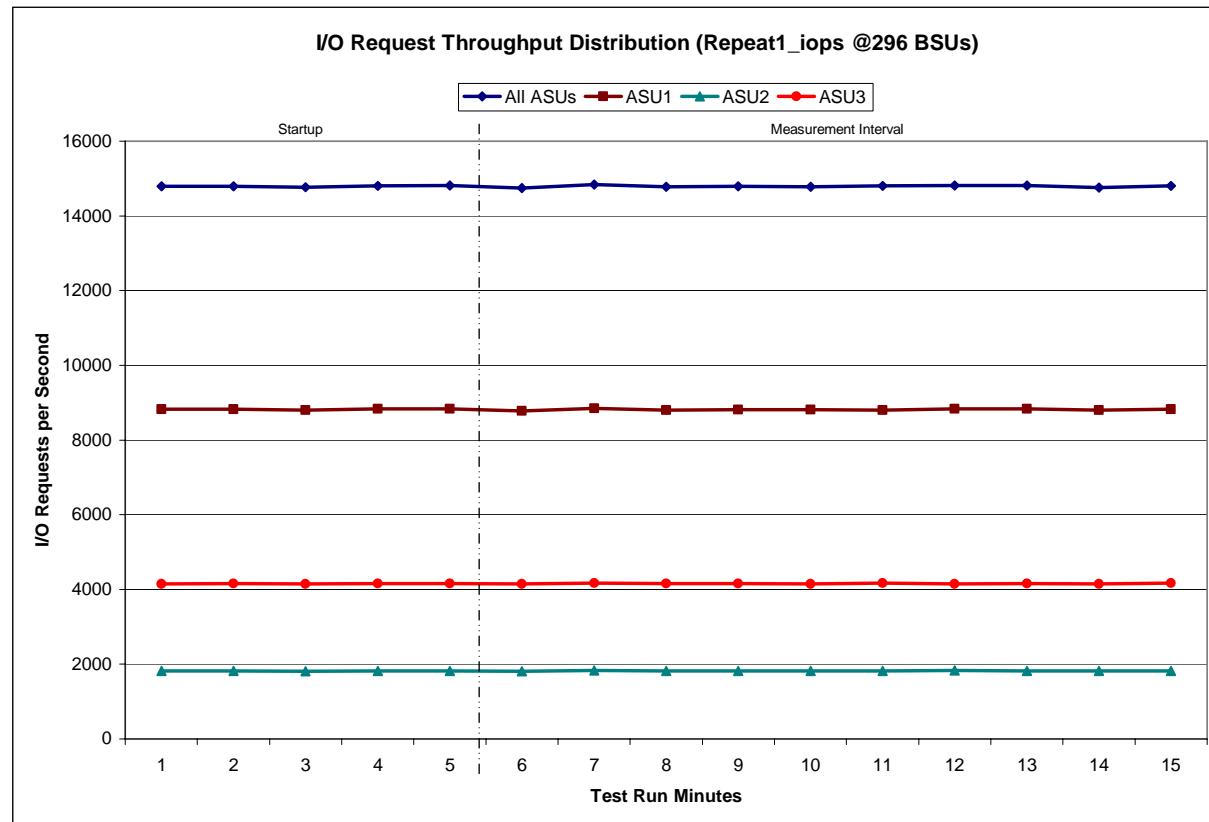
Repeatability 1 IOPS –Average Response Time (ms) Distribution Data

296 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	19:02:52	19:07:53	0-4	0:05:01
Measurement Interval	19:07:53	19:17:53	3-14	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	18.59	19.31	34.41	10.11
1	23.38	23.28	39.93	16.34
2	19.02	19.83	35.58	10.08
3	18.74	19.56	35.62	9.59
4	19.28	20.19	36.08	10.00
5	29.17	27.66	45.21	25.35
6	37.66	34.03	53.76	38.28
7	32.00	29.83	48.23	29.48
8	18.44	19.35	35.14	9.23
9	24.29	23.90	40.92	17.81
10	25.28	24.69	41.75	19.36
11	20.92	21.23	37.58	12.90
12	14.68	16.52	31.64	3.34
13	16.24	17.67	32.91	5.90
14	18.92	19.80	35.62	9.78
Average	*23.76*	*23.47*	*40.28*	*17.14*

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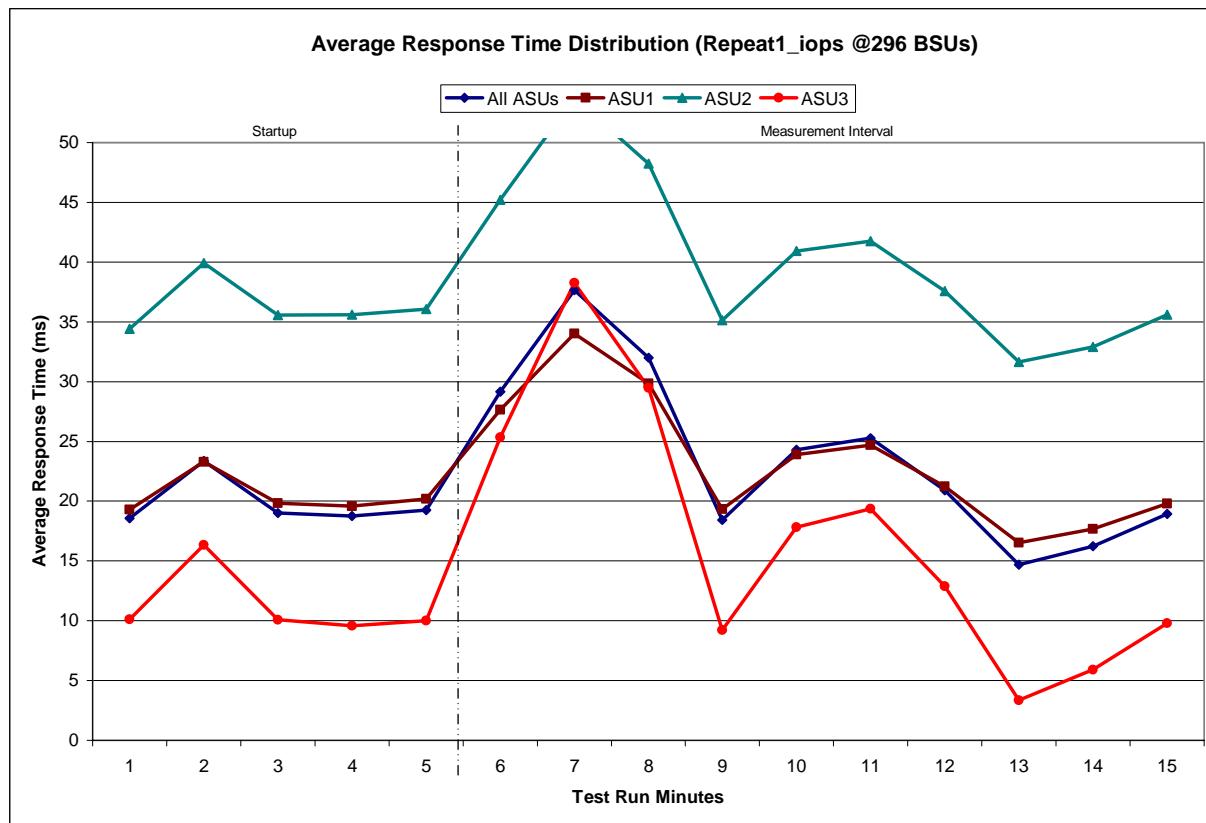
Repeatability 2 LRT – I/O Request Throughput Distribution Data

29 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	19:17:57	19:22:57	0-4	0:05:00
Measurement Interval	19:22:57	19:32:57	3-14	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	1,457.08	871.25	176.62	409.22
1	1,452.92	863.52	178.35	411.05
2	1,451.88	863.13	180.77	407.98
3	1,446.18	866.55	177.42	402.22
4	1,455.72	867.68	178.12	409.92
5	1,447.47	863.65	176.88	406.93
6	1,455.57	866.88	182.22	406.47
7	1,447.38	859.98	177.90	409.50
8	1,448.12	860.43	177.02	410.67
9	1,447.98	862.90	176.10	408.98
10	1,451.45	862.98	182.13	406.33
11	1,454.98	865.45	178.60	410.93
12	1,449.32	863.80	179.58	405.93
13	1,451.25	866.18	177.02	408.05
14	1,448.93	864.68	179.98	404.27
Average	*1,450.25*	*863.70*	*178.74*	*407.81*

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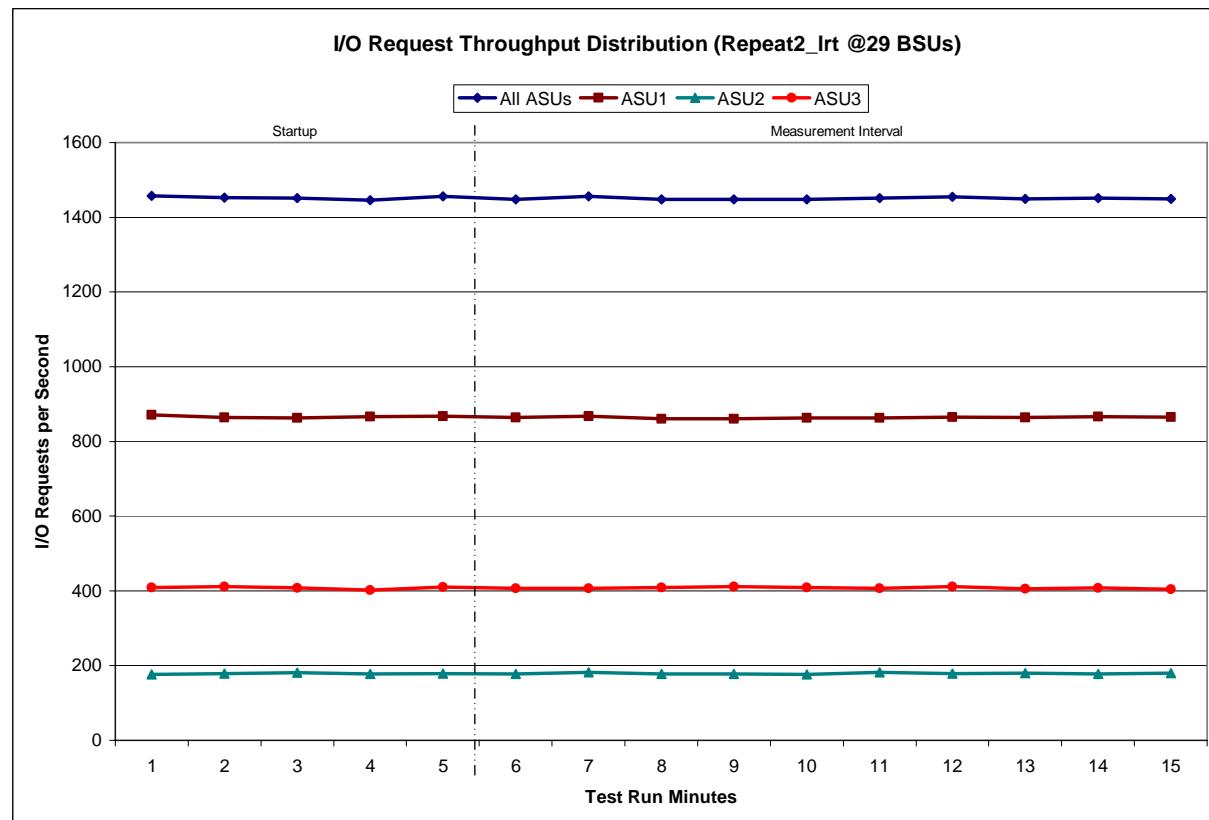
Repeatability 2 LRT –Average Response Time (ms) Distribution Data

29 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	19:17:57	19:22:57	0-4	0:05:00
Measurement Interval	19:22:57	19:32:57	3-14	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	4.35	4.85	7.12	2.09
1	6.36	5.28	6.79	8.44
2	5.07	5.31	6.19	4.07
3	4.17	4.20	5.54	3.50
4	4.83	4.33	5.93	5.42
5	5.51	5.01	6.95	5.95
6	4.94	4.49	5.82	5.51
7	4.90	4.71	6.65	4.53
8	4.51	4.40	5.43	4.35
9	6.28	4.83	8.97	8.18
10	4.95	4.65	5.86	5.16
11	4.14	4.40	5.00	3.23
12	4.36	4.36	5.48	3.86
13	5.31	4.80	5.93	6.11
14	3.02	3.81	3.75	1.01
Average	*4.79*	*4.55*	*5.99*	*4.79*

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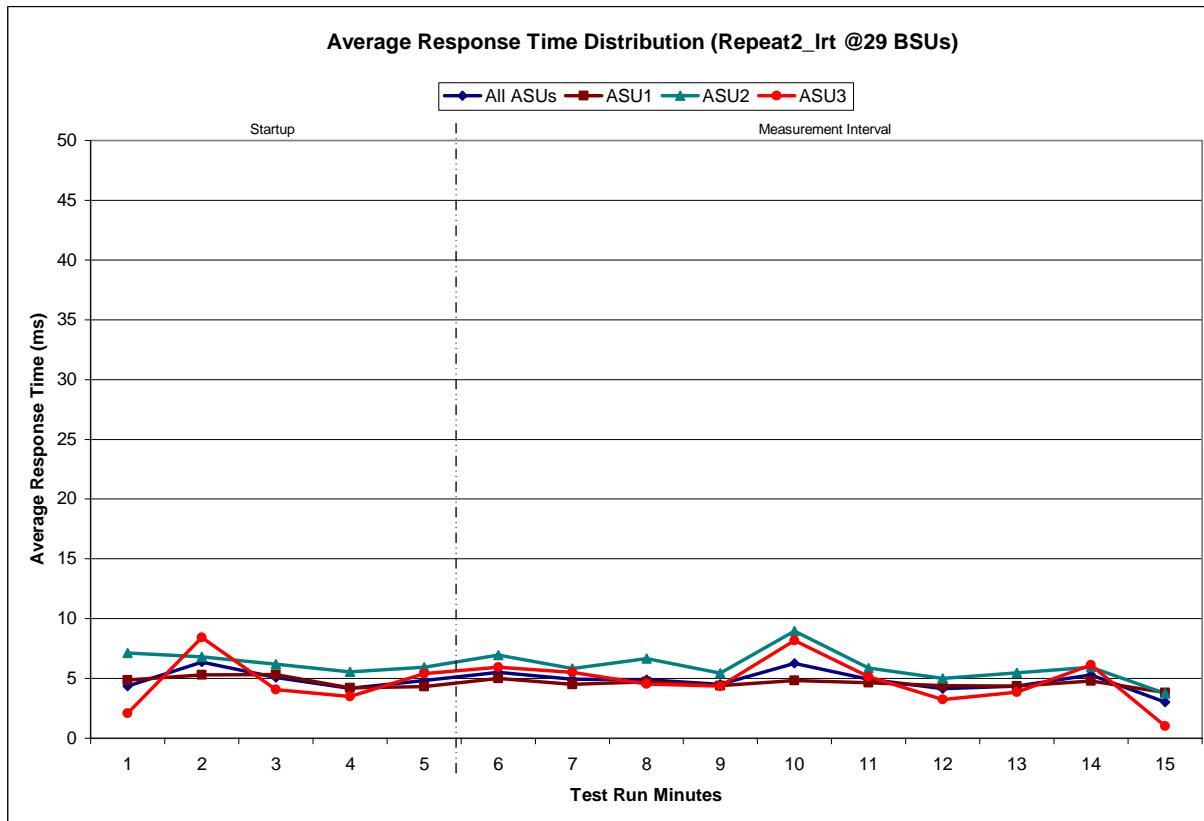
Repeatability 2 IOPS – I/O Request Throughput Distribution Data

296 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	19:32:58	19:37:59	0-4	0:05:01
Measurement Interval	19:37:59	19:47:59	3-14	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	14,797.58	8,822.87	1,817.05	4,157.67
1	14,802.15	8,812.63	1,820.88	4,168.63
2	14,811.02	8,826.97	1,818.47	4,165.58
3	14,793.62	8,818.93	1,818.17	4,156.52
4	14,794.08	8,814.97	1,818.03	4,161.08
5	14,837.68	8,846.42	1,827.42	4,163.85
6	14,792.45	8,815.45	1,823.88	4,153.12
7	14,801.67	8,822.95	1,825.13	4,153.58
8	14,803.57	8,817.68	1,822.92	4,162.97
9	14,798.48	8,821.85	1,821.92	4,154.72
10	14,799.58	8,825.38	1,822.75	4,151.45
11	14,793.55	8,838.57	1,815.28	4,139.70
12	14,794.98	8,814.85	1,817.62	4,162.52
13	14,780.75	8,804.28	1,812.02	4,164.45
14	14,813.63	8,821.57	1,824.95	4,167.12
Average	*14,801.64*	*8,822.90*	*1,821.39*	*4,157.35*

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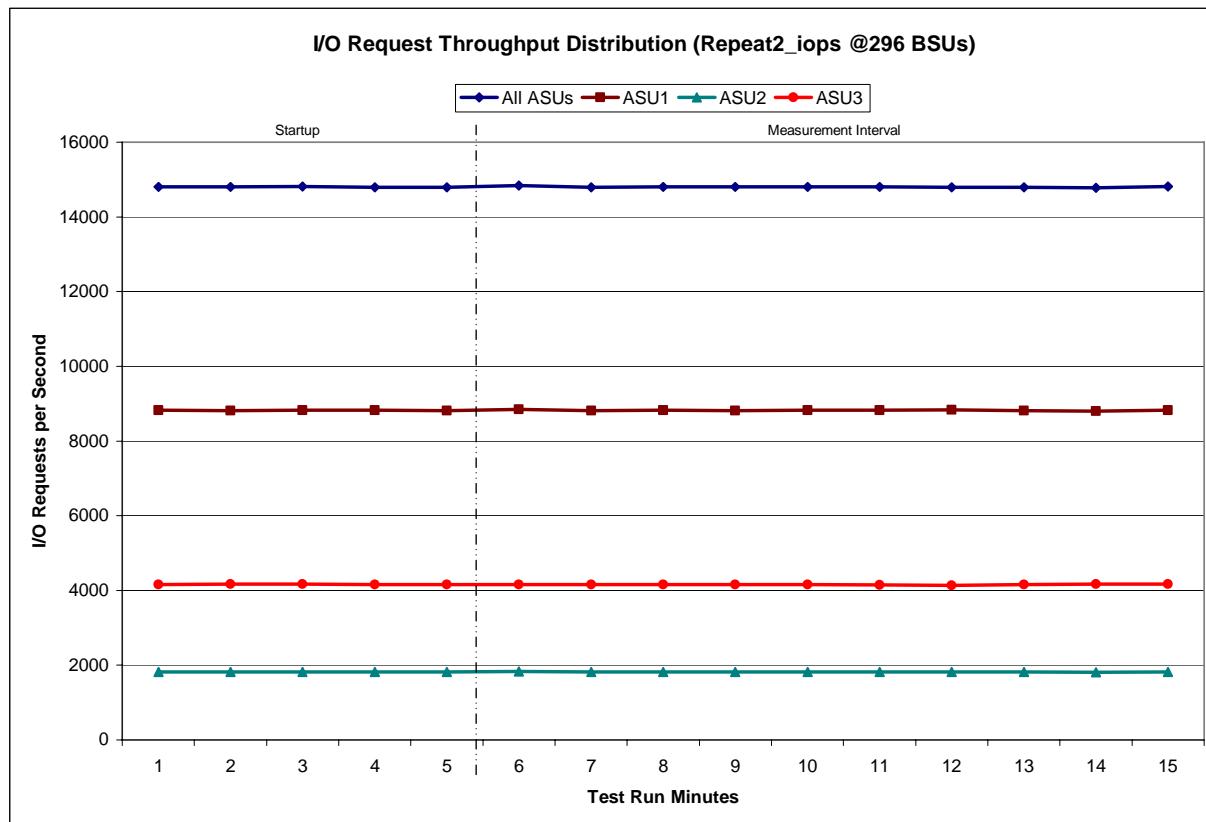
Repeatability 2 IOPS –Average Response Time (ms) Distribution Data

296 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	19:32:58	19:37:59	0-4	0:05:01
Measurement Interval	19:37:59	19:47:59	3-14	0:10:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	19.21	19.65	34.87	11.43
1	12.77	15.00	29.03	0.94
2	12.81	15.05	29.06	0.99
3	12.72	14.97	28.68	0.95
4	12.93	15.18	29.21	1.05
5	12.86	15.13	28.88	0.99
6	12.87	15.07	29.27	1.00
7	12.77	15.00	28.89	0.96
8	12.83	15.13	28.73	1.00
9	13.02	15.20	29.86	1.00
10	12.82	15.05	29.08	0.94
11	12.87	15.04	29.35	1.02
12	12.79	15.05	28.86	0.97
13	12.78	15.10	28.61	0.99
14	12.94	15.16	29.40	1.03
Average	*12.85*	*15.09*	*29.09*	*0.99*

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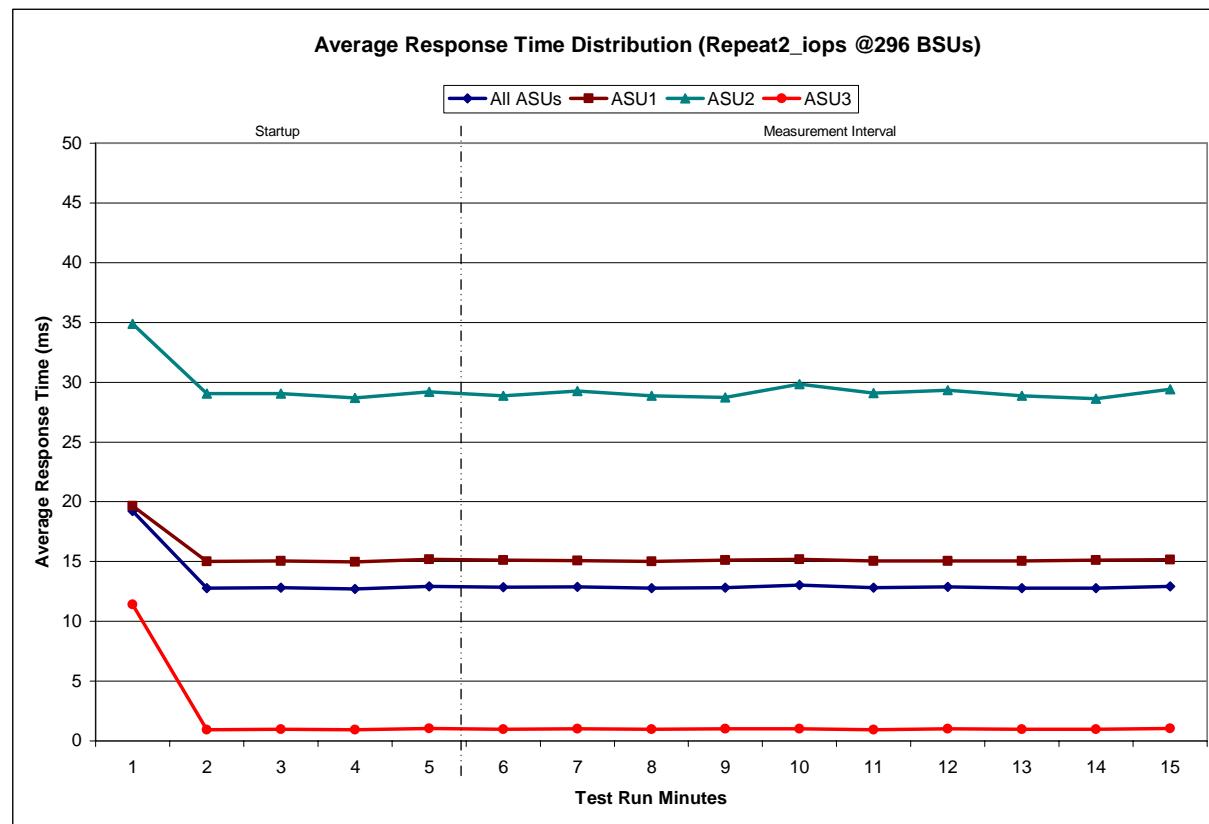
Repeatability 1 (LRT)
Measured Intensity Multiplier and Coefficient of Variation

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 5.1.10 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.*

	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	0.0348	0.2817	0.0701	0.2096	0.0178	0.0702	0.0349	0.2809
COV	0.027	0.006	0.013	0.007	0.019	0.015	0.020	0.004

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

	ASU1-1	ASU1-2	ASU1-3	ASU1-4	ASU2-1	ASU2-2	ASU2-3	ASU3-1
IM	*0.0350*	*0.2810*	*0.0700*	*0.2100*	*0.0180*	*0.0700*	*0.0350*	*0.2810*
MIM	0.0351	0.2807	0.0700	0.2100	0.0180	0.0701	0.0351	0.2811
COV	0.005	0.001	0.004	0.002	0.008	0.004	0.007	0.002

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	0.0348	0.2808	0.0698	0.2101	0.0180	0.0700	0.0353	0.2812
COV	0.016	0.004	0.011	0.006	0.015	0.013	0.026	0.006

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

	ASU1-1	ASU1-2	ASU1-3	ASU1-4	ASU2-1	ASU2-2	ASU2-3	ASU3-1
IM	*0.0350*	*0.2810*	*0.0700*	*0.2100*	*0.0180*	*0.0700*	*0.0350*	*0.2810*
MIM	0.0350	0.2809	0.0702	0.2100	0.0181	0.0699	0.0350	0.2809
COV	0.008	0.001	0.004	0.002	0.003	0.004	0.005	0.002

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 IOPS™ 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 Tested Storage Configuration (TSC) 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 9.4.3.8

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	23,941,936
Total Number of Logical Blocks Verified	22,759,808
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 for the Priced Storage Configuration must be the date at which all components are committed to be available.

The IBM System Storage® DS3524 Express   as documented in this Full Disclosure Report is currently available for customer purchase and shipment.

PRICING INFORMATION

Clause 9.4.3.3.6

The Executive Summary shall contain a pricing spreadsheet as documented in Clause 8.3.1.

Pricing information may found in the Priced Storage Configuration Pricing section on page 14.

TESTED STORAGE CONFIGURATION (TSC) AND PRICED STORAGE CONFIGURATION DIFFERENCES

Clause 9.4.3.3.7

The Executive Summary shall contain a pricing a list of all differenced between the Tested Storage Configuration (TSC) and the Priced Storage Configuration.

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 9.4.3.10

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® DS3524 Express .

APPENDIX A: SPC-1 GLOSSARY

"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

Protected: This level will ensure data protection in the event of a single point of failure of any configured storage device. A brief description of the data protection utilized is included in the Executive Summary.

Unprotected: No claim of data protection is asserted in the event of a single point of failure.

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

APPENDIX A: Page 60 of 67
SPC-1 GLOSSARY

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
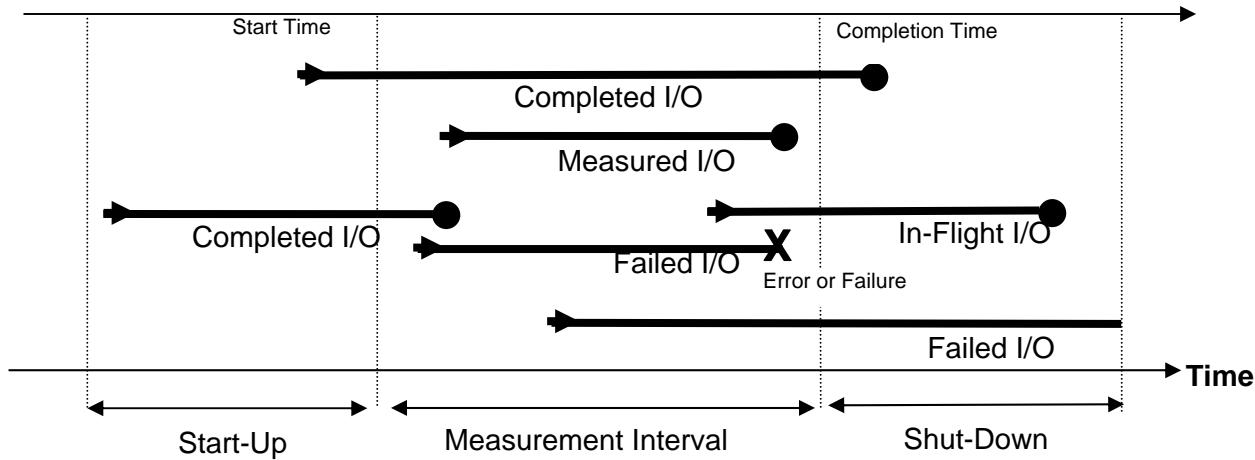
SPC BENCHMARK 1™ V1.12   FULL DISCLOSURE REPORT   Submission Identifier: A00101
IBM Corporation   Submitted for Review: DECEMBER 31, 2010
IBM System Storage® DS3524 Express
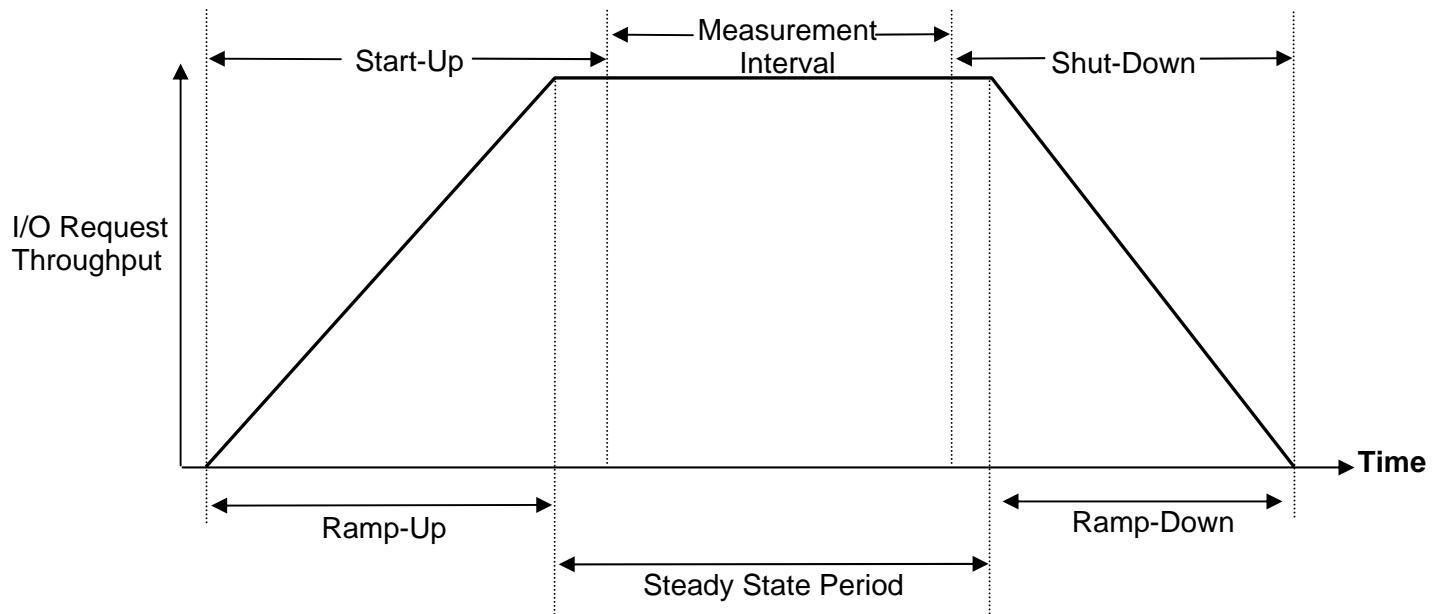
APPENDIX B: CUSTOMER TUNABLE PARAMETERS AND OPTIONS

Windows Server 2003 Registry Changes

Registry Parameter	Name	Type	Default Value	New Value
\HKEY_LOCAL_MACHINE\CurrentControlSet\Services\Lsi_sas2\Parameters\Device	DriverParameter	REG_SZ	32	MaximumTargetQueueDepth=254;
\HKEY_LOCAL_MACHINE\CurrentControlSet\Services\Disk	TimeOutValue	REG_DWORD	0x3C	0xa0

MaximumTargetQueueDepth - Change the SAS HBA driver maximum queue depth per device from 32 to 254.

TimeOutValue - Change the time that Windows will wait for a response to an IO command from 60 to 160 seconds.

LSI HBA BIOS Modifications

Configurable via **lsiutil** utility *(option 10 – Change IOC settings (interrupt coalescing))*:

Disable Interrupt Coalescing

Interrupt Coalescing - Disable the HBA feature to send multiple messages to the host processor during a single interrupt.

Configurable via **lsiutil** utility *(option 13 – Change SAS IO Unit settings)*:

Driver Parameter	Default Value	New Value
SAS Max Queue Depth, Narrow	0	65535
SAS Max Queue Depth, Wide	0	65535
Device Missing Report Delay	0	144
Device Missing I/O Delay	0	8

SAS Max Queue Depth, Narrow - Change the queue depth allowed for IO's to each narrow SAS device from 0 (device maximum) to 255.

SAS Max Queue Depth, Wide - Change the queue depth allowed for IO's to each wide SAS device from 0 (device maximum) to 255.

Device Missing Report Delay - Change the number of seconds that the HBA will delay reporting a target or expander as missing after it becomes unavailable from 10 to 144 seconds.

Device Missing I/O Delay - Change the number of seconds the HBA will delay replying to SCSI initiator messages when the addressed device is missing due to the inability to access the target device from 5 to 8 seconds.

APPENDIX C: TESTED STORAGE CONFIGURATION (TSC) CREATION

Before creating volumes on the storage array, please refer to Appendix B *(page 61)* for a listing of the required Windows Server 2003 registry and HBA BIOS modifications.

Storage Array Volume Creation

The storage management utility, **SANtricity**, was used to create 4 volume groups on the storage subsystem. Each volume group contains one RAID1 (mirrored) volumes. All four RAID1 volumes are visible by the attached host.

The physical storage volumes are created on the storage array using the SANtricity Storage Manger script editor. Launch SANtricity Storage Manager. From the Enterprise Management window, right-click the name of the storage array that you will be creating volumes on and select *Execute Script* from the pop-up menu. In the Script Editor window load the **SPC1_48drive_base_base.cfg** script *(listed below)*. Once the script is loaded, select *Execute* from the Tools menu. The **SPC1_48drive_base_base.cfg** script appears at the end of the appendix.

SPC-1 Logical Volume Creation

The steps that follow are required to define the Windows partitions, volumes, and stripe sets that will be used by the SPC-1 benchmark and are executed on the host.

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 the Disk Management utility under Computer Management.

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

4. Create a Windows Striped (RAID 0) volume using all eight 32MB partitions.

5. Delete the remaining large volume on each of the Dynamic Disks.

6. Create a Windows Striped (RAID 0) volume for ASU 3.
   a. Select all four volumes.
   b. Set capacity to 159894 MB.
   c. Assign drive letter "N" to the volume. Do not format the volume.

7. Create a Windows Striped (RAID 0) volume for ASU 1.
   a. Select all four volumes.
   b. Set capacity to 719523 MB.
   c. Assign drive letter "L" to the volume. Do not format the volume.

8. Create a Windows Striped (RAID 0) volume for ASU 2.
   a. Select all four volumes.
   b. Set capacity to 719523 MB.
   c. Assign drive letter "M" to the volume. Do not format the volume.

9. Reboot the Host System.

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IBM System Storage® DS3524 Express

SPC1_48drive_base_base.cfg

```
SPC1_48drive_base_base.cfg// Logical configuration information from Storage Array
bmsmc1ab.
// Saved on October 26, 2010
// Firmware package version for Storage Array bmsmc1ab = 07.70.16.00
// NVSRAM package version for Storage Array bmsmc1ab = N26X0-770834-407


//on error stop;

// Uncomment the two lines below to delete the existing configuration.
//show "Deleting the existing configuration.";
//clear storageArray configuration;



// Storage Array global logical configuration script commands
show "Setting the Storage Array user label to bmsmc1ab.";
set storageArray userLabel="bmsmc1ab";

show "Setting the Storage Array media scan rate to disabled.";
set storageArray mediaScanRate=disabled;

// Uncomment the three lines below to remove the default volume (if exists). NOTE:
Default volume name is always = "Unnamed".
//on error continue;
//show "Deleting the default volume created during the removal of the existing
configuration.";
//delete volume["Unnamed"] removeVolumeGroup=true;
//on error stop;

// Copies the hot spare settings
// NOTE: These statements are wrapped in on-error continue and on-error stop
statements to
// account for minor differences in capacity from the drive of the Storage Array on
which the
// configuration was saved to that of the drives on which the configuration will be
copied.
show "Setting the Storage Array cache block size to 16.";
set storageArray cacheBlockSize=16;

show "Setting the Storage Array to begin cache flush at 80% full.";
set storageArray cacheFlushStart=80;

show "Setting the Storage Array to end cache flush at 80% full.";
set storageArray cacheFlushStop=80;

// Creating Host Topology
show "Creating Host BM3650W with Host Type Index 1.";
// This Host Type Index corresponds to Type Windows 2000/Server 2003/Server 2008
Non-Clustered
create host userLabel="BM3650W" hostType=1;

show "Creating Host Port BM3650WP0 on Host BM3650W with WWN 500605b0006c18d0 and
with interfaceType SAS.";
create hostPort host="BM3650W" userLabel="BM3650WP0" identifier="500605b0006c18d0"
interfaceType=SAS;

show "Creating Host Port BM3650WP1 on Host BM3650W with WWN 500605b0006c1920 and
with interfaceType SAS.";
create hostPort host="BM3650W" userLabel="BM3650WP1" identifier="500605b0006c1920"
interfaceType=SAS;
```

```
show "Creating RAID 1 Volume LUN_0 on new Volume Group 0.";
//This command creates volume group <0> and the initial volume <LUN_0> with offset 0
on the volume group.
// NOTE: For Volume Groups that use all available capacity, the last Volume on this
group is
// created using all remaining capacity by omitting the capacity= volume creation
parameter.
create volume drives=(0,1 0,2 0,3 0,4 0,5 0,6 0,7 0,8 0,9 0,10 0,11 0,12)
raidLevel=1 userLabel="LUN_0" volumeGroupUserLabel="0" owner=A segmentSize=128
dssPreAllocate=true securityType=none;
show "Setting additional attributes for Volume LUN_0.";
// Configuration settings that can not be set during Volume creation.
set volume["LUN_0"] cacheFlushModifier=10;
set volume["LUN_0"] cacheWithoutBatteryEnabled=false;
set volume["LUN_0"] mirrorEnabled=true;
set volume["LUN_0"] readCacheEnabled=true;
set volume["LUN_0"] writeCacheEnabled=true;
set volume["LUN_0"] mediaScanEnabled=false;
set volume["LUN_0"] redundancyCheckEnabled=false;
set volume["LUN_0"] readAheadMultiplier=0;
set volume["LUN_0"] modificationPriority=high;
set volume["LUN_0"] preReadRedundancyCheck=false;
show "Creating Volume-to-LUN Mapping for Volume LUN_0 to LUN 0.";
set volume ["LUN_0"] logicalUnitNumber=0 hostGroup=defaultGroup;


show "Creating RAID 1 Volume LUN_1 on new Volume Group 1.";
//This command creates volume group <1> and the initial volume <LUN_1> with offset 0
on the volume group.
// NOTE: For Volume Groups that use all available capacity, the last Volume on this
group is
// created using all remaining capacity by omitting the capacity= volume creation
parameter.
create volume drives=(0,13 0,14 0,15 0,16 0,17 0,18 0,19 0,20 0,21 0,22 0,23 0,24)
raidLevel=1 userLabel="LUN_1" volumeGroupUserLabel="1" owner=B segmentSize=128
dssPreAllocate=true securityType=none;
show "Setting additional attributes for Volume LUN_1.";
// Configuration settings that can not be set during Volume creation.
set volume["LUN_1"] cacheFlushModifier=10;
set volume["LUN_1"] cacheWithoutBatteryEnabled=false;
set volume["LUN_1"] mirrorEnabled=true;
set volume["LUN_1"] readCacheEnabled=true;
set volume["LUN_1"] writeCacheEnabled=true;
set volume["LUN_1"] mediaScanEnabled=false;
set volume["LUN_1"] redundancyCheckEnabled=false;
set volume["LUN_1"] readAheadMultiplier=0;
set volume["LUN_1"] modificationPriority=high;
set volume["LUN_1"] preReadRedundancyCheck=false;
show "Creating Volume-to-LUN Mapping for Volume LUN_1 to LUN 1.";
set volume ["LUN_1"] logicalUnitNumber=1 hostGroup=defaultGroup;


show "Creating RAID 1 Volume LUN_2 on new Volume Group 2.";
//This command creates volume group <2> and the initial volume <LUN_2> with offset 0
on the volume group.
// NOTE: For Volume Groups that use all available capacity, the last Volume on this
group is
// created using all remaining capacity by omitting the capacity= volume creation
parameter.
create volume drives=(1,1 1,2 1,3 1,4 1,5 1,6 1,7 1,8 1,9 1,10 1,11 1,12)
raidLevel=1 userLabel="LUN_2" volumeGroupUserLabel="2" owner=A segmentSize=128
dssPreAllocate=true securityType=none;
show "Setting additional attributes for Volume LUN_2.";
// Configuration settings that can not be set during Volume creation.
```

```
set volume["LUN_2"] cacheFlushModifier=10;
set volume["LUN_2"] cacheWithoutBatteryEnabled=false;
set volume["LUN_2"] mirrorEnabled=true;
set volume["LUN_2"] readCacheEnabled=true;
set volume["LUN_2"] writeCacheEnabled=true;
set volume["LUN_2"] mediaScanEnabled=false;
set volume["LUN_2"] redundancyCheckEnabled=false;
set volume["LUN_2"] readAheadMultiplier=0;
set volume["LUN_2"] modificationPriority=high;
set volume["LUN_2"] preReadRedundancyCheck=false;
show "Creating Volume-to-LUN Mapping for Volume LUN_2 to LUN 2.";
set volume ["LUN_2"] logicalUnitNumber=2 hostGroup=defaultGroup;


show "Creating RAID 1 Volume LUN_3 on new Volume Group 3.";
//This command creates volume group <3> and the initial volume <LUN_3> with offset 0
on the volume group.
// NOTE: For Volume Groups that use all available capacity, the last Volume on this
group is
// created using all remaining capacity by omitting the capacity= volume creation
parameter.
create volume drives=(1,13 1,14 1,15 1,16 1,17 1,18 1,19 1,20 1,21 1,22 1,23 1,24)
raidLevel=1 userLabel="LUN_3" volumeGroupUserLabel="3" owner=B segmentSize=128
dssPreAllocate=true securityType=none;
show "Setting additional attributes for Volume LUN_3.";
// Configuration settings that can not be set during Volume creation.
set volume["LUN_3"] cacheFlushModifier=10;
set volume["LUN_3"] cacheWithoutBatteryEnabled=false;
set volume["LUN_3"] mirrorEnabled=true;
set volume["LUN_3"] readCacheEnabled=true;
set volume["LUN_3"] writeCacheEnabled=true;
set volume["LUN_3"] mediaScanEnabled=false;
set volume["LUN_3"] redundancyCheckEnabled=false;
set volume["LUN_3"] readAheadMultiplier=0;
set volume["LUN_3"] modificationPriority=high;
set volume["LUN_3"] preReadRedundancyCheck=false;
show "Creating Volume-to-LUN Mapping for Volume LUN_3 to LUN 3.";
set volume ["LUN_3"] logicalUnitNumber=3 hostGroup=defaultGroup;
```

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

The content of SPC-1 Workload Generator command and parameter file, used in this benchmark to execute the Primary Metrics, Repeatability and Persistence Tests, is listed below.

```
* spc1_iops.cfg

javaparms="-Xms1024m -Xmx1024m"

sd=asu1_1,lun=\\.\L:,size=3017898196992
sd=asu2_1,lun=\\.\M:,size=3017898196992
sd=asu3_1,lun=\\.\N:,size=670644043776

eof
```

APPENDIX E: SPC-1 WORKLOAD GENERATOR INPUT PARAMETERS

Primary Metrics Test, Repeatability Test, and Persistence Test Run 1

The following script was used to execute the Primary Metrics 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 in an uninterrupted sequence.**

```
REM Get storage array profile
"c:\program files\StorageManager\client\smcli" 172.22.201.161 172.22.201.162 -c
"show storageArray profile;" -o
"c:\bench\vdbench\spc1\output\spc1_profile_before_run.txt"

copy /y spc1_iops.cfg spc1.cfg
java metrics -b 296 -s 300
java repeat1 -b 296 -s 300
java repeat2 -b 296 -s 300

copy /y spc1_persist.cfg spc1.cfg
java persist1 -b 296
```

Persistence Test Run 2

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

```
copy /y spc1_persist.cfg spc1.cfg
java persist2

REM Get storage array profile
"c:\program files\StorageManager\client\smcli" 172.22.201.161 172.22.201.162 -c
"show storageArray profile;" -o
"c:\bench\vdbench\spc1\output\spc1_profile_after_run.txt"
```