SPC BENCHMARK 1™

FULL DISCLOSURE REPORT

DELL, INC.
DELL EQUALLOGIC PS6210XV ARRAY

SPC-1 V1.14

Submitted for Review: June 9, 2014
Submission Identifier: A00144

First Edition – June 2014

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Dell, Inc.   Submitted for Review: JUNE 9, 2014
Dell EqualLogic PS6210XV Array

AUDIT CERTIFICATION

Storage Performance Council

Gradient SYSTEMS

Scott Saktanaset
Dell, Inc.
300 Innovative Way
Nashua, NH 03062

June 6, 2014

The SPC Benchmark 1™ Reported Data listed below for the Dell EqualLogic PS6210XV Array was produced in compliance with the SPC Benchmark 1™ v1.14 Onsite Audit requirements.

SPC Benchmark 1™ v1.14 Reported Data	
Tested Storage Product (TSP) Name:	
Dell EqualLogic PS6210XV Array	
Metric	**Reported Result**
SPC-1 IOPS™	25,147.22
SPC-1 Price-Performance	$3.87/SPC-1 IOPS™
Total ASU Capacity	6,023 GB
Data Protection Level	Protected 2 *(Mirroring)*
Total Price (including three-year maintenance)	$97,402.81
Currency Used	U.S. Dollars
Target Country for availability, sales and support	USA

The following SPC Benchmark 1™ Onsite Audit requirements were reviewed and found compliant with 1.14 of the SPC Benchmark 1™ specification:

- A Letter of Good Faith, signed by a senior executive.
- The following Data Repository storage items were verified by physical inspection and information supplied by Dell, Inc.:
  - ✓ 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.
- The total Application Storage Unit (ASU) Capacity was filled with random data, using an auditor approved tool, prior to execution of the SPC-1 Tests.
- An appropriate diagram of the Benchmark Configuration (BC)/Tested Storage Configuration (TSC).

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

AUDIT CERTIFICATION *(CONT.)*

Dell EqualLogic PS6210XV Array
SPC-1 Audit Certification

Page 2

- Physical verification of the components to match the above diagram.

- 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.

- The following Host System requirements were verified by physical inspection and information supplied by Dell, Inc.:
  - ✓ 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 execution of each Test, Test Phase, and Test Run was observed and found compliant with all of the requirements and constraints of Clauses 4, 5, and 11 of the SPC-1 Benchmark Specification.

- The Test Results Files and resultant Summary Results Files received from Dell, Inc. 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

- There were no differences between the Tested Storage Configuration and Priced Storage Configuration.

- 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,
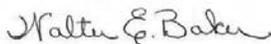
Walter E. Baker

Walter E. Baker
SPC Auditor

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LETTER OF GOOD FAITH

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Mr. Walter E. Baker, SPC Auditor
Gradient Systems
643 Bair Island Road, Suite 103
Redwood City, CA 94063-2755

April 16, 2014

Subject: SPC-1 Letter of Good Faith for the Dell EqualLogic PS6210XV-3 Array SAN

Dell Inc. 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 v1.14 of the SPC-1 benchmark specification.

In addition, we have reported any items in the Benchmark Configuration and execution of the benchmark that affected the reported results even if the items are not explicitly required to be disclosed by the SPC-1 benchmark specification.

Sincerely,

Alan Atkinson
Vice President/General Manager
Dell Storage

EXECUTIVE SUMMARY

Test Sponsor and Contact Information

Test Sponsor and Contact Information	
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Revision Information and Key Dates

Revision Information and Key Dates	
SPC-1 Specification revision number	V1.14
SPC-1 Workload Generator revision number	V2.3.0
Date Results were first used publicly	June 9, 2014
Date the FDR was submitted to the SPC	June 9, 2014
Date the Priced Storage Configuration is available for shipment to customers	currently available
Date the TSC completed audit certification	June 6, 2014

Tested Storage Product (TSP) Description

Built on an advanced, peer storage architecture, EqualLogic storage simplifies the deployment and administration of consolidated storage environments, enabling:

- Perpetual self-optimization with automated load balancing across disks, RAID sets, connections, cache and controllers.

- Efficient enterprise scalability for both performance and capacity without fork-lift upgrades.

- Powerful, intelligent and simplified management.

- Improved productivity and streamlined IT infrastructure through unified block and file storage capabilities.

What's more, EqualLogic products include a comprehensive software portfolio with easy-to-use array software, host integration tools and no licensing fees. EqualLogic virtualized-storage offers a simple path to rapid deployment, comprehensive data protection, enterprise-class performance and reliability, and seamless pay-as-you grow expansion. All EqualLogic PS Series arrays are completely interoperable and can be mixed and matched to build tiered storage within a single storage pool or across multiple pools.

EqualLogic PS6210 Series arrays bring a new level of performance to service more of your most demanding applications and virtualization requirements, while delivering the simplicity of the EqualLogic management experience. Featuring six array configurations, including 2U/2.5" drive options with All Flash and Hybrid Arrays, it is ideal for companies and organizations with growing data and performance needs.

Summary of Results

SPC-1 Reported Data	
Tested Storage Product (TSP) Name: Dell EqualLogic PS6210XV Array	
Metric	**Reported Result**
SPC-1 IOPS™	25,147.22
SPC-1 Price-Performance™	$3.87/SPC-1 IOPS™
Total ASU Capacity	6,023.786 GB
Data Protection Level	Protected 2 *(mirroring)*
Total Price	$97,402.81
Currency Used	U.S. Dollars
Target Country for availability, sales and support	USA

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

SPC-1 Price-Performance™ is the ratio of **Total Price** to **SPC-1 IOPS™**.

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

A **Data Protection Level** of **Protected 2** using *Mirroring* configures two or more identical copies of user data.

> **Protected 2:** *The single point of failure of any **component** in the configuration will not result in permanent loss of access to or integrity of the SPC-1 Data Repository.*

Total Price includes the cost of the Priced Storage Configuration plus three years of hardware maintenance and software support as detailed on page 17.

Currency Used is formal name for the currency used in calculating the **Total Price** and **SPC-1 Price-Performance™**. That currency may be the local currency of the **Target Country** or the currency of a difference country *(non-local currency)*.

The **Target Country** is the country in which the Priced Storage Configuration is available for sale and in which the required hardware maintenance and software support is provided either directly from the Test Sponsor or indirectly via a third-party supplier.

Storage Capacities, Relationships, and Utilization

The following four charts 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.

The capacity values in each of the following four charts are listed as integer values, for readability, rather than the decimal values listed elsewhere in this document.

Configured Storage Capacity: 20,536 GB

Configured Storage
Capacity Available
for Application Use:
18,736 GB 91.23%

Sparing Capacity:
1,800 GB 8.77%

Addressable Storage
Capacity:
6,024 GB 29.33%

Data Protection
Capacity *(used)*:
6,024 GB 29.33%

Unused Configured
Capacity:
6,688 GB 32.57%

*Includes 3,344 GB
in Unused Data
Protection Capacity*

Addressable Storage Capacity: 6,024 GB

Unused Addressable
Capacity:
0 GB 0.00%

ASU Capacity:
6,024 GB 100.00%

*4 Logical Volumes, 676 GB per Volume (ASU-1)
4 Logical Volumes, 676 GB per Volume (ASU-2)
2 Logical Volumes, 306 GB per Volume (ASU-3)*

ASU-1 Capacity:
2,706 GB 44.92%

ASU-2 Capacity:
2,706 GB 44.92%

ASU-3 Capacity:
612 GB 10.16%

Total Unused Storage Capacity Ratio and Details

Physical Storage Capacity:
21,602 GB

Unused Physical
Capacity: 0 GB

Physical Storage
Capacity Used:
14,914 GB 69.04%

Total Unused
Storage Capacity:
6,688 GB 30.96%

Unused Configured
Capacity:
6,688 GB

Includes 3,344 GB
in Unused Data
Protection Capacity

Unused Addressable
Capacity: 0 GB

SPC-1 Storage Capacity Utilization	
Application Utilization	27.89%
Protected Application Utilization	55.77%
Unused Storage Ratio	30.96%

Application Utilization: Total ASU Capacity *(6,023.786 GB)* divided by Physical Storage Capacity *(21,601.657 GB)*.

Protected Application Utilization: (Total ASU Capacity *(6,023.786 GB)* plus total Data Protection Capacity *(9,367.839 GB)* minus unused Data Protection Capacity *(3,344.072 GB)*) divided by Physical Storage Capacity *(21,601.657 GB)*.

Unused Storage Ratio: Total Unused Capacity *(6,688.143 GB)* divided by Physical Storage Capacity *(21,601.657 GB)* and may not exceed 45%.

Detailed information for the various storage capacities and utilizations is available on pages 24-25.

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.
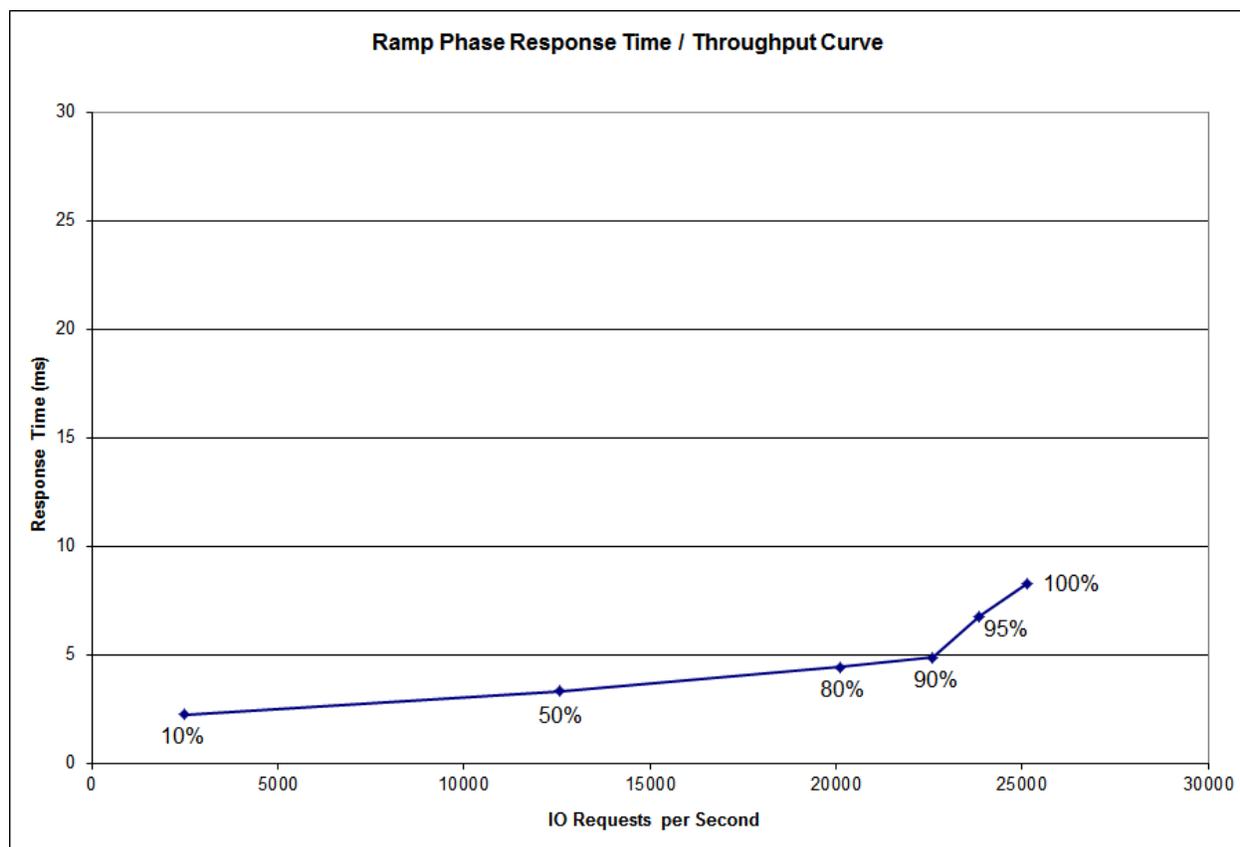
Response Time – Throughput Data

	10% Load	50% Load	80% Load	90% Load	95% Load	100% Load
I/O Request Throughput	2,501.17	12,555.69	20,100.50	22,593.98	23,847.64	25,147.22
Average Response Time (ms):						
All ASUs	2.25	3.33	4.43	4.86	6.78	8.30
ASU-1	3.03	4.46	5.68	6.18	8.55	10.41
ASU-2	2.39	4.41	7.45	8.56	12.65	15.95
ASU-3	0.52	0.45	0.44	0.45	0.46	0.48
Reads	4.59	6.94	9.73	10.83	15.63	19.43
Writes	0.72	0.98	0.97	0.97	1.02	1.05

Priced Storage Configuration Pricing

Quantity	Part Number	Description	Discount Percentage	Reference Price	Extended Price
3	210-ABPJ	Dell EqualLogic PS6210XV, 2 controller nodes, each with 16GB non-volatile cache of memory, 2 10GBASE-T RJ45 auto-sensing (10Gb/1Gb/100Mb) ports, 2 10GbE SFP+ ports for fibre or copper cabling, 24 300GB 15k 2.5" SAS drives + 3 Yr Pro Support Maintenance	43%	$48,372.00	$82,716.12
2	225-3586	Dell PowerConnect 8132 SFP Layer 3 10GbE + 3 Yr Pro Support Maintenance	55%	$15,813.00	$14,231.70
1	A3612382	Intel E10G42BTDA Server Adapter X520-DA2 10Gbps	9%	$ 499.99	$ 454.99
		Total System Price			**$97,402.81**

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 within four (4) hours.

- Onsite presence 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

A second Dell PowerConnect 10GbE switch was included in the Priced Storage Configuration as a spare to fulfill one of the requirements for a data protection level of **Protected 2**.

Priced Storage Configuration Diagram

Intel E10G42BTDA
Server Adapter
X520-DA2 10Gbps

2 – 10GbE
connections

Dell PowerConnect
PC8132 10GbE Switch

6 – 10GbE iSCSI connections
(2 connections per array)

3 – Dell EqualLogic PS6210XV Arrays
72 - 300GB, 2.5", 15K RPM, SAS HDDs
(24 HDDs per Array)
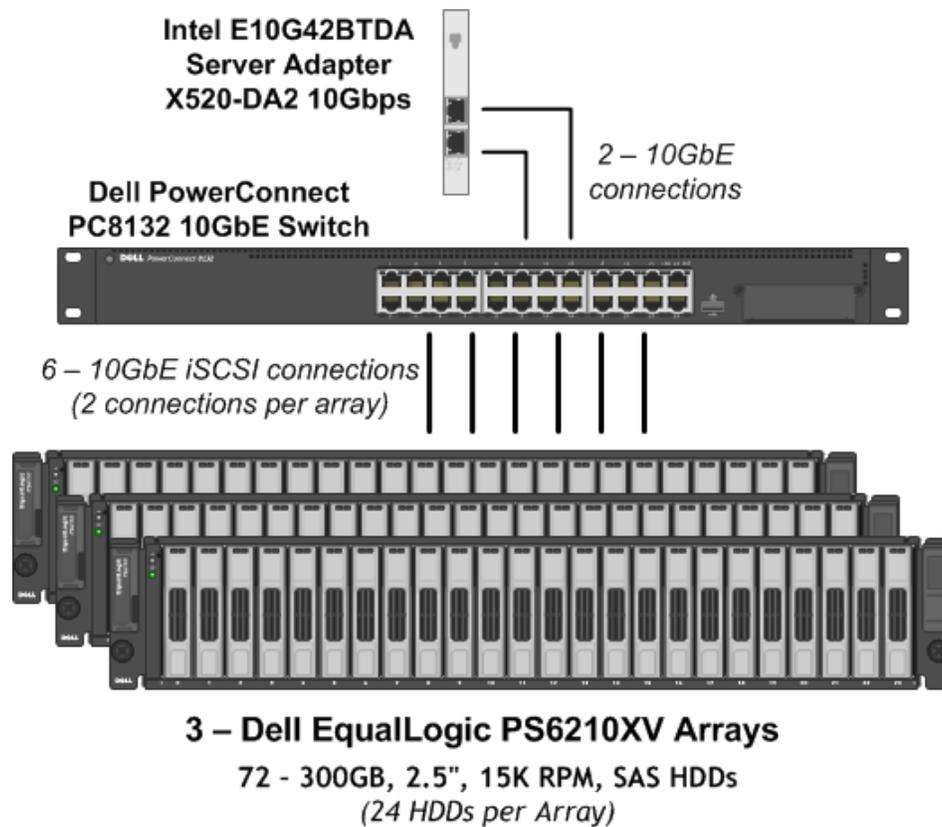
Priced Storage Configuration Components

Priced Storage Configuration
1 – Intel E10G42BTDA Server Adapter X520-DA2 10Gbps
2 – Dell PowerConnect PC8132 10GbE Switches *(second switch included as a spare)*
3 – Dell EqualLogic PS6210XV Arrays each array with: 2 – controller nodes with 16 GB cache *(6 controller nodes total)* 2 – 10GBASE-T auto-sensing *(10Gb/1Gb/100Mb)* ports *(6 ports total)* 2 – 10GbE SFP+ front-end ports *(6 ports total, 6 ports used)* 1 – 6Gb SAS connection *(3 total, 3 used)* 24 – 300 GB, 2.5", 15K RPM, SAS HDDs *(72 HDDs total)*

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 20 (*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 portion of the Benchmark Configuration(BC)/Tested Storage Configuration (TSC) is illustrated on page *20* (*Benchmark Configuration/Tested Storage Configuration Diagram*).

Host System(s) 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).

The Host System(s) and TSC table of components may be found on page 21 (*Host System and Tested Storage Configuration Components*).

Benchmark Configuration/Tested Storage Configuration Diagram

Dell PowerEdge R620 rack server with
1 – Intel E10G42BTDA Server Adapter X520-DA2 10 Gbps

**Dell PowerConnect
PC8132 10GbE Switch**

2 – 10GbE
connections

6 – 10GbE iSCSI connections
(2 connections per array)

3 – Dell EqualLogic PS6210XV Arrays
72 – 300GB, 2.5", 15K RPM, SAS HDDs
(24 HDDs per Array)
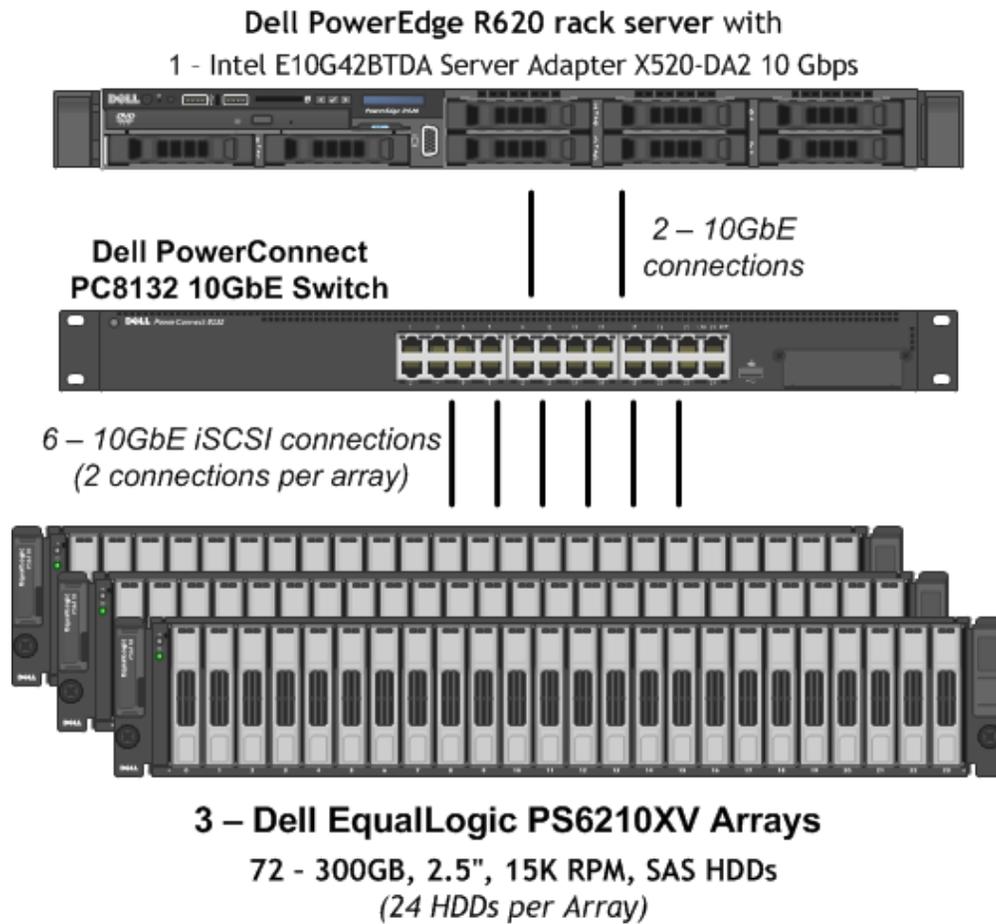
Host System and Tested Storage Configuration Components

Host System
1 – Dell PowerEdge R620 rack server, with:

> 2 – Intel® Xeon® 2.20 GHz E502660 processors
>   each with 8 cores and 2.5 MB cache per core
>
> 128 GB main memory
>
> Windows Server 2008 R2 Enterprise with SP1
>
> PCIe 3.0

Tested Storage Configuration (TSC) Components
1 – Intel E10G42BTDA Server Adapter X520-DA2 10Gbps
1 – Dell PowerConnect PC8132 10GbE Switche

3 – Dell EqualLogic PS6210XV Arrays

each array with:

> 2 – controller nodes with 16 GB cache
>   *(6 controller nodes total)*
>
> 2 – 10GBASE-T auto-sensing *(10Gb/1Gb/100Mb)* ports
>   *(6 ports total)*
>
> 2 – 10GbE SFP+ front-end ports
>   *(6 ports total, 6 ports used)*
>
> 1 – 6Gb SAS connection *(3 total, 3 used)*
>
> 24 – 300 GB, 2.5", 15K RPM, SAS HDDs
>   *(72 HDDs total)*

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 65 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 66 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 80.

ASU Pre-Fill

Clause 5.3.3

Each of the three SPC-1 ASUs (ASU-1, ASU-2 and ASU-3) is required to be completely filled with specified content prior to the execution of audited SPC-1 Tests. The content is required to consist of random data pattern such as that produced by an SPC recommended tool.

The configuration file used to complete the required ASU pre-fill appears in Appendix D: SPC-1 Workload Generator Storage Commands and Parameters on page 80.

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

Storage Capacities and Relationships

Clause 9.4.3.6.1

Two tables and four charts documenting the storage capacities and relationships of the SPC-1 Storage Hierarchy (Clause 2.1) shall be included in the FDR. … The capacity value in each chart may be listed as an integer value, for readability, rather than the decimal value listed in the table below.

SPC-1 Storage Capacities

The Physical Storage Capacity consisted of 21,601.657 GB distributed over 72 disk drives (HDDs), 48 disk drives with a formatted capacity of 300 GB and 24 disk drives with a formatted capacity of 300.069 GB. There was 0.000 GB (0.00%) of Unused Storage within the Physical Storage Capacity. Global Storage Overhead consisted of 1,065.841 GB (4.93%) of the Physical Storage Capacity. There was 6,688.143 GB (32.57%) 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 9,367.839 GB of which 6,023.767 GB was utilized. The total Unused Storage capacity was 6,688.143 GB.

Note: The configured Storage Devices may include additional storage capacity reserved for system overhead, which is not accessible for application use. That storage capacity may not be included in the value presented for Physical Storage Capacity.

SPC-1 Storage Capacities		
Storage Hierarchy Component	**Units**	**Capacity**
Total ASU Capacity	Gigabytes (GB)	6,023.786
Addressable Storage Capacity	Gigabytes (GB)	6,023.686
Configured Storage Capacity	Gigabytes (GB)	20,535.816
Physical Storage Capacity	Gigabytes (GB)	21,601.657
Data Protection *(Mirroring)*	Gigabytes (GB)	9,367.839
Required Storage *(metadata/overhead/spares)*	Gigabytes (GB)	1,800.138
Global Storage Overhead	Gigabytes (GB)	1,065.841
Total Unused Storage	Gigabytes (GB)	6,688.143

SPC-1 Storage Hierarchy Ratios

	Addressable Storage Capacity	Configured Storage Capacity	Physical Storage Capacity
Total ASU Capacity	100.00%	29.33%	27.89%
Required for Data Protection (Mirroring)		45.62%	43.37%
Addressable Storage Capacity		29.33%	27.89%
Required Storage (spares, overhead)		8.77%	8.33%
Configured Storage Capacity			95.07%
Global Storage Overhead			4.93%
Unused Storage:			
Addressable	0.00%		
Configured		32.57%	
Physical			0.00%

SPC-1 Storage Capacity Charts

Physical Storage Capacity: 21,602 GB

Overhead/Metadata: 0 GB 0.00%

Unused Physical Capacity: 0 GB 0.00%

Storage Pool Capacity: 9,368 GB 43.37%

Configured Storage Capacity: 20,536 GB 95.07%

Data Protection Capacity: 9,368 GB 43.37%

Sparing Capacity: 1,800 GB 8.33%

■ Global Storage Overhead: 1,066 GB 4.93%

Configured Storage Capacity: 20,536 GB

Configured Storage Capacity Available for Application Use:
18,736 GB 91.23%

Sparing Capacity:
1,800 GB 8.77%

Addressable Storage Capacity:
6,024 GB 29.33%

Data Protection Capacity *(used)*:
6,024 GB 29.33%

Unused Configured Capacity:
6,688 GB 32.57%

Includes 3,344 GB in Unused Data Protection Capacity

Addressable Storage Capacity: 6,024 GB

Unused Addressable Capacity:
0 GB 0.00%

ASU Capacity:
6,024 GB 100.00%

4 Logical Volumes, 676 GB per Volume (ASU-1)
4 Logical Volumes, 676 GB per Volume (ASU-2)
2 Logical Volumes, 306 GB per Volume (ASU-3)

ASU-1 Capacity:
2,706 GB 44.92%

ASU-2 Capacity:
2,706 GB 44.92%

ASU-3 Capacity:
612 GB 10.16%

Total Unused Storage Capacity Ratio and Details

Physical Storage Capacity: 21,602 GB

Unused Physical Capacity: 0 GB

Physical Storage Capacity Used: 14,914 GB 69.04%

Total Unused Storage Capacity: 6,688 GB 30.96%

Unused Configured Capacity: 6,688 GB

Includes 3,344 GB in Unused Data Protection Capacity

Unused Addressable Capacity: 0 GB

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	27.89%
Protected Application Utilization	55.77%
Unused Storage Ratio	30.96%

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 (2,705.829 GB)	**ASU-2 (2,705.829 GB)**	**ASU-3 (612.127 GB)**
4 Logical Volumes 676.457 GB per Logical Volume (676.457 GB used per Logical Volume)	4 Logical Volumes 676.457 GB per Logical Volume (676.457 GB used per Logical Volume)	2 Logical Volumes 306.064 GB per Logical Volume (306.064 GB used per Logical Volume))

The Data Protection Level used for all Logical Volumes was **Protected 2** using *Mirroring* as described on page 12. See "ASU Configuration" in the **IOPS Test Results File** for more detailed configuration information.

SPC-1 BENCHMARK EXECUTION RESULTS

This portion of the Full Disclosure Report documents the results of the various SPC-1 Tests, Test Phases, and Test Runs. An SPC-1 glossary on page 61 contains definitions of terms specific to the SPC-1 Tests, Test Phases, and Test Runs.

Clause 5.4.3

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

SPC-1 Tests, Test Phases, and Test Runs

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

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

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

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

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

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

"Ramp-Up" Test Runs

Clause 5.3.13

In order to warm-up caches or perform the initial ASU data migration in a multi-tier configuration, a Test Sponsor may perform a series of "Ramp-Up" Test Runs as a substitute for an initial, gradual Ramp-Up.

Clause 5.3.13.3

The "Ramp-Up" Test Runs will immediately precede the Primary Metrics Test as part of the uninterrupted SPC-1 measurement sequence.

Clause 9.4.3.7.1

If a series of "Ramp-Up" Test Runs were included in the SPC-1 measurement sequence, the FDR shall report the duration (ramp-up and measurement interval), BSU level, SPC-1 IOPS and average response time for each "Ramp-Up" Test Run in an appropriate table.

There were no "Ramp-Up" Test Runs executed.

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 eight (8) 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 9.4.3.7.2

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 82.

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)

The Sustainability Data Rate table of data is not embedded in this document due to its size. The table is available via the following URL:

Sustainability Data Rate Table

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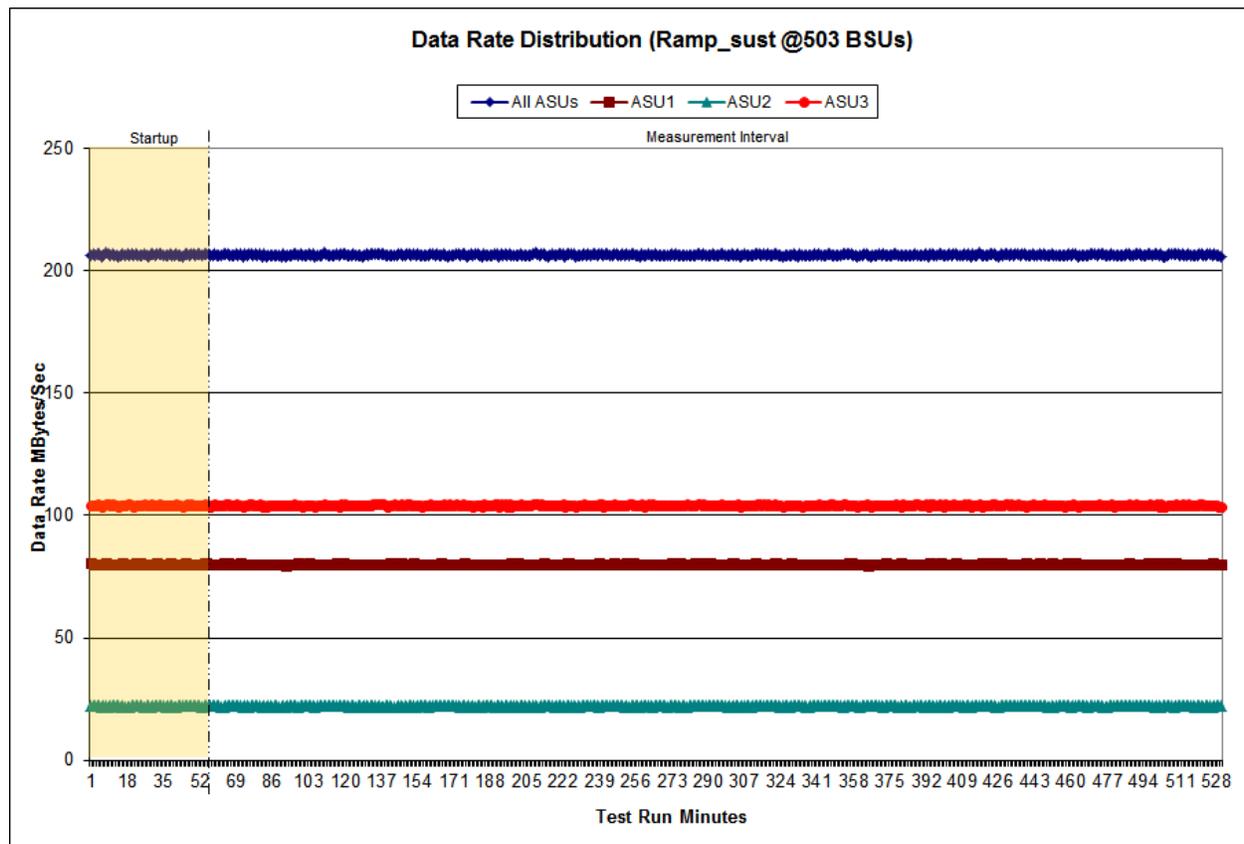
Sustainability – I/O Request Throughput Distribution Data

The Sustainability I/O Request Throughput table of data is not embedded in this document due to its size. The table is available via the following URL:

Sustainability I/O Request Throughput Table

Sustainability – I/O Request Throughput Distribution Graph
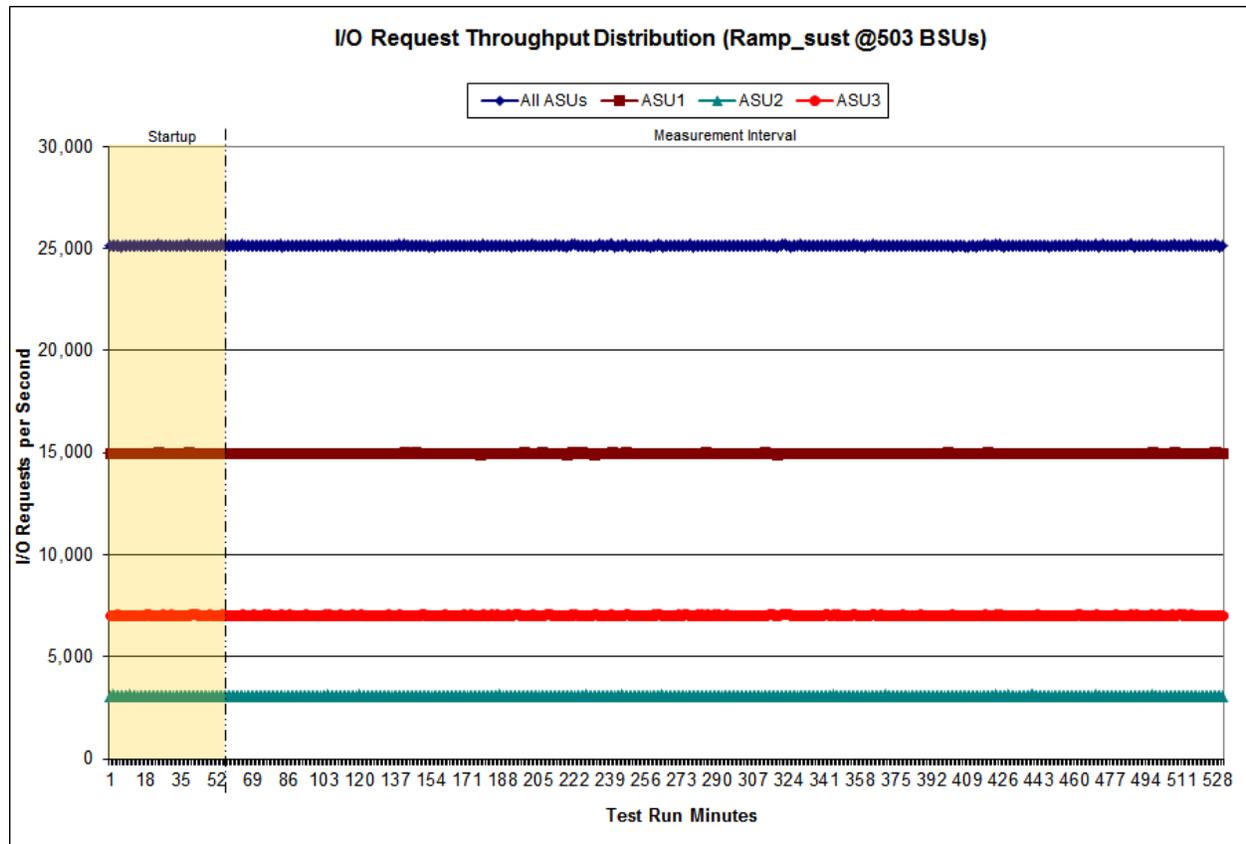
Sustainability – Average Response Time (ms) Distribution Data

The Sustainability Average Response Time table of data is not embedded in this document due to its size. The table is available via the following URL:

Sustainability Average Response Time Table

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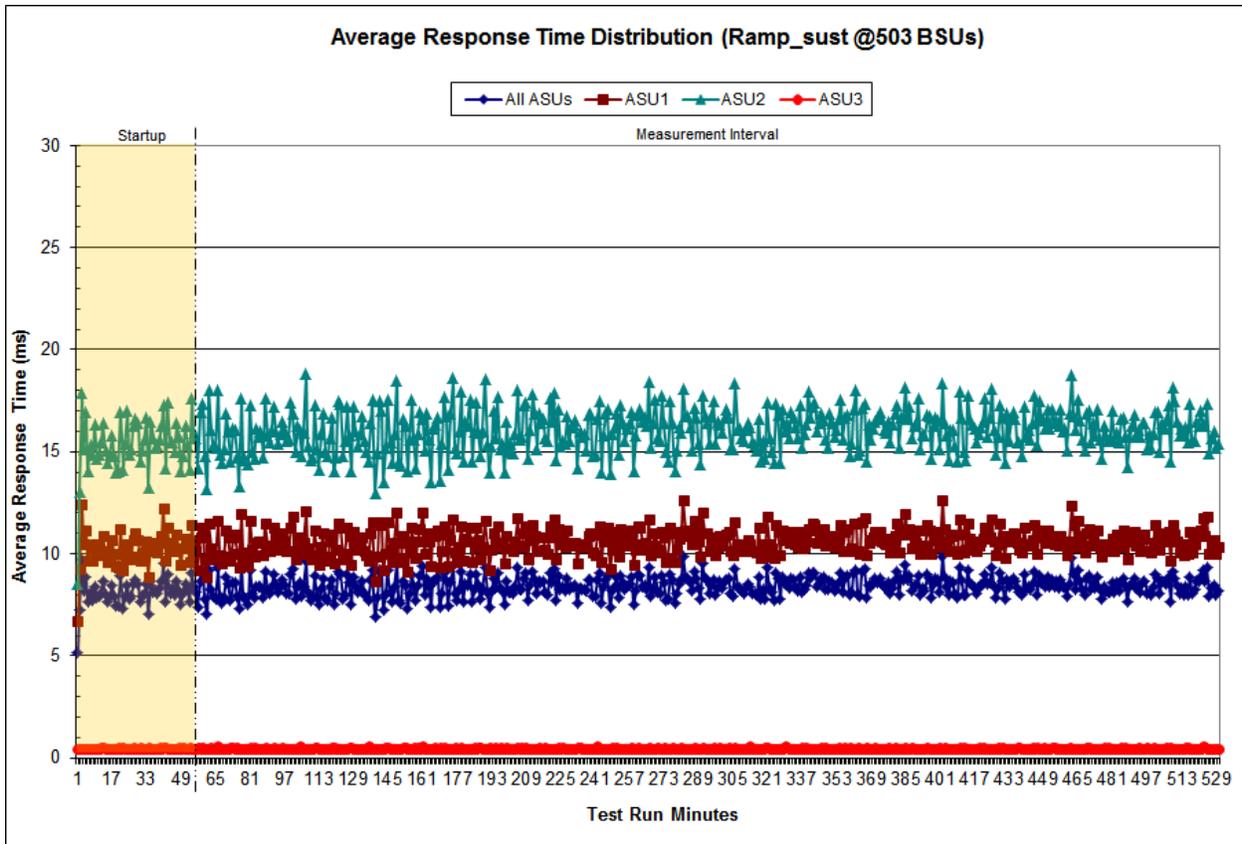
Sustainability – Response Time Frequency Distribution Data

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	9,526,451	12,555,580	2,977,997	3,075,237	1,539,319	1,348,981	1,335,714	1,910,868
Write	106,054,850	214,166,723	22,456,006	27,415,993	9,728,165	9,456,070	4,967,169	5,210,323
All ASUs	115,581,301	226,722,303	25,434,003	30,491,230	11,267,484	10,805,051	6,302,883	7,121,191
ASU1	43,261,594	87,925,656	16,935,251	17,527,579	8,245,019	9,925,828	5,670,321	6,360,107
ASU2	10,728,221	18,495,162	1,861,315	2,411,542	851,831	777,354	608,146	721,194
ASU3	61,591,486	120,301,485	6,637,437	10,552,109	2,170,634	101,869	24,416	39,890

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	4,382,435	6,620,159	7,405,757	9,727,889	9,847,314	11,723,500	22,928,812	19,761,158
Write	8,451,898	5,522,387	4,579,776	3,036,867	2,576,560	1,736,598	2,595,737	1,677,060
All ASUs	12,834,333	12,142,546	11,985,533	12,764,756	12,423,874	13,460,098	25,524,549	21,438,218
ASU1	11,300,240	10,500,840	10,211,893	10,778,910	10,410,080	11,332,399	21,439,833	17,842,383
ASU2	1,418,036	1,618,165	1,696,384	1,967,867	1,951,653	2,113,779	4,017,153	3,535,080
ASU3	116,057	23,541	77,256	17,979	62,141	13,920	67,563	60,755

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	16,249,836	13,789,585	12,320,835	39,715,118	19,871,606	11,510,762	7,517,374	38,039,284
Write	1,175,649	884,120	694,619	2,677,231	1,642,127	561,667	321,973	1,069,557
All ASUs	17,425,485	14,673,705	13,015,454	42,392,349	21,513,733	12,072,429	7,839,347	39,108,841
ASU1	14,428,242	12,120,129	10,679,507	33,640,678	16,327,268	9,224,641	5,955,272	29,668,132
ASU2	2,941,514	2,500,603	2,284,848	8,005,910	4,529,149	2,792,487	1,872,999	9,402,561
ASU3	55,729	52,973	51,099	745,761	657,316	55,301	11,076	38,148

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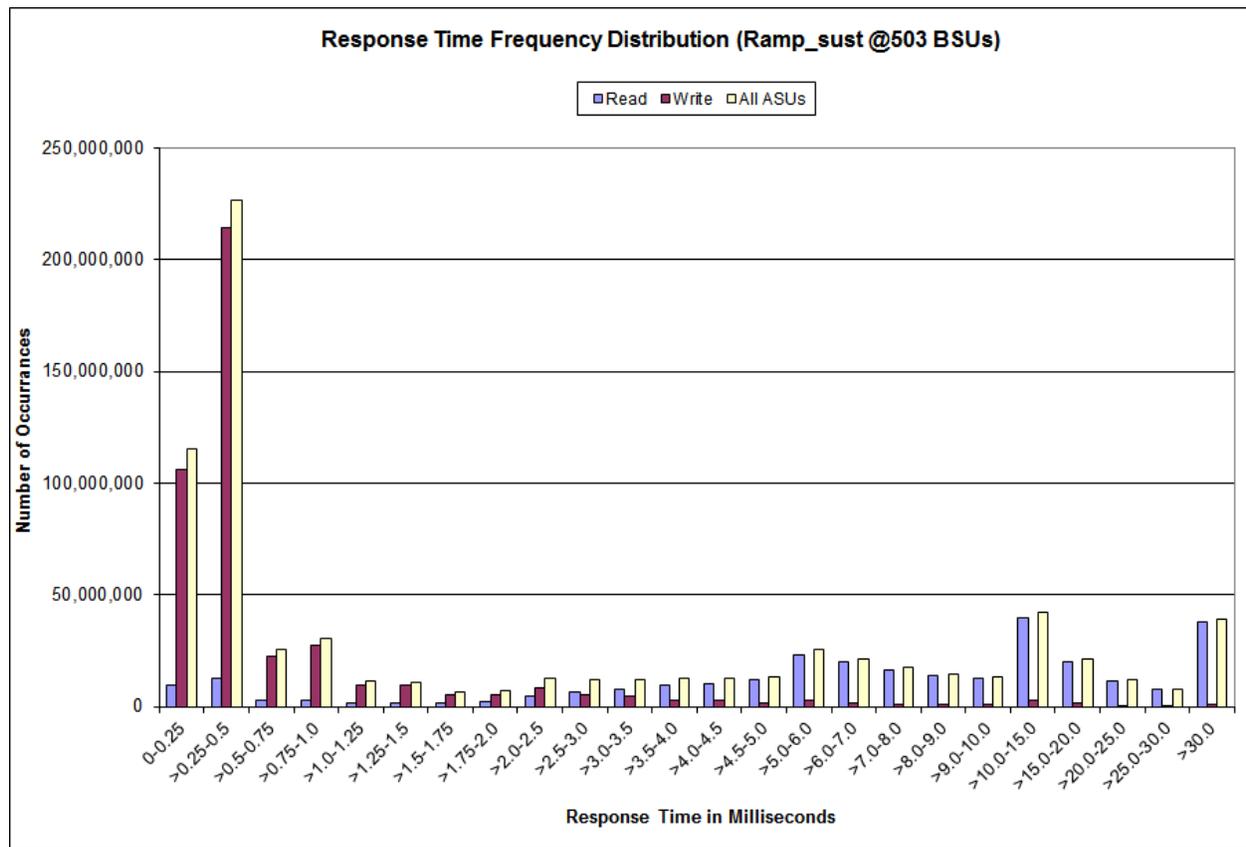
Sustainability – Measured Intensity Multiplier and Coefficient of Variation

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 5.3.15.2

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 5.3.15.3

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	02810	0.0700	0.210	0.0180	0.0700	0.0350	0.2810
COV	0.004	0.001	0.003	0.002	0.005	0.003	0.004	0.001

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 9.4.3.7.3

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 to 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 82.

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

503 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	1:13:17	1:16:18	0-2	0:03:01
Measurement Interval	1:16:18	1:26:18	3-12	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	25,178.98	15,006.45	3,093.73	7,078.80
1	25,087.87	14,943.23	3,093.72	7,050.92
2	25,142.48	14,983.97	3,095.80	7,062.72
3	25,138.53	14,968.78	3,104.17	7,065.58
4	25,177.03	15,022.97	3,086.97	7,067.10
5	25,169.65	15,001.67	3,099.37	7,068.62
6	25,170.72	14,990.43	3,096.02	7,084.27
7	25,130.52	14,985.48	3,091.02	7,054.02
8	25,147.25	14,991.75	3,090.67	7,064.83
9	25,126.17	14,966.72	3,090.25	7,069.20
10	25,115.85	14,969.10	3,093.48	7,053.27
11	25,141.72	14,980.67	3,102.85	7,058.20
12	25,154.78	14,993.77	3,094.23	7,066.78
Average	*25,147.22*	*14,987.13*	*3,094.90*	*7,065.19*

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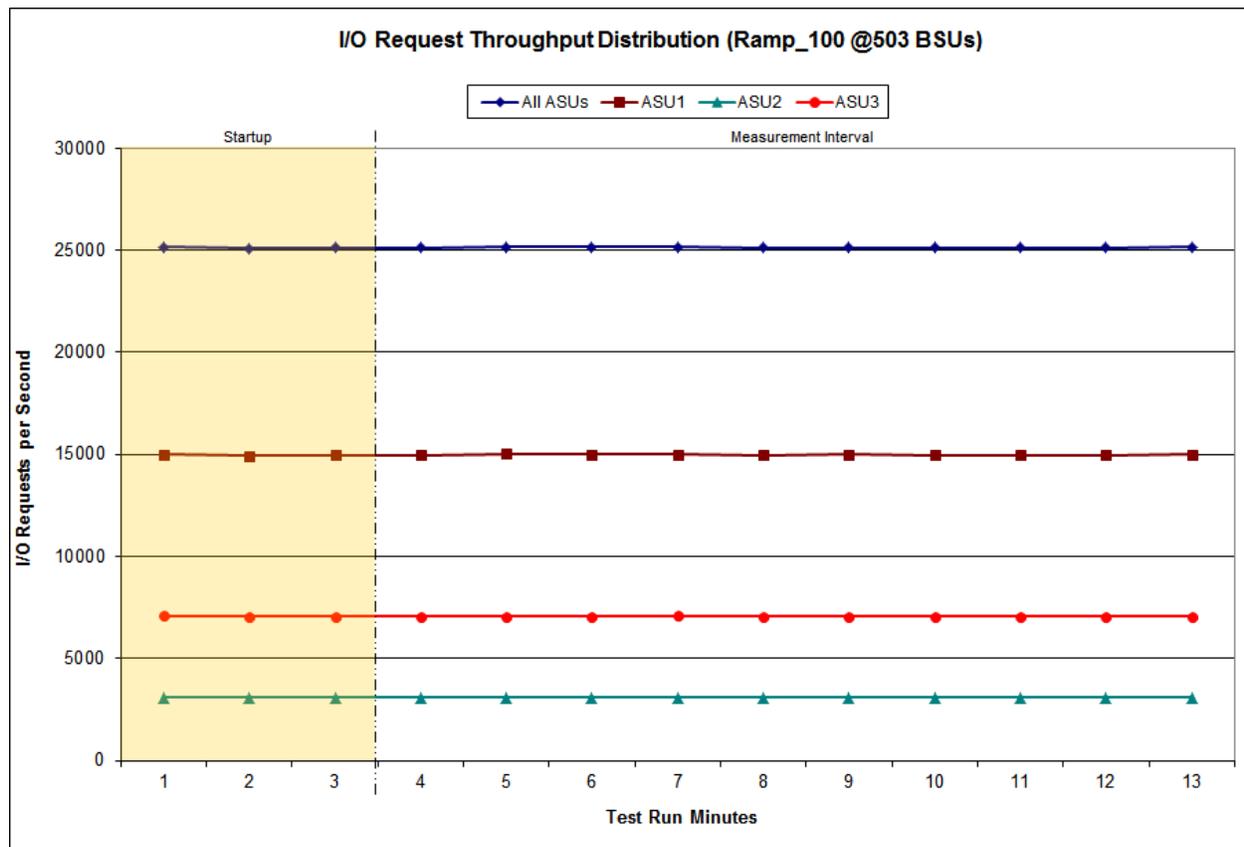
IOPS Test Run – Average Response Time (ms) Distribution Data

503 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	1:13:17	1:16:18	0-2	0:03:01
Measurement Interval	1:16:18	1:26:18	3-12	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	5.55	7.16	9.36	0.47
1	6.96	8.90	12.32	0.50
2	10.27	13.02	19.37	0.46
3	8.88	11.19	16.87	0.49
4	8.16	10.18	15.97	0.46
5	8.23	10.28	16.03	0.46
6	9.26	11.61	18.00	0.46
7	7.66	9.63	14.57	0.47
8	7.89	9.91	15.05	0.47
9	8.18	10.29	15.62	0.47
10	8.51	10.68	16.25	0.52
11	7.87	9.89	14.93	0.46
12	8.36	10.45	16.20	0.49
Average	*8.30*	*10.41*	*15.95*	*0.48*

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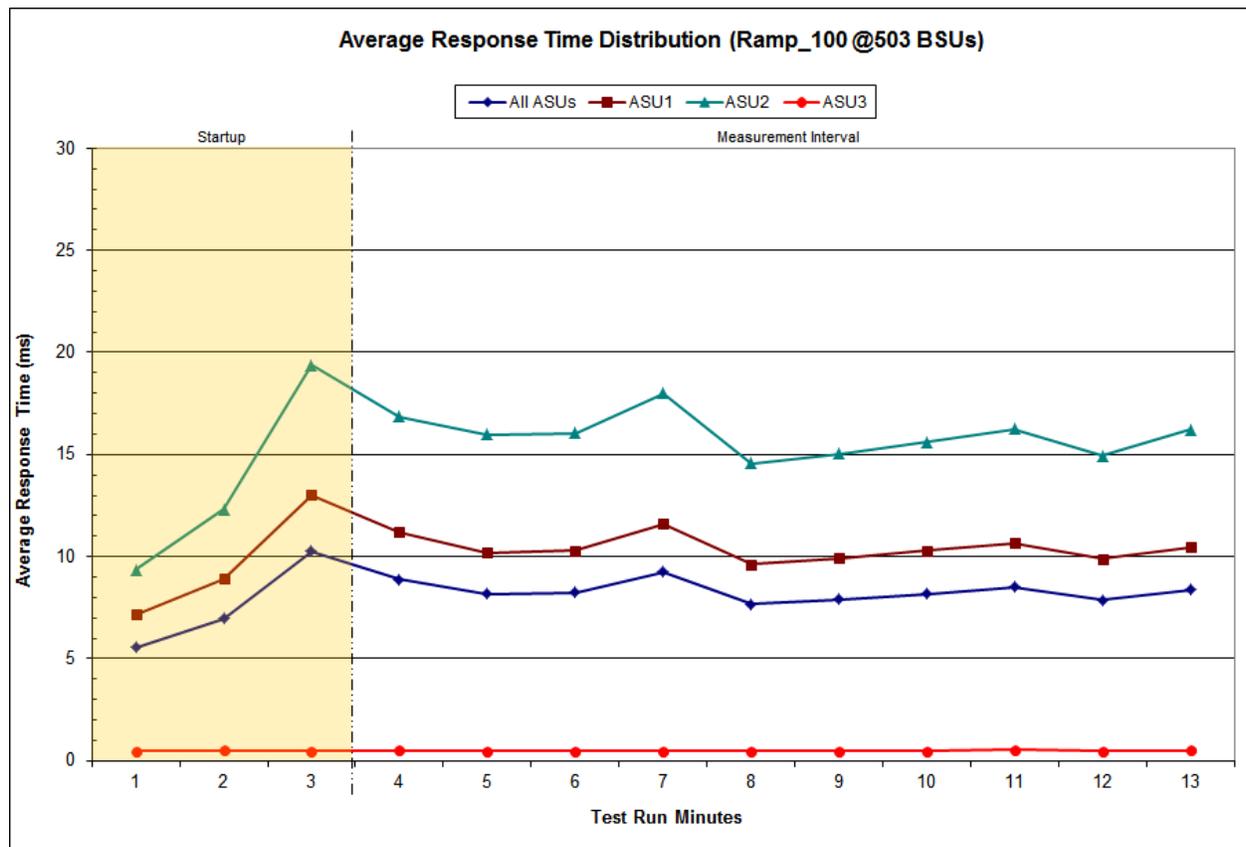
IOPS Test Run –Response Time Frequency Distribution Data

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	226,518	299,269	69,632	69,401	37,065	31,860	30,785	42,203
Write	2,178,246	4,528,998	466,020	534,020	204,793	194,347	102,478	105,722
All ASUs	2,404,764	4,828,267	535,652	603,421	241,858	226,207	133,263	147,925
ASU1	934,891	1,882,148	357,822	353,554	174,966	208,263	120,085	131,945
ASU2	218,778	395,295	39,433	47,516	18,439	15,806	12,693	15,048
ASU3	1,251,095	2,550,824	138,397	202,351	48,453	2,138	485	932

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	93,959	137,730	153,184	201,099	201,591	240,394	469,051	404,825
Write	174,838	114,062	95,041	63,566	54,772	36,106	54,916	35,461
All ASUs	268,797	251,792	248,225	264,665	256,363	276,500	523,967	440,286
ASU1	236,825	217,545	211,516	223,231	214,167	232,217	438,450	365,075
ASU2	29,432	33,773	35,219	41,028	40,921	44,020	84,085	73,891
ASU3	2,540	474	1,490	406	1,275	263	1,432	1,320

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	331,443	282,813	254,080	816,536	405,187	232,909	150,941	767,213
Write	25,157	18,951	14,627	58,431	36,280	12,039	6,643	22,809
All ASUs	356,600	301,764	268,707	874,967	441,467	244,948	157,584	790,022
ASU1	294,207	248,095	219,364	691,193	333,939	186,379	119,246	596,940
ASU2	61,092	52,574	48,237	168,071	93,820	57,429	38,110	192,130
ASU3	1,301	1,095	1,106	15,703	13,708	1,140	228	952

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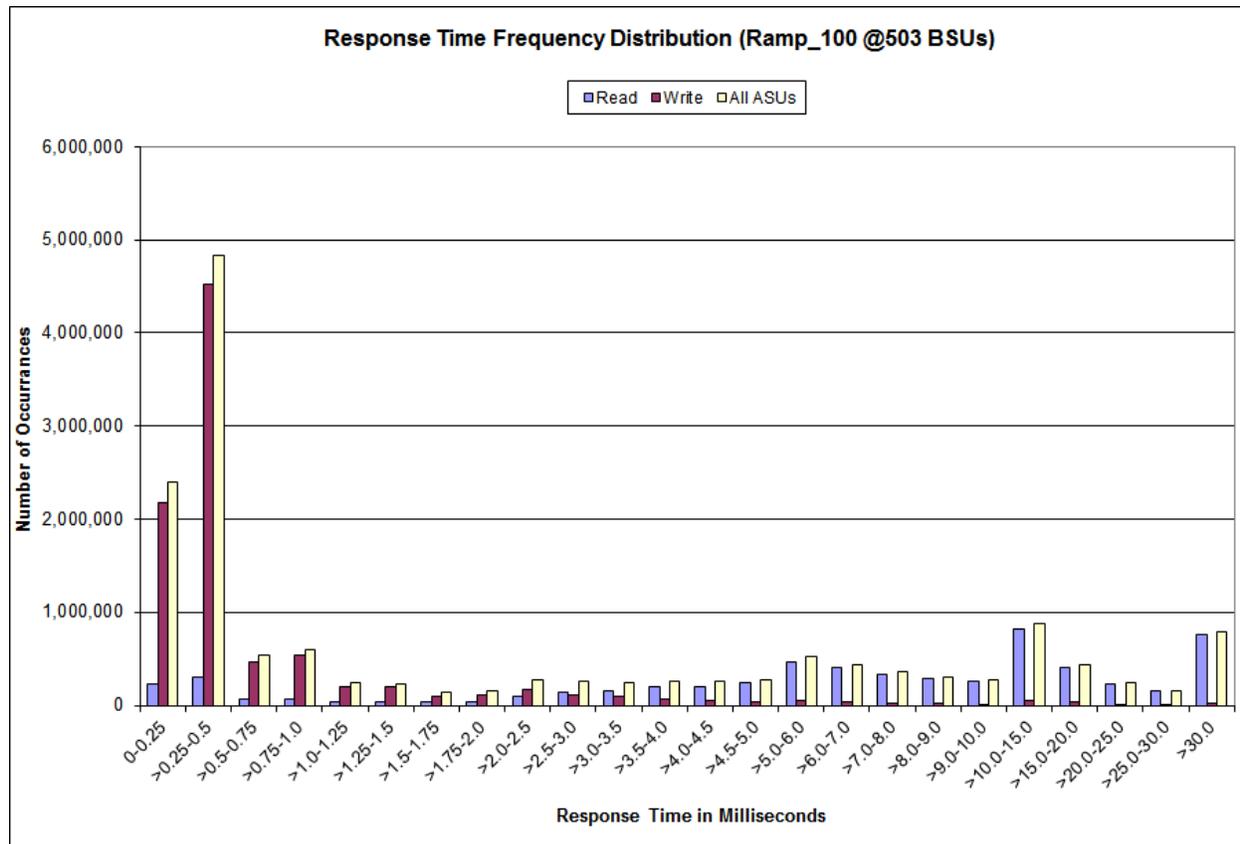
IOPS Test Run – I/O Request Information

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
15,088,011	14,29,989	790,022

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 5.3.15.2

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 5.3.15.3

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	0.2811	0.0702	0.2097	0.0180	0.0701	0.0350	0.2810
COV	0.005	0.001	0.003	0.002	0.009	0.003	0.004	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 16.

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 9.4.3.7.4

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 82.

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
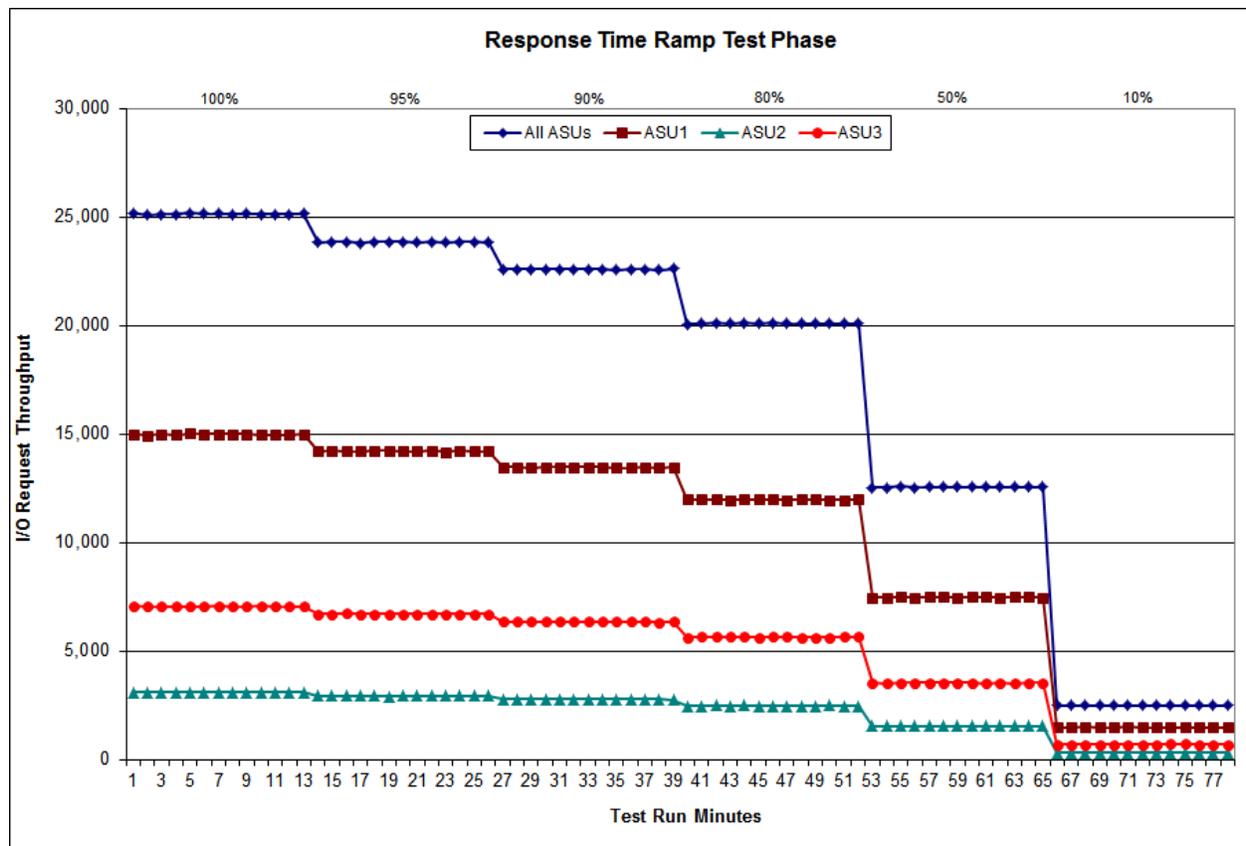
Response Time Ramp Distribution (IOPS) Data

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 table and graph for completeness.

100% Load Level: 503 BSUs	Start	Stop	Interval	Duration	95% Load Level: 477 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	1:13:17	1:16:18	0-3	0:03:01	Start-Up/Ramp-Up	1:26:22	1:29:23	0-3	0:03:01
Measurement Interval	1:16:18	1:26:18	3-12	0:10:00	Measurement Interval	1:29:23	1:39:23	3-12	0:10:00
(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3	(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3
Minutes of Test Run	All ASUs	ASU1	ASU2	ASU3	Minutes of Test Run	All ASUs	ASU1	ASU2	ASU3
0	25,178.98	15,006.45	3,093.73	7,078.80	0	23,836.88	14,207.97	2,936.82	6,692.10
1	25,087.87	14,943.23	3,093.72	7,050.92	1	23,862.48	14,227.92	2,926.35	6,708.22
2	25,142.48	14,983.97	3,095.80	7,062.72	2	23,868.08	14,211.32	2,932.72	6,724.05
3	25,138.53	14,968.78	3,104.17	7,065.58	3	23,809.80	14,194.43	2,923.52	6,691.85
4	25,177.03	15,022.97	3,086.97	7,067.10	4	23,873.48	14,225.30	2,928.33	6,719.85
5	25,169.65	15,001.67	3,099.37	7,068.62	5	23,858.43	14,230.70	2,918.18	6,709.55
6	25,170.72	14,990.43	3,096.02	7,084.27	6	23,864.83	14,221.27	2,938.63	6,704.93
7	25,130.52	14,985.48	3,091.02	7,054.02	7	23,828.50	14,197.12	2,925.33	6,706.05
8	25,147.25	14,991.75	3,090.67	7,064.83	8	23,856.13	14,225.10	2,933.30	6,697.73
9	25,126.17	14,966.72	3,090.25	7,069.20	9	23,814.88	14,190.87	2,932.08	6,691.93
10	25,115.85	14,969.10	3,093.48	7,053.27	10	23,870.52	14,233.50	2,937.15	6,699.87
11	25,141.72	14,980.67	3,102.85	7,058.20	11	23,855.82	14,221.80	2,927.87	6,706.15
12	25,154.78	14,993.77	3,094.23	7,066.78	12	23,844.02	14,192.58	2,939.43	6,712.00

90% Load Level: 452 BSUs	Start	Stop	Interval	Duration	80% Load Level: 402 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	1:39:27	1:42:28	0-3	0:03:01	Start-Up/Ramp-Up	1:52:32	1:55:33	0-3	0:03:01
Measurement Interval	1:42:28	1:52:28	3-12	0:10:00	Measurement Interval	1:55:33	2:05:33	3-12	0:10:00
(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3	(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3
Minutes of Test Run	All ASUs	ASU1	ASU2	ASU3	Minutes of Test Run	All ASUs	ASU1	ASU2	ASU3
0	22,610.15	13,473.92	2,777.02	6,359.22	0	20,077.97	11,977.42	2,464.83	5,635.72
1	22,609.38	13,472.02	2,775.73	6,361.63	1	20,093.98	11,979.68	2,469.47	5,644.83
2	22,583.53	13,460.20	2,773.87	6,349.47	2	20,115.42	11,978.95	2,479.63	5,656.83
3	22,600.62	13,472.55	2,776.32	6,351.75	3	20,097.90	11,971.95	2,467.53	5,658.42
4	22,609.13	13,463.47	2,785.25	6,360.42	4	20,127.10	11,984.57	2,485.18	5,657.35
5	22,609.57	13,469.08	2,775.83	6,364.65	5	20,104.33	11,996.50	2,466.87	5,640.97
6	22,594.20	13,463.92	2,779.35	6,350.93	6	20,118.73	11,987.85	2,473.92	5,656.97
7	22,581.30	13,466.18	2,773.87	6,341.25	7	20,092.08	11,968.57	2,466.95	5,656.57
8	22,576.53	13,456.45	2,774.05	6,346.03	8	20,090.37	11,987.43	2,465.78	5,637.15
9	22,592.17	13,459.52	2,769.02	6,363.63	9	20,088.32	11,979.23	2,471.75	5,637.33
10	22,596.82	13,472.38	2,779.67	6,344.77	10	20,093.33	11,972.58	2,483.82	5,636.93
11	22,567.08	13,459.22	2,775.43	6,332.43	11	20,090.50	11,964.50	2,468.35	5,657.65
12	22,612.37	13,481.77	2,761.12	6,369.48	12	20,102.28	11,982.42	2,473.43	5,646.43

Response Time Ramp Distribution (IOPS) Data *(continued)*

| 50% Load Level: 251 BSUs	Start	Stop	Interval	Duration	10% Load Level: 50 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	2:05:37	2:08:38	0-3	0:03:01	Start-Up/Ramp-Up	2:18:41	2:21:42	0-3	0:03:01
Measurement Interval	2:08:38	2:18:38	3-12	0:10:00	Measurement Interval	2:21:42	2:31:42	3-12	0:10:00
(60 second intervals)	**All ASUs**	**ASU-1**	**ASU-2**	**ASU-3**	*(60 second intervals)*	**All ASUs**	**ASU-1**	**ASU-2**	**ASU-3**
Minutes of Test Run	All ASUs	ASU1	ASU2	ASU3	Minutes of Test Run	All ASUs	ASU1	ASU2	ASU3
0	12,543.77	7,468.63	1,540.85	3,534.28	0	2,501.52	1,491.20	307.93	702.38
1	12,539.60	7,477.18	1,540.65	3,521.77	1	2,502.58	1,494.08	308.83	699.67
2	12,584.85	7,502.93	1,540.20	3,541.72	2	2,508.70	1,500.02	305.53	703.15
3	12,531.47	7,468.82	1,538.83	3,523.82	3	2,505.32	1,493.37	309.25	702.70
4	12,555.78	7,486.77	1,540.28	3,528.73	4	2,492.85	1,480.47	307.90	704.48
5	12,556.78	7,489.70	1,538.35	3,528.73	5	2,510.17	1,498.72	309.17	702.28
6	12,556.15	7,472.73	1,546.20	3,537.22	6	2,505.63	1,493.70	309.30	702.63
7	12,571.08	7,492.13	1,551.18	3,527.77	7	2,500.13	1,488.13	307.98	704.02
8	12,545.78	7,480.67	1,551.52	3,513.60	8	2,500.68	1,489.85	303.57	707.27
9	12,546.17	7,472.97	1,547.22	3,525.98	9	2,505.42	1,486.58	309.68	709.15
10	12,561.28	7,494.27	1,546.30	3,520.72	10	2,503.90	1,495.58	306.93	701.38
11	12,563.20	7,491.93	1,538.33	3,532.93	11	2,494.77	1,483.02	308.18	703.57
12	*12,569.20*	*7,477.45*	*1,552.42*	*3,539.33*	*12*	*2,492.78*	*1,485.47*	*304.43*	*702.88*

Response Time Ramp Distribution (IOPS) Graph

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

50 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	2:18:41	2:21:42	0-2	0:03:01
Measurement Interval	2:21:42	2:31:42	3-12	0:10:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	2.41	3.28	2.49	0.54
1	2.23	3.02	2.30	0.51
2	2.26	3.03	2.49	0.52
3	2.38	3.23	2.51	0.51
4	2.20	2.96	2.39	0.53
5	2.21	3.00	2.30	0.50
6	2.26	3.01	2.55	0.52
7	2.30	3.12	2.39	0.52
8	2.16	2.90	2.29	0.55
9	2.18	2.95	2.32	0.48
10	2.25	3.04	2.36	0.53
11	2.31	3.14	2.37	0.54
12	2.23	3.00	2.43	0.51
Average	*2.25*	*3.03*	*2.39*	*0.52*

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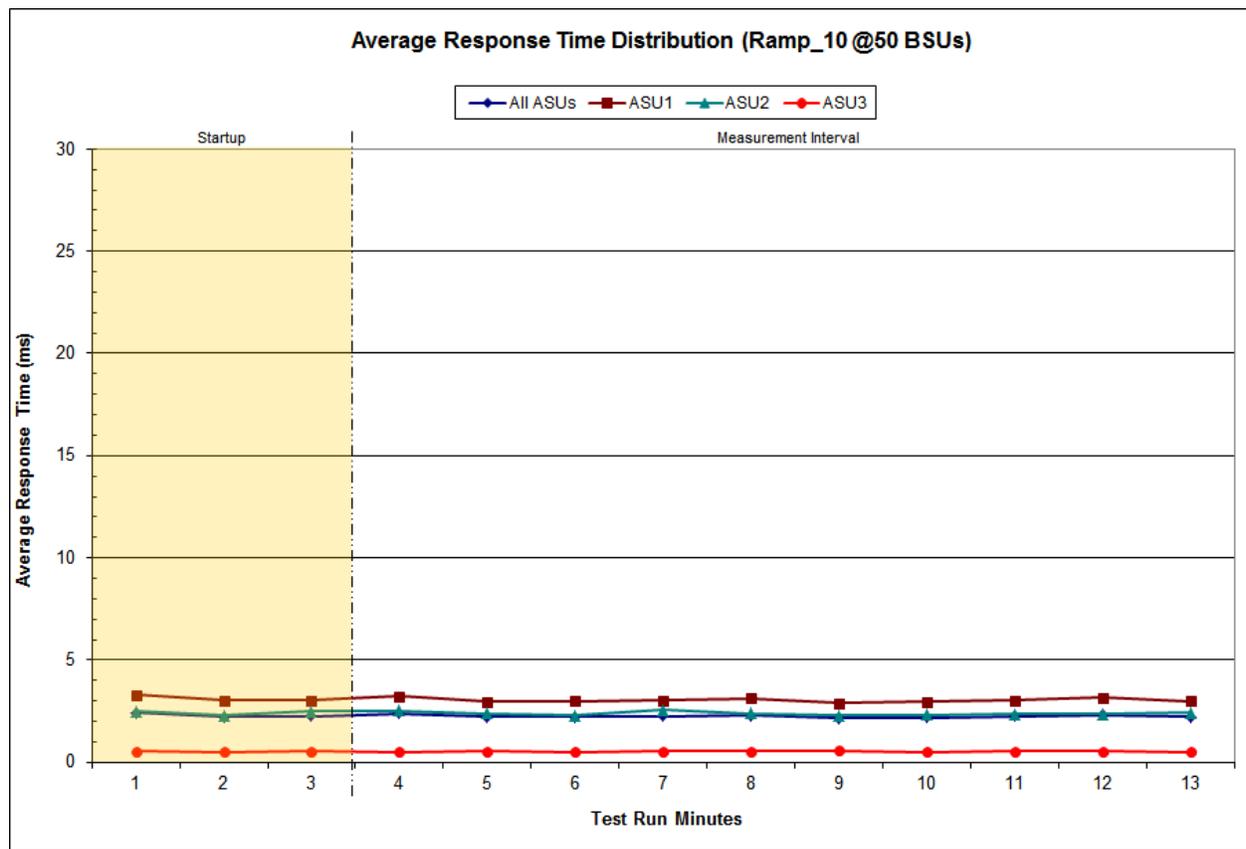
SPC-1 LRT™ (10%) – Measured Intensity Multiplier and Coefficient of Variation

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 5.3.15.2

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 5.3.15.3

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	0.0351	0.2810	0.0697	0.2097	0.0180	0.0700	0.0351	0.2815
COV	0.012	0.003	0.009	0.004	0.018	0.009	0.014	0.004

Repeatability Test

Clause 5.4.5

The Repeatability Test demonstrates the repeatability and reproducibility of the SPC-1 IOPS™ primary metric and the 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 9.4.3.7.5

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 82.

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	*25,147.22*
Repeatability Test Phase 1	25,147.56
Repeatability Test Phase 2	25,166.77

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	*2.25 ms*
Repeatability Test Phase 1	2.21 ms
Repeatability Test Phase 2	2.20 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 plus 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

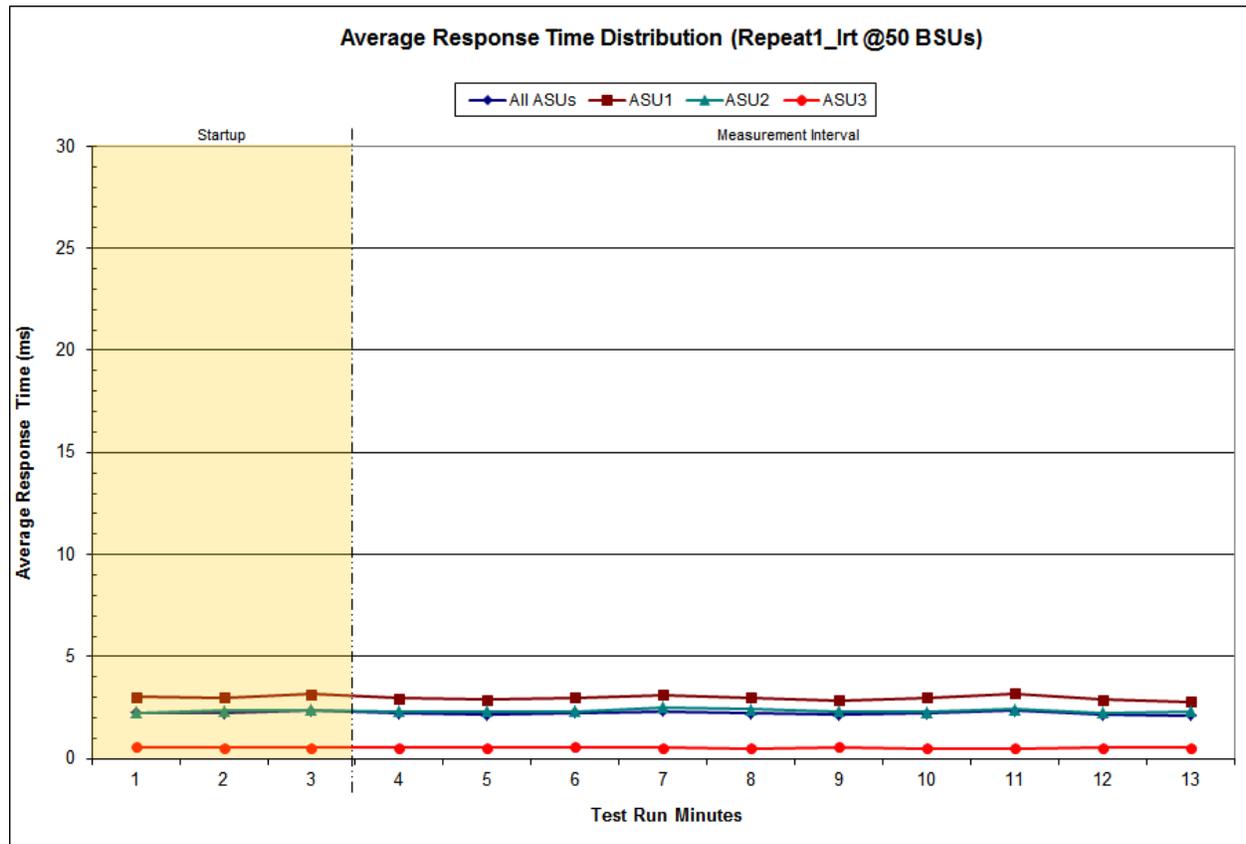| 50 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	2:31:50	2:34:50	0-2	0:03:00
Measurement Interval	2:34:50	2:44:50	3-12	0:10:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	2,487.68	1,487.00	308.55	692.13
1	2,496.15	1,481.93	310.67	703.55
2	2,505.43	1,494.30	309.03	702.10
3	2,497.20	1,485.43	310.58	701.18
4	2,491.67	1,491.30	304.67	695.70
5	2,503.65	1,489.08	308.63	705.93
6	2,491.53	1,487.53	309.03	694.97
7	2,497.90	1,483.10	311.15	703.65
8	2,493.17	1,483.37	304.10	705.70
9	2,505.03	1,493.50	308.05	703.48
10	2,502.12	1,493.50	305.67	702.95
11	2,502.67	1,495.58	306.23	700.85
12	2,497.62	1,487.67	310.00	699.95
Average	*2,498.26*	*1,489.01*	*307.81*	*701.44*

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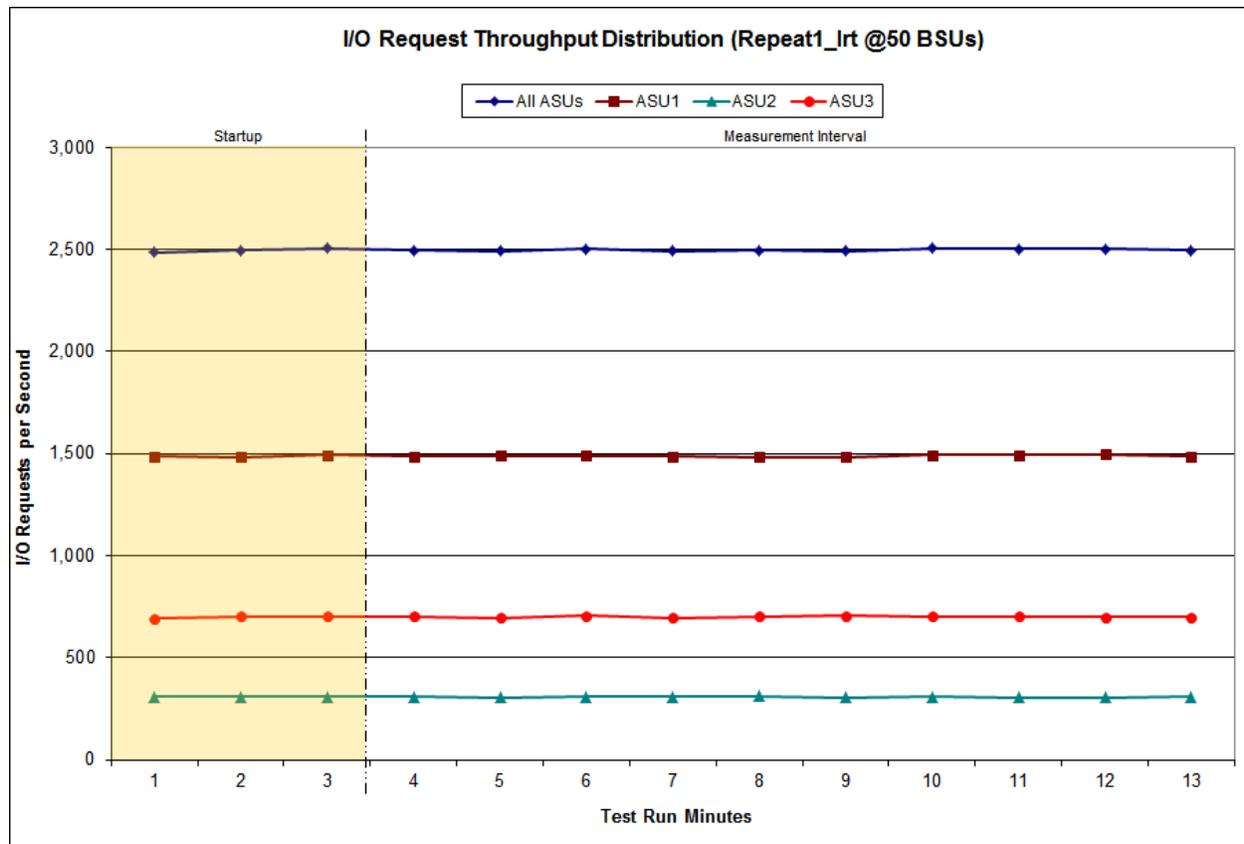
Repeatability 1 LRT –Average Response Time (ms) Distribution Data

50 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	2:31:50	2:34:50	0-2	0:03:00
Measurement Interval	2:34:50	2:44:50	3-12	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	2.24	3.01	2.26	0.58
1	2.21	2.98	2.33	0.52
2	2.33	3.17	2.39	0.52
3	2.21	2.97	2.33	0.54
4	2.16	2.88	2.32	0.53
5	2.23	3.00	2.33	0.57
6	2.31	3.11	2.52	0.52
7	2.21	2.99	2.41	0.49
8	2.15	2.87	2.33	0.56
9	2.20	2.98	2.27	0.52
10	2.34	3.19	2.41	0.51
11	2.15	2.89	2.26	0.52
12	2.11	2.80	2.32	0.54
Average	*2.21*	*2.97*	*2.35*	*0.53*

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

Repeatability 1 IOPS – I/O Request Throughput Distribution Data

503 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	2:44:56	2:47:57	0-2	0:03:01
Measurement Interval	2:47:57	2:57:57	3-12	0:10:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	25,149.83	14,978.28	3,099.20	7,072.35
1	25,158.68	14,999.27	3,088.30	7,071.12
2	25,160.13	14,992.47	3,089.93	7,077.73
3	25,131.08	14,976.38	3,109.05	7,045.65
4	25,145.90	14,983.85	3,103.90	7,058.15
5	25,163.92	14,986.58	3,094.10	7,083.23
6	25,144.55	14,998.52	3,081.72	7,064.32
7	25,119.45	14,965.87	3,087.13	7,066.45
8	25,159.62	14,975.22	3,100.10	7,084.30
9	25,133.07	14,982.42	3,088.67	7,061.98
10	25,168.60	14,996.20	3,094.82	7,077.58
11	25,160.92	14,989.05	3,099.33	7,072.53
12	25,148.47	14,994.53	3,086.27	7,067.67
Average	*25,147.56*	*14,984.86*	*3,094.51*	*7,068.19*

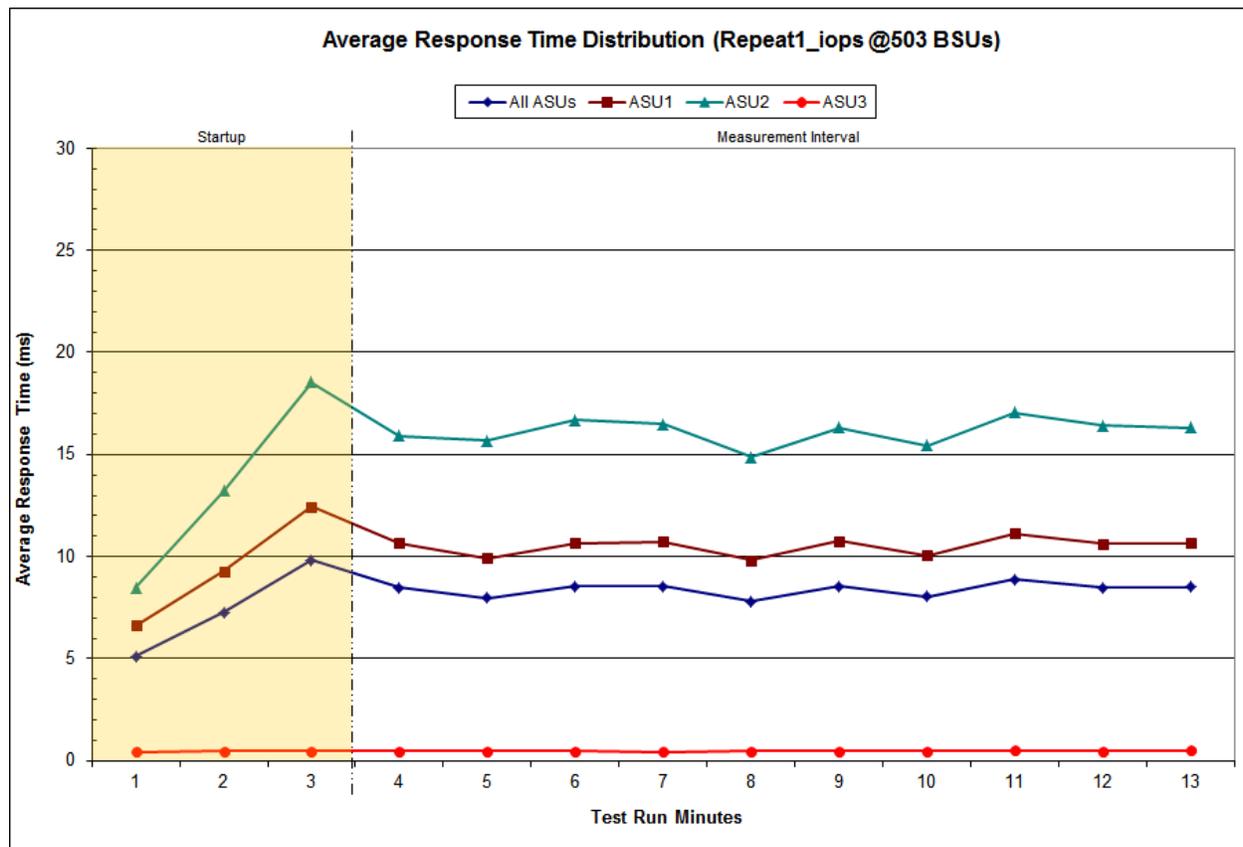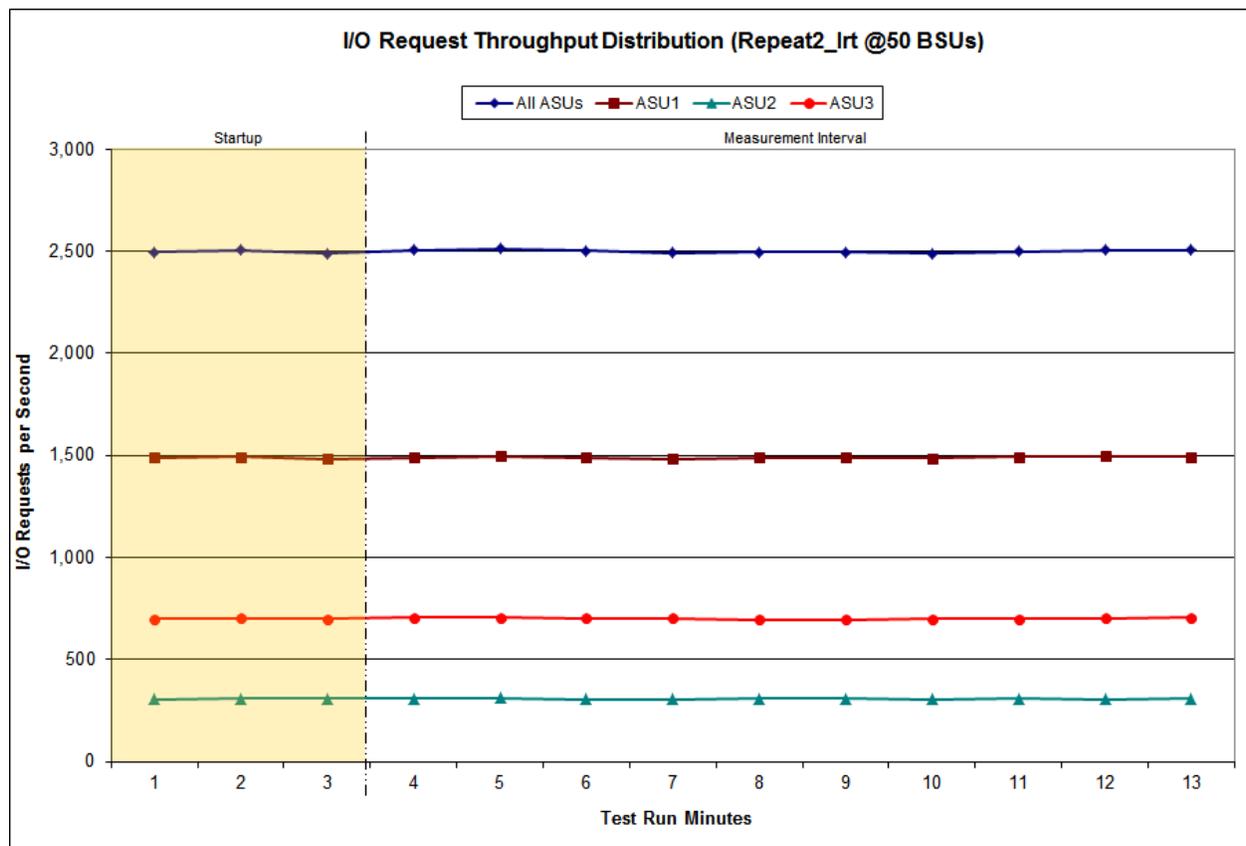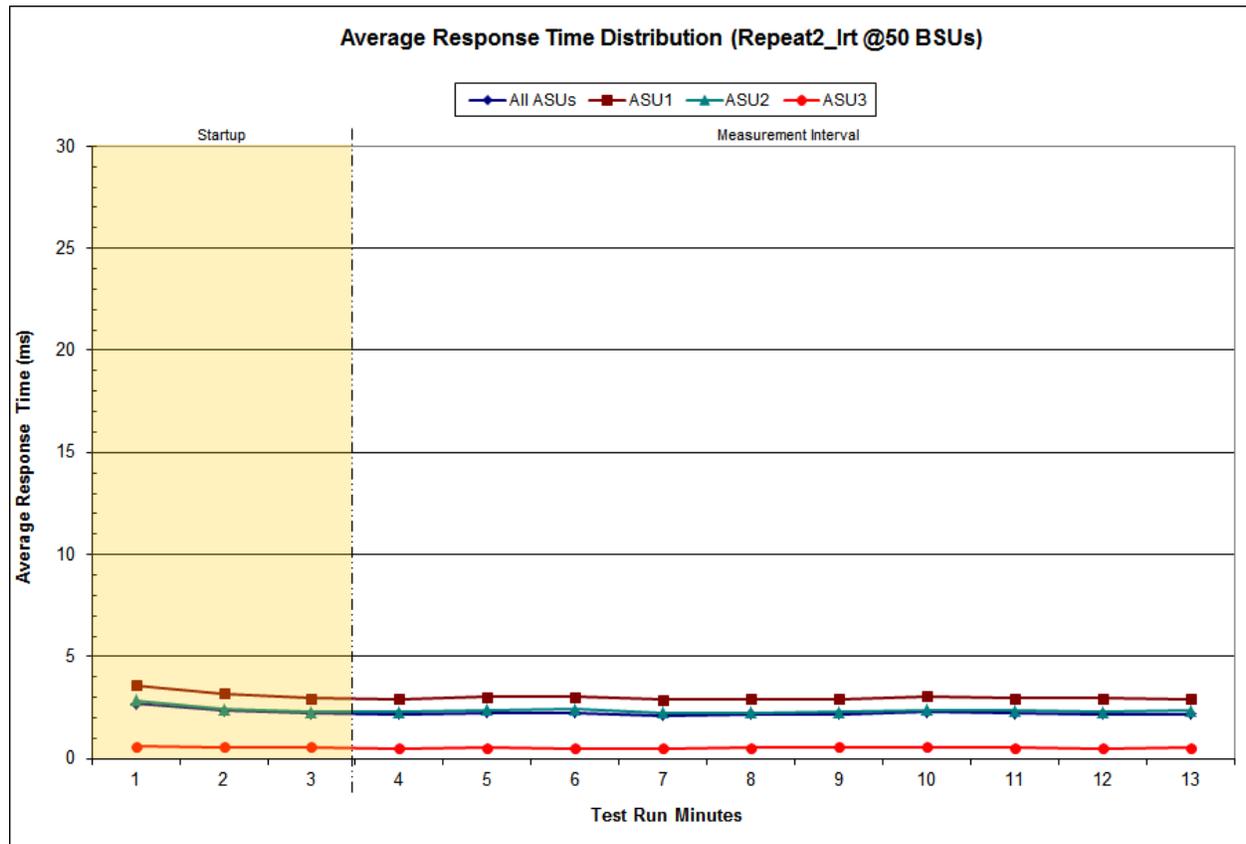## Repeatability 1 IOPS – I/O Request Throughput Distribution Graph
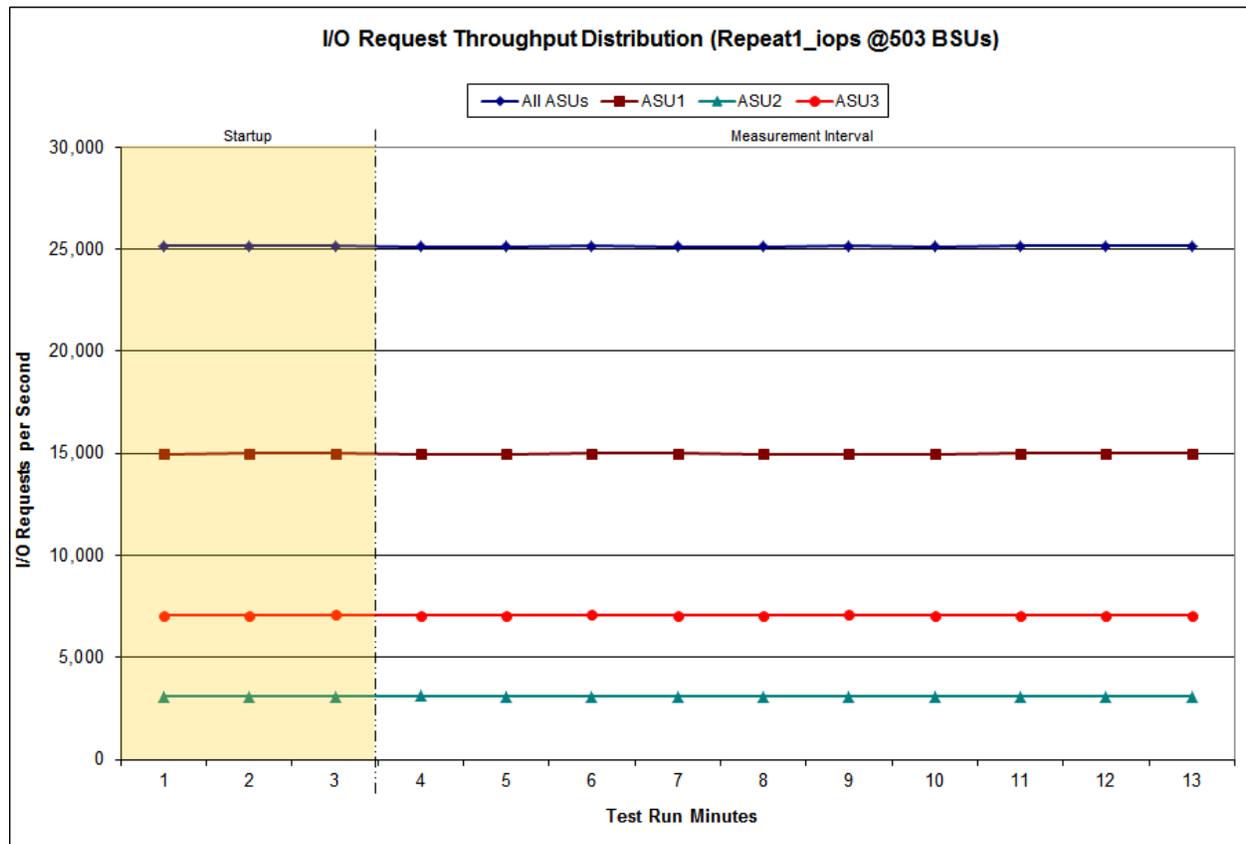
Repeatability 1 IOPS –Average Response Time (ms) Distribution Data

503 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	2:44:56	2:47:57	0-2	0:03:01
Measurement Interval	2:47:57	2:57:57	3-12	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	5.12	6.64	8.49	0.44
1	7.28	9.27	13.21	0.46
2	9.83	12.46	18.55	0.46
3	8.46	10.67	15.91	0.47
4	7.97	9.91	15.67	0.45
5	8.53	10.67	16.67	0.45
6	8.54	10.71	16.49	0.44
7	7.81	9.82	14.86	0.45
8	8.55	10.76	16.31	0.46
9	8.03	10.07	15.45	0.45
10	8.87	11.14	17.05	0.50
11	8.49	10.64	16.43	0.45
12	8.50	10.66	16.31	0.50
Average	*8.37*	*10.51*	*16.12*	*0.46*

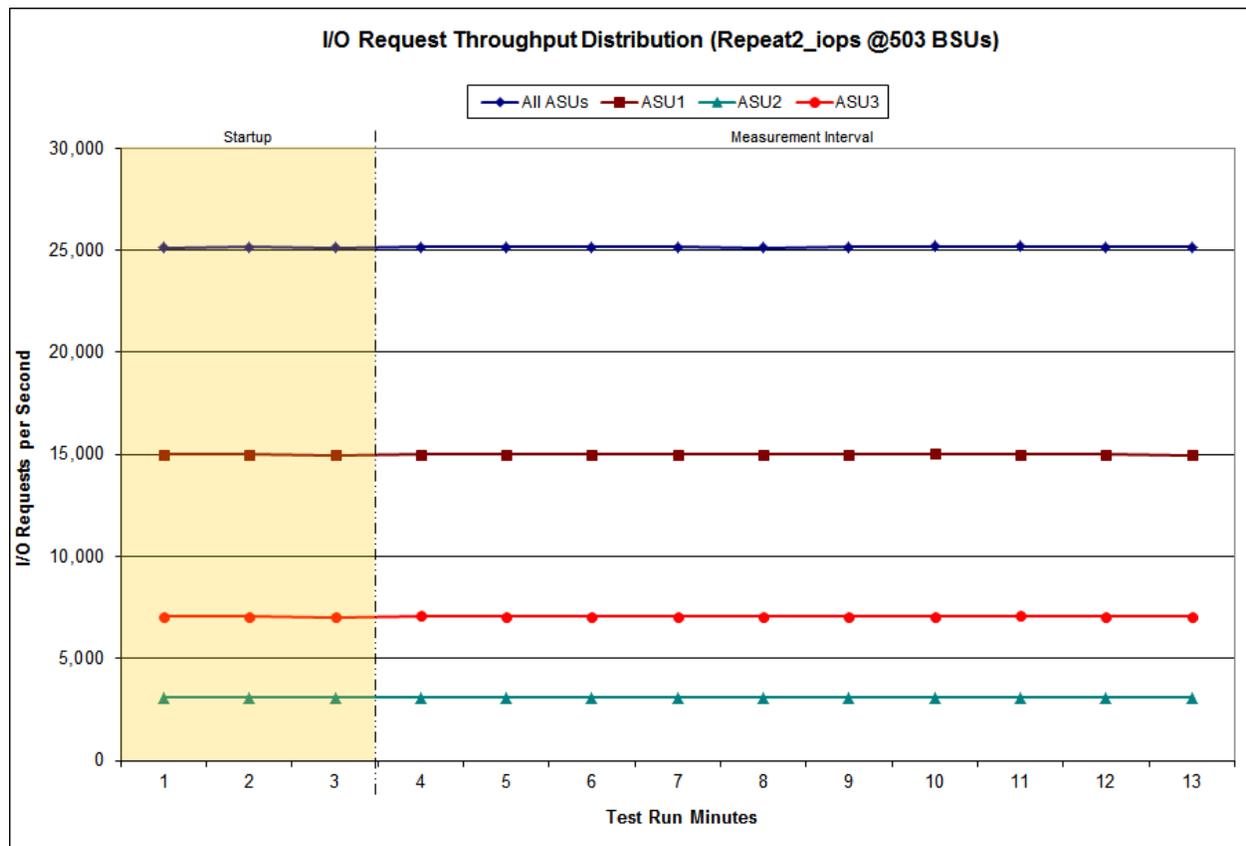## Repeatability 1 IOPS –Average Response Time (ms) Distribution Graph

Repeatability 2 LRT – I/O Request Throughput Distribution Data

| 50 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	2:58:05	3:01:05	0-2	0:03:00
Measurement Interval	3:01:05	3:11:05	3-12	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	2,496.30	1,489.83	306.17	700.30
1	2,506.47	1,494.70	309.82	701.95
2	2,490.23	1,482.32	307.38	700.53
3	2,505.58	1,489.50	308.78	707.30
4	2,514.45	1,496.50	311.72	706.23
5	2,501.63	1,491.75	306.90	702.98
6	2,494.40	1,485.03	306.80	702.57
7	2,496.53	1,490.50	309.82	696.22
8	2,497.05	1,491.53	308.08	697.43
9	2,490.95	1,486.78	305.77	698.40
10	2,499.07	1,492.10	308.53	698.43
11	2,505.80	1,497.70	306.77	701.33
12	2,506.95	1,492.45	307.65	706.85
Average	*2,501.24*	*1,491.39*	*308.08*	*701.78*

Repeatability 2 LRT – I/O Request Throughput Distribution Graph

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

50 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	2:58:05	3:01:05	0-2	0:03:00
Measurement Interval	3:01:05	3:11:05	3-12	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	2.67	3.60	2.87	0.61
1	2.35	3.18	2.40	0.56
2	2.20	2.96	2.27	0.56
3	2.17	2.94	2.28	0.51
4	2.26	3.04	2.38	0.54
5	2.24	3.03	2.42	0.50
6	2.13	2.88	2.24	0.50
7	2.17	2.91	2.25	0.54
8	2.18	2.91	2.30	0.55
9	2.28	3.07	2.39	0.57
10	2.21	2.97	2.35	0.54
11	2.17	2.94	2.27	0.48
12	2.18	2.93	2.34	0.53
Average	**2.20**	**2.96**	**2.32**	**0.53**

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

Repeatability 2 IOPS – I/O Request Throughput Distribution Data

503 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	3:11:11	3:14:12	0-2	0:03:01
Measurement Interval	3:14:12	3:24:12	3-12	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	25,142.70	14,999.32	3,085.95	7,057.43
1	25,165.68	15,000.05	3,096.57	7,069.07
2	25,117.53	14,968.42	3,105.63	7,043.48
3	25,180.15	15,000.17	3,091.47	7,088.52
4	25,164.25	15,011.23	3,085.10	7,067.92
5	25,151.20	14,996.47	3,087.83	7,066.90
6	25,169.78	14,998.77	3,104.48	7,066.53
7	25,139.33	14,989.57	3,082.03	7,067.73
8	25,159.40	14,991.72	3,097.83	7,069.85
9	25,189.00	15,029.42	3,097.52	7,062.07
10	25,199.90	15,007.52	3,096.58	7,095.80
11	25,163.03	15,006.50	3,091.12	7,065.42
12	25,151.68	14,981.10	3,103.45	7,067.13
Average	*25,166.77*	*15,001.25*	*3,093.74*	*7,071.79*

Repeatability 2 IOPS – I/O Request Throughput Distribution Graph

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

503 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	3:11:11	3:14:12	0-2	0:03:01
Measurement Interval	3:14:12	3:24:12	3-12	0:10:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	5.16	6.69	8.47	0.45
1	7.39	9.32	13.90	0.45
2	9.56	12.05	18.16	0.47
3	8.80	11.09	16.79	0.46
4	8.95	11.18	17.53	0.46
5	8.20	10.25	15.92	0.46
6	8.21	10.18	16.31	0.45
7	9.14	11.40	18.16	0.43
8	8.45	10.50	16.74	0.45
9	8.42	10.49	16.48	0.47
10	8.14	10.13	16.07	0.46
11	8.77	10.92	17.17	0.53
12	8.91	11.18	16.98	0.55
Average	*8.60*	*10.73*	*16.81*	*0.47*

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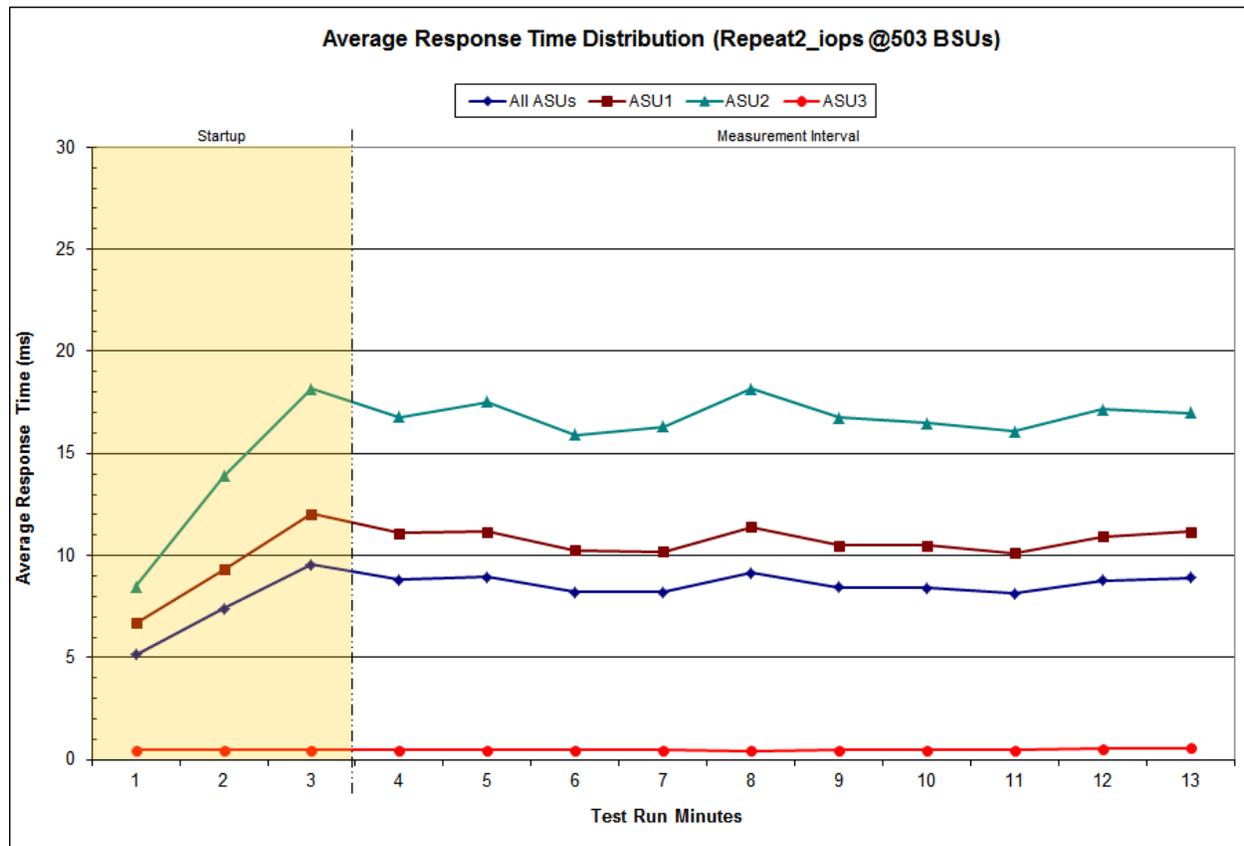
Repeatability 1 (LRT)
Measured Intensity Multiplier and Coefficient of Variation

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.*

Clauses5.1.10 and 5.3.15.2

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 5.3.15.3

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	0.0351	0.2810	0.0700	0.2100	0.0179	0.0702	0.0351	0.2808
COV	0.013	0.004	0.005	0.004	0.021	0.009	0.012	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	0.0350	0.2810	0.0700	0.2098	0.0180	0.0701	0.0350	0.2811
COV	0.003	0.001	0.002	0.002	0.009	0.003	0.004	0.001

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

	ASU1-1	ASU1-2	ASU1-3	ASU1-4	ASU2-1	ASU2-2	ASU2-3	ASU3-1
IM	*0.0350*	*0.2810*	*0.0700*	*0.2100*	*0.0180*	*0.0700*	*0.0350*	*0.2810*
MIM	0.0351	0.2809	0.0699	0.2104	0.0180	0.0699	0.0352	0.2806
COV	0.010	0.003	0.009	0.005	0.022	0.008	0.009	0.004

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	0.0349	0.2809	0.0701	0.2101	0.0180	0.0699	0.0350	0.2810
COV	0.004	0.001	0.003	0.002	0.005	0.003	0.004	0.001

Data Persistence Test

Clause 6

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

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

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

The SPC-1 Workload Generator will write 16 block I/O requests at random over the total Addressable Storage Capacity of the TSC for ten (10) minutes at a minimum of 25% of the load used to generate the SPC-1 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 (may be contained in an appendix).*

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 82.

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	60,015,312
Total Number of Logical Blocks Verified	52,858,640
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 9.4.3.9

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 Dell EqualLogic PS6210XV Array 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 be found in the Priced Storage Configuration Pricing section on page 17.

TESTED STORAGE CONFIGURATION (TSC) AND PRICED STORAGE CONFIGURATION DIFFERENCES

Clause 9.4.3.3.8

The Executive Summary shall contain a list of all differences 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 17.

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 Onsite Audit of the Dell EqualLogic PS6210XV Array.

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 1: The single point of failure of any *storage device* in the configuration will not result in permanent loss of access to or integrity of the SPC-1 Data Repository.

Protected 2: The single point of failure of any *component* in the configuration will not result in permanent loss of access to or integrity of the SPC-1 Data Repository.

SPC-1 Test Execution Definitions

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Steady State: The consistent and sustainable throughput of the TSC. During this period the load presented to the TSC by the Workload Generator is constant.

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

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

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

I/O Completion Types
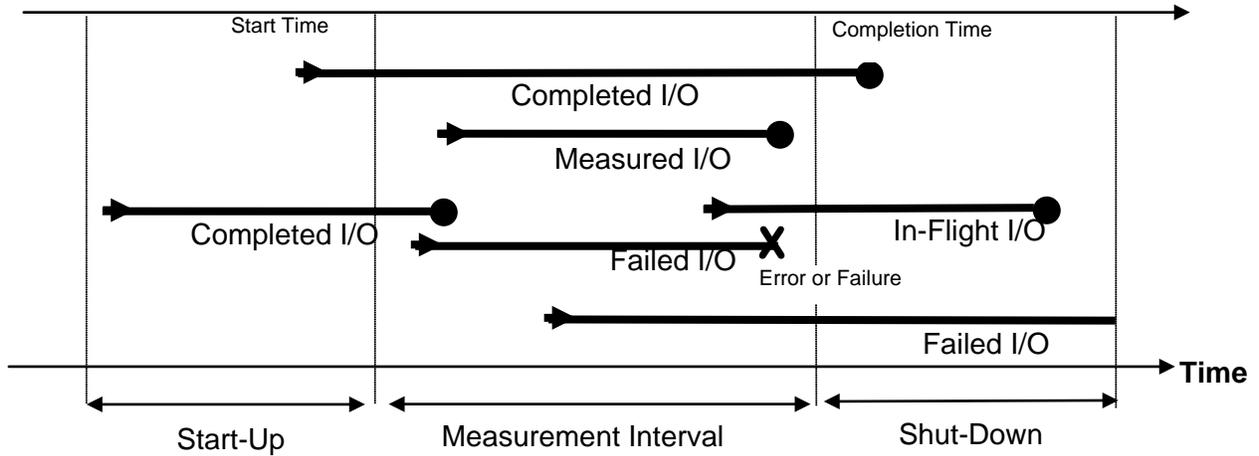
SPC-1 Test Run Components
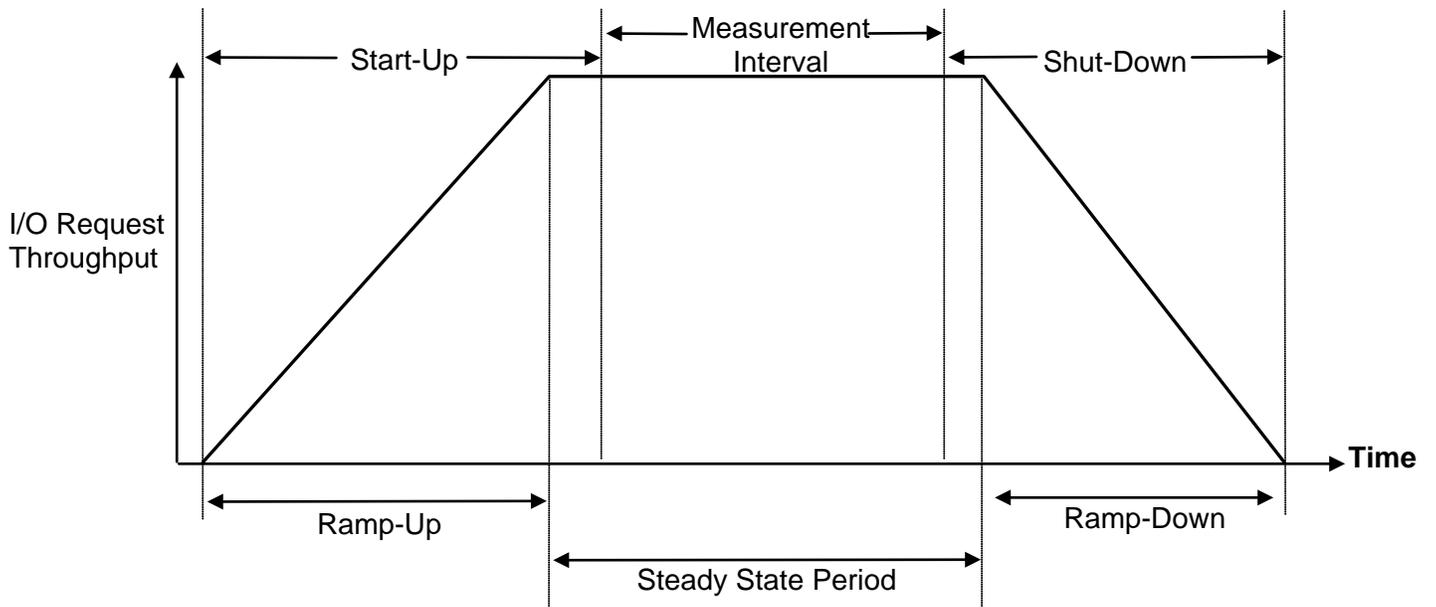
APPENDIX B: CUSTOMER TUNABLE PARAMETERS AND OPTIONS

There were no customer tunable parameter or options changed from their default values. Firmware auto-tunes critical performance affecting parameters.

APPENDIX C: TESTED STORAGE CONFIGURATION (TSC) CREATION

The Dell EqualLogic Group Manager GUI was used to create and configure the Tested Storage Configuration (TSC). The Dell EqualLogic Host Integration Tools for Windows was installed on the Host System. The Group Manager GUI also required installation of Java.

Starting the Group Manager GUI:
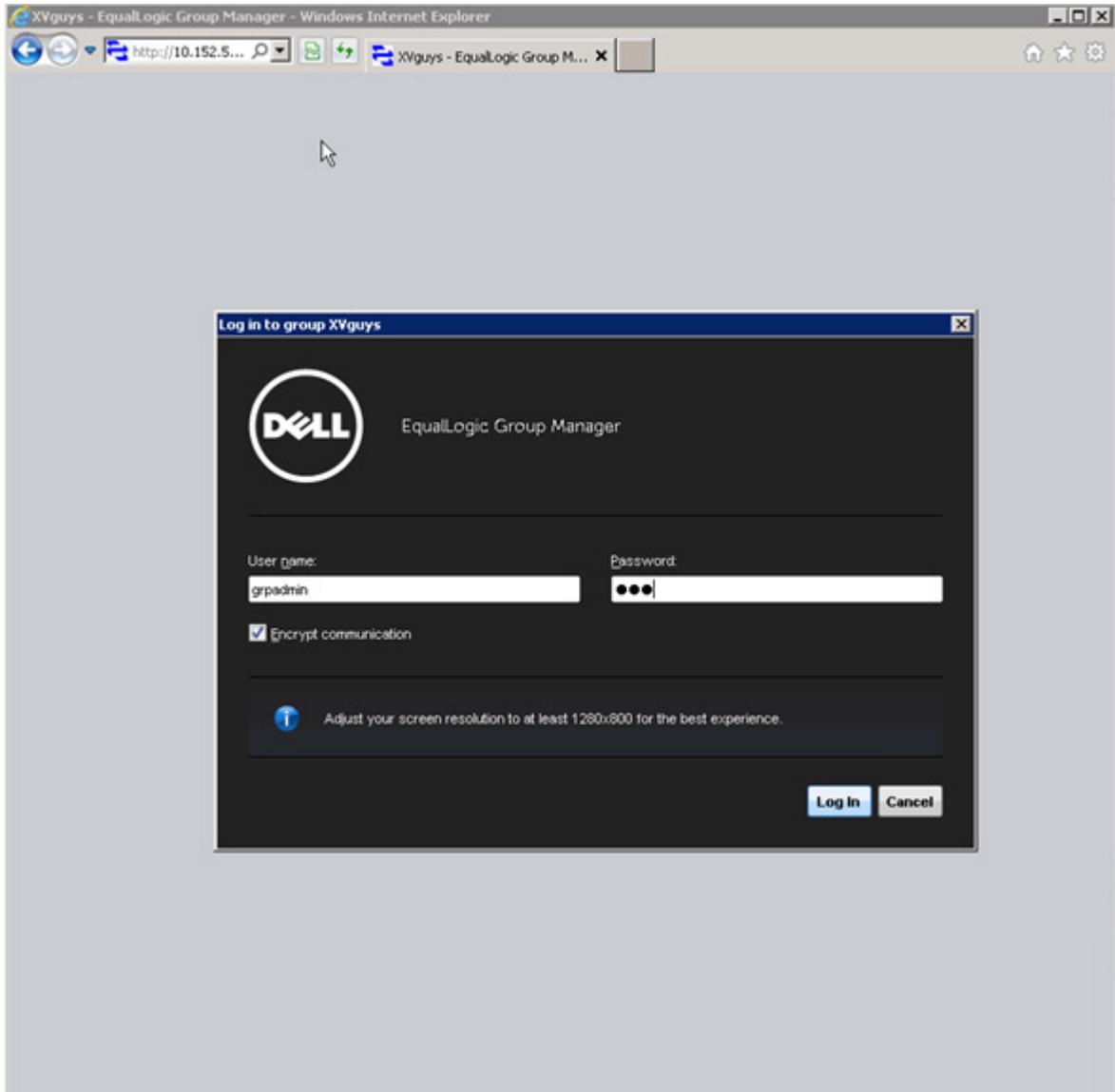
1. Start a web browser on the Host System where the Dell EqualLogic Integration Tools are installed.

2. Start the Group Manager GUI by entering the IP Address of the Dell EqualLogic 6210XV in the address bar of the web browser.

3. Perform the following to logon to the Group Manager GUI as illustrated above:
   a. Enter **grpadmin** in the **User name** box.
   b. Enter the password of the user account entered above in the **Password** box.
   c. Click **Log In** to open the Group Manager GUI.

Create Custom Storage Pool
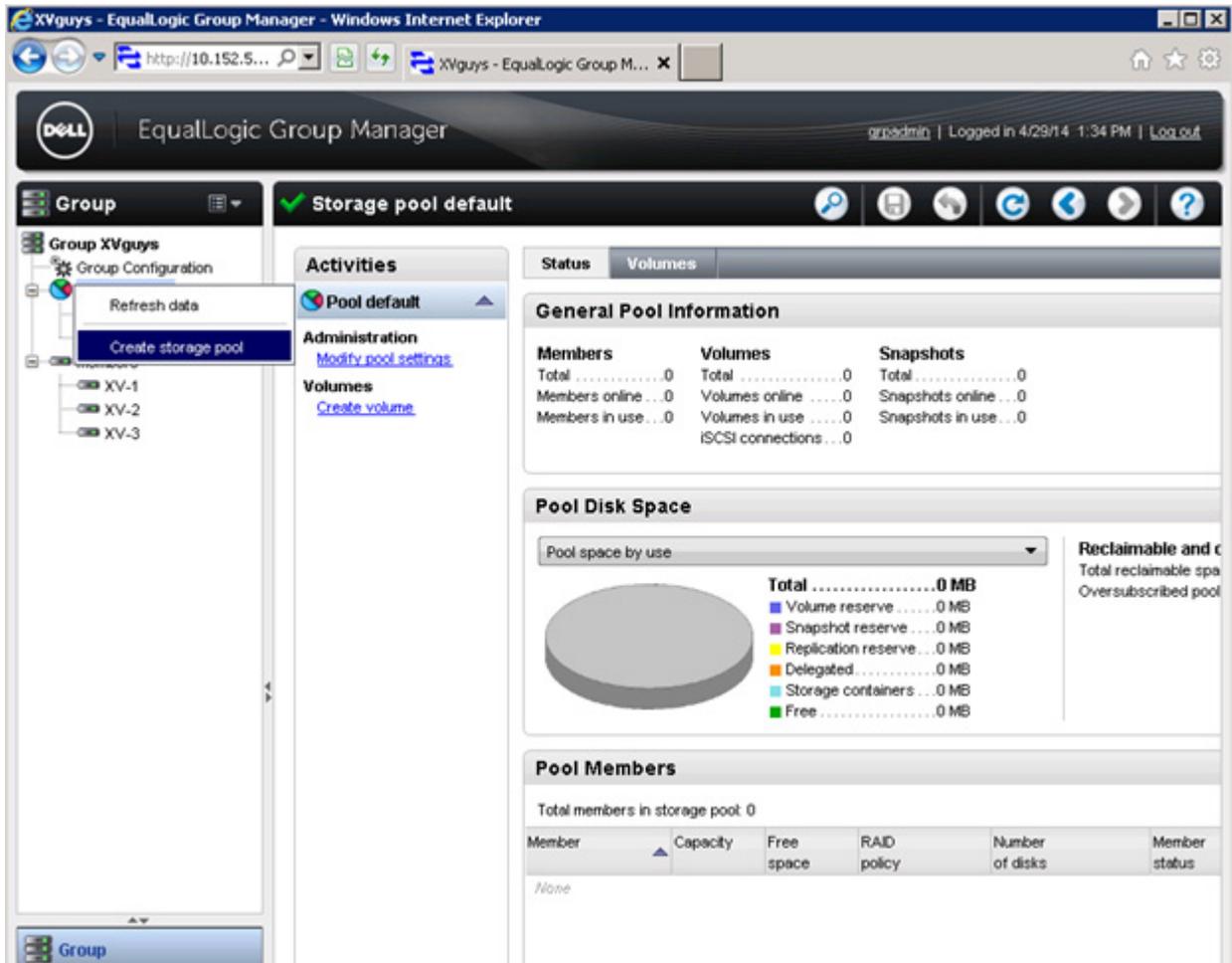
1. By default, there is a **default** pool created by the storage system. To create a custom pool, right click on **Storage Pools** and select **Create storage pool** as illustrated above.
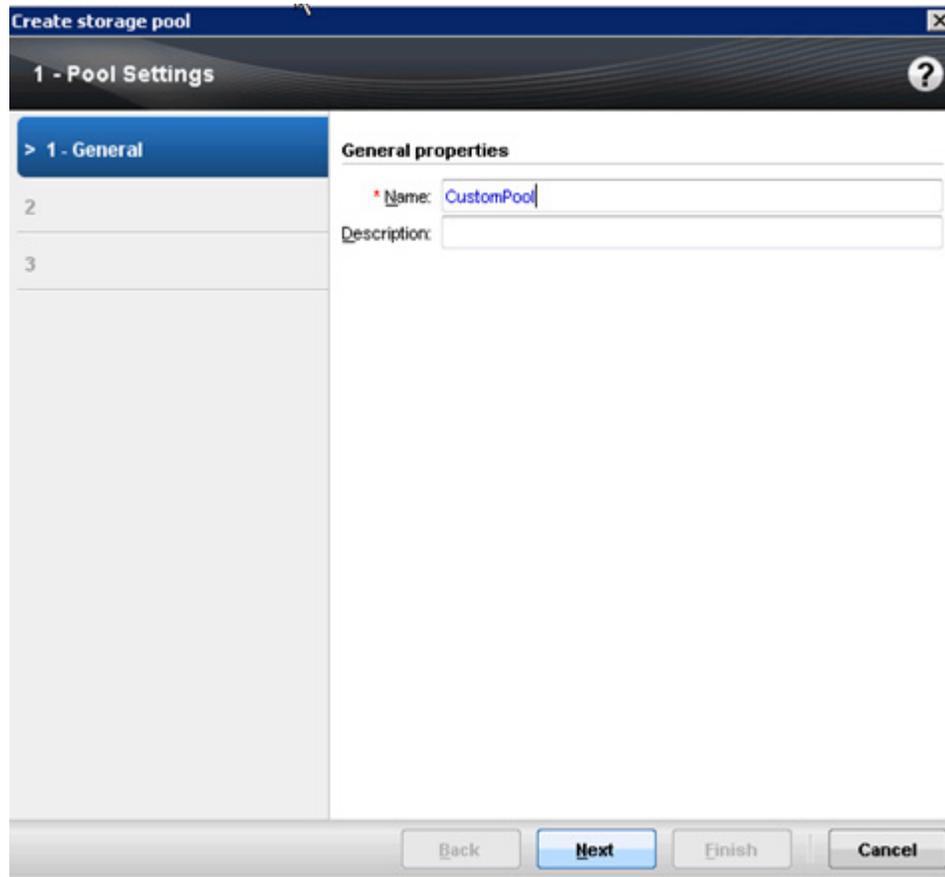
2. Enter the desired pool name as illustrated above.
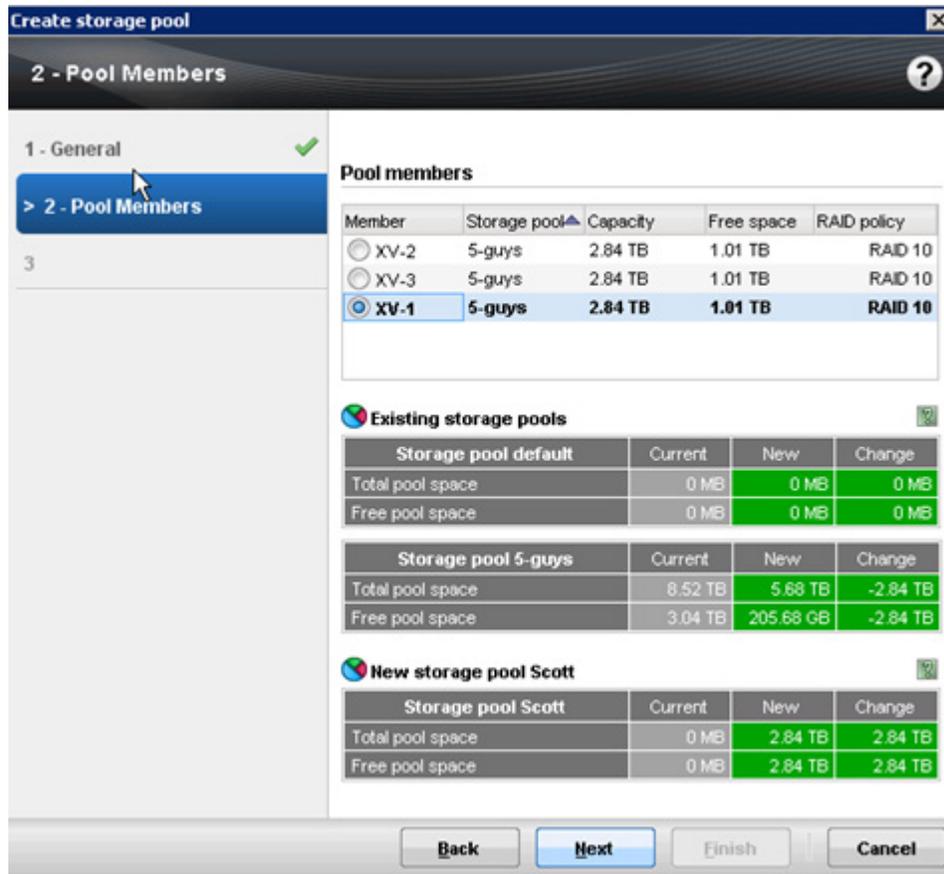
3. Select the 3 PS6210XV Array the member used for the TSC, repeating the operation for each member.

A summary screenshot of the storage pool and 3 members appears below.
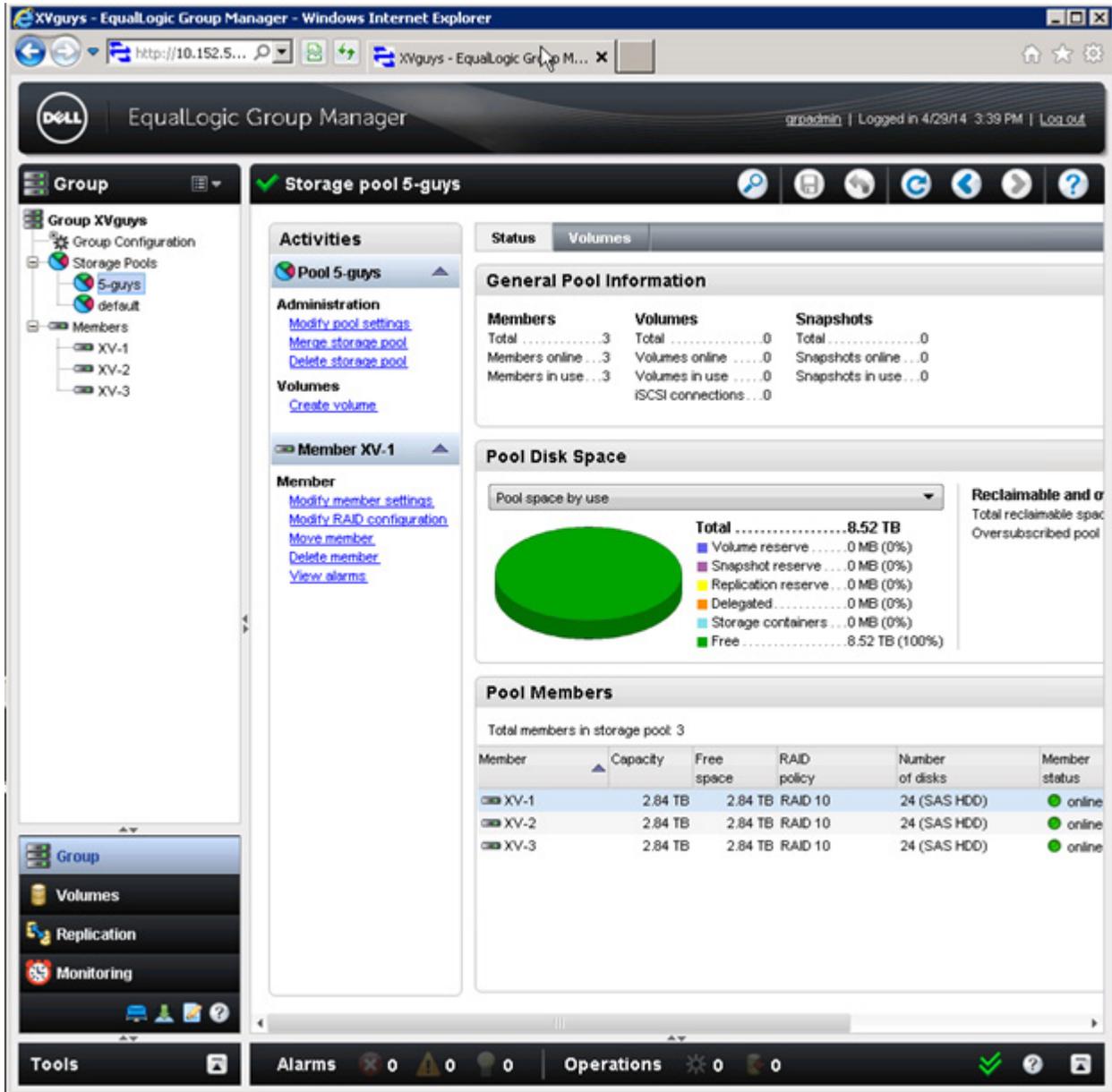
Creating SPC-1 Volumes

1. The TSC"s SPC-1 Logical Volumes are created by clicking on **Volumes**, which appears in the above summary screenshot, then right clickling on **Volumes** and then **Create volume** as illustrated below.
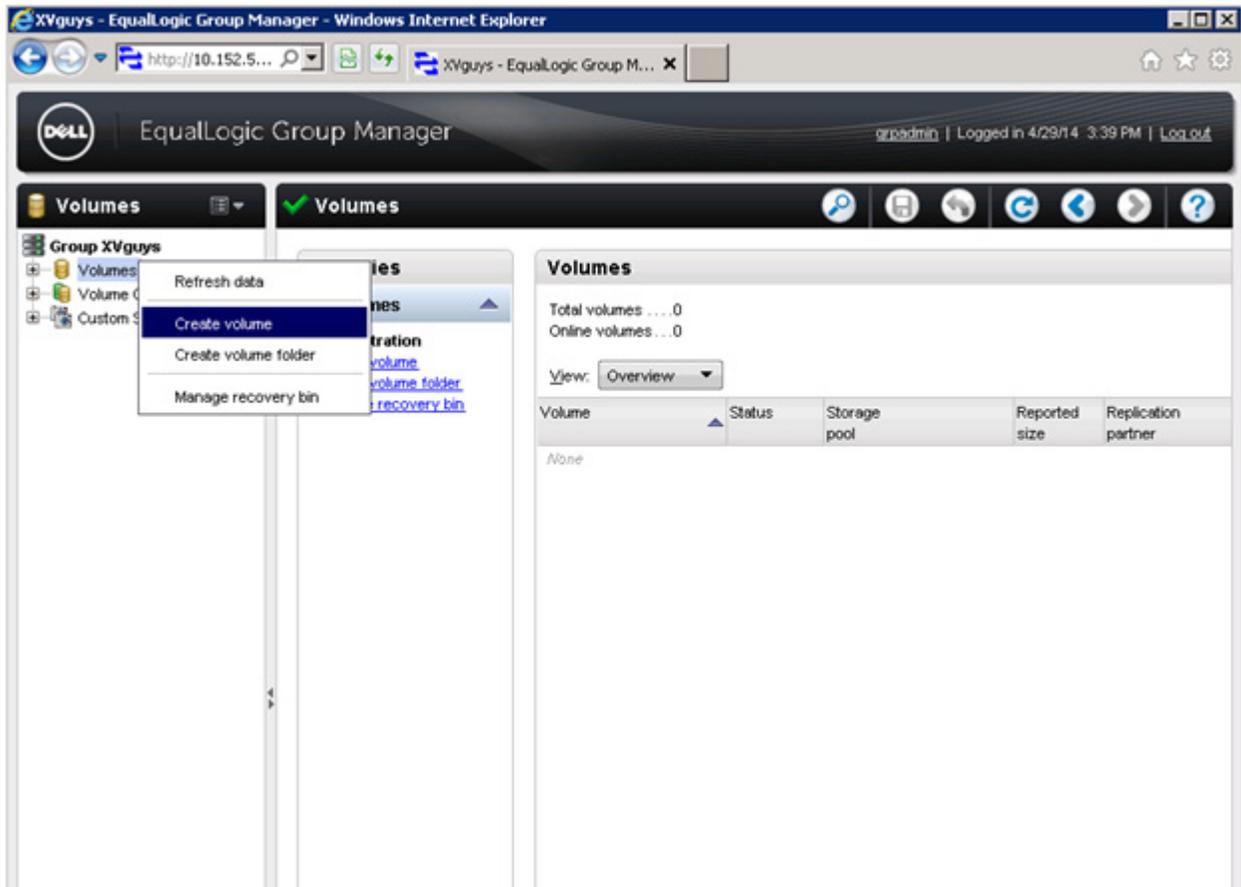

2. Name the volume **spc1**, select the previously created pool. Specify a volume capacity of 630 GB and ensure the **Thin provisioned volume** checkbox is UNCHECKED. The snapshot reserve percentage (%) should be set to zero (0). The above operations are illustrated in the following two screenshots.
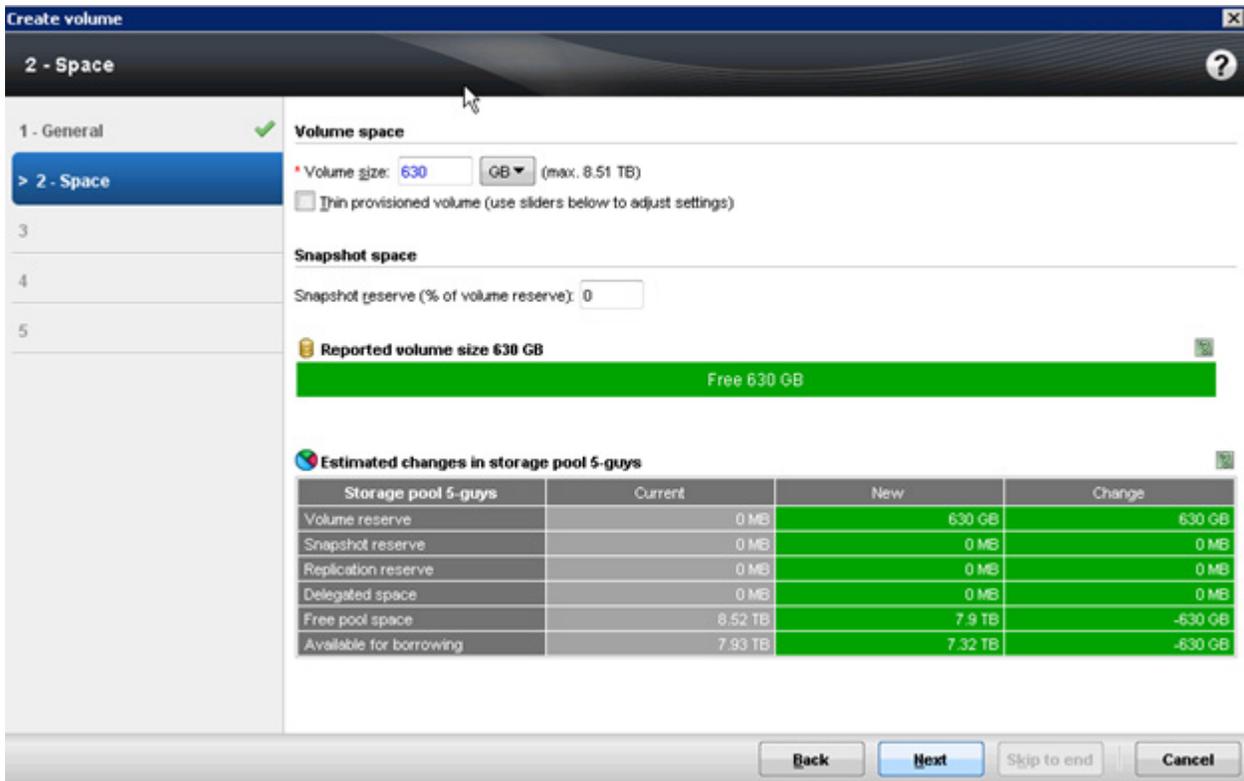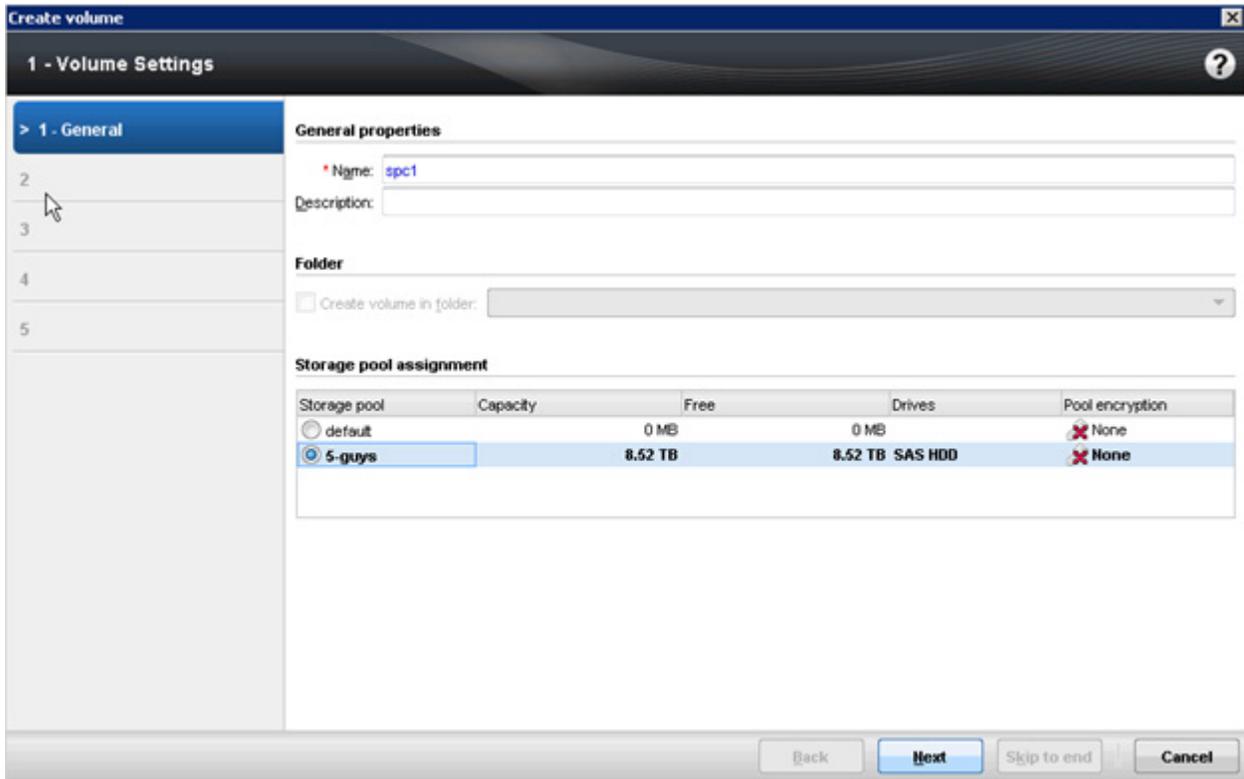
3. Select an access policy to allow public access to all the volumes for the TSC. Click **New** on the screenshot below to create a new universal access policy. Supply a name to the new universal access policy and specify "*.*.*.*" to provide access to all IP addresses. Click **OK** to return to the **Define iSCSI access points** screen. Select the new access policy, click **Add** and click **Skip to End** to create the volume, then click **Finish**. The above operations are illustrated in the next series of five screenshots.
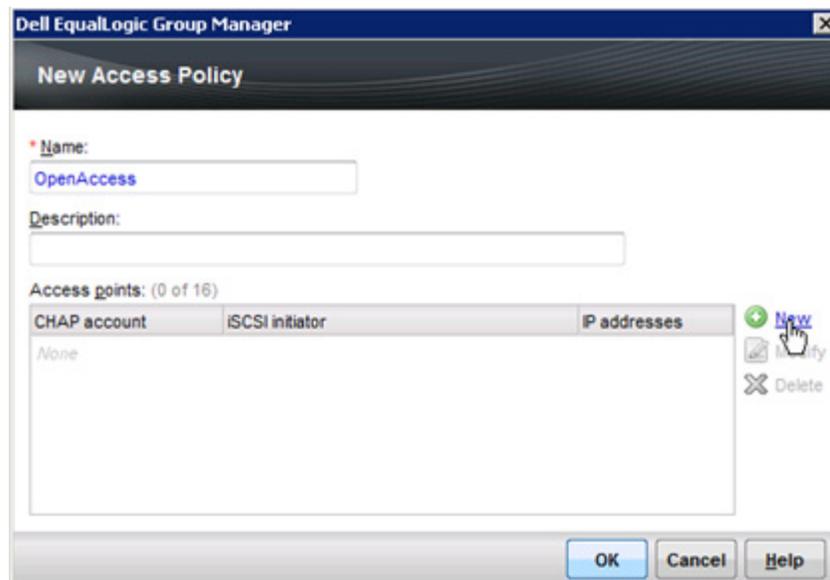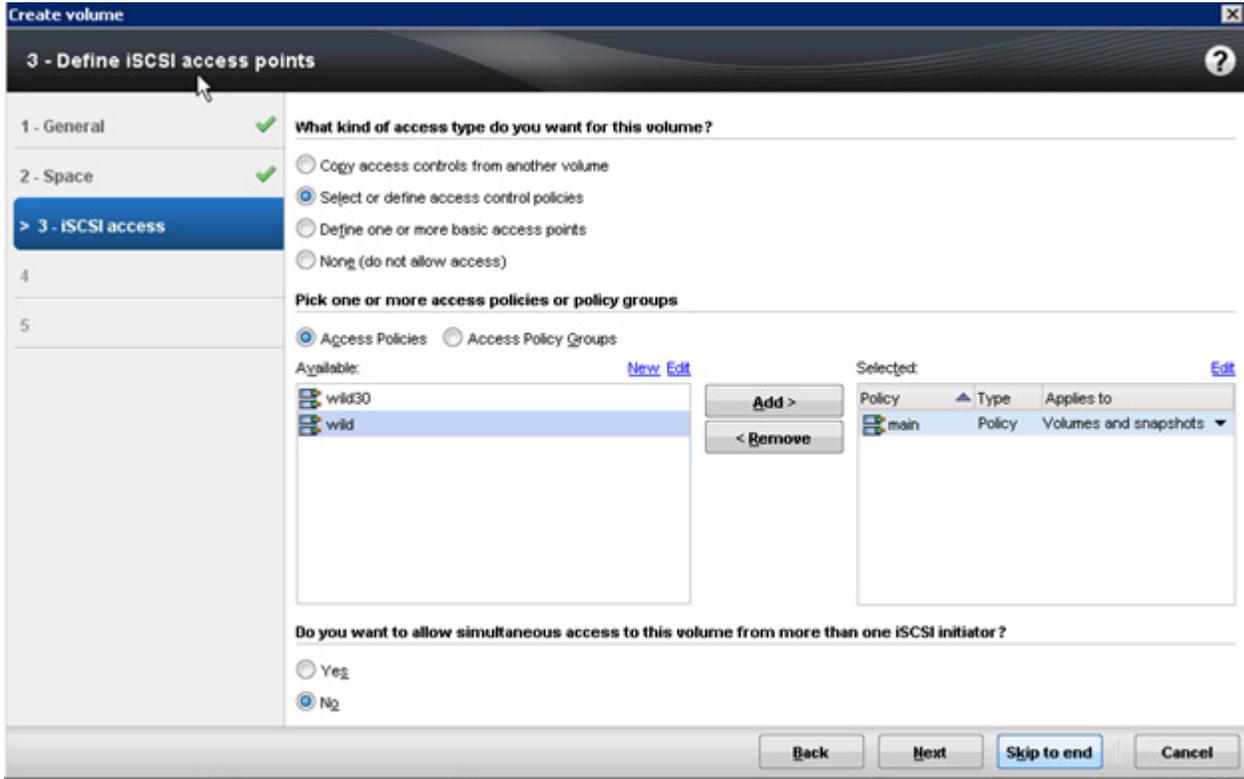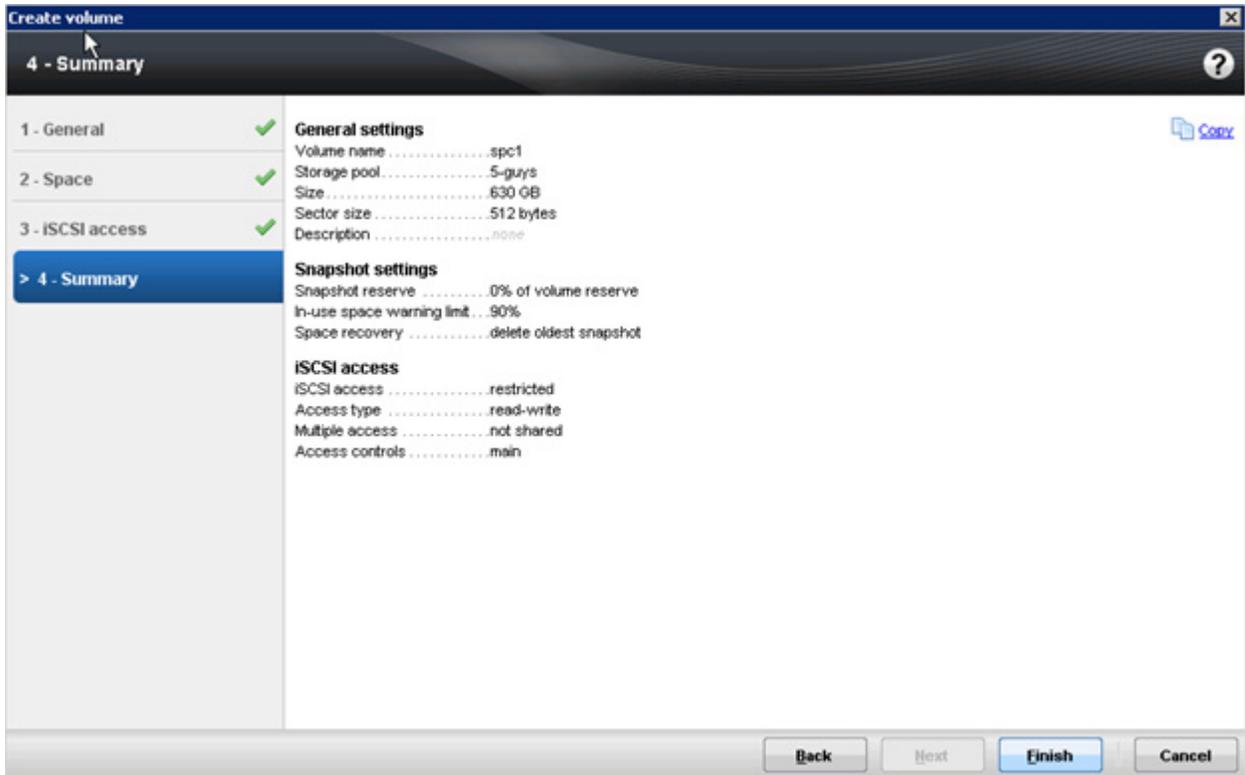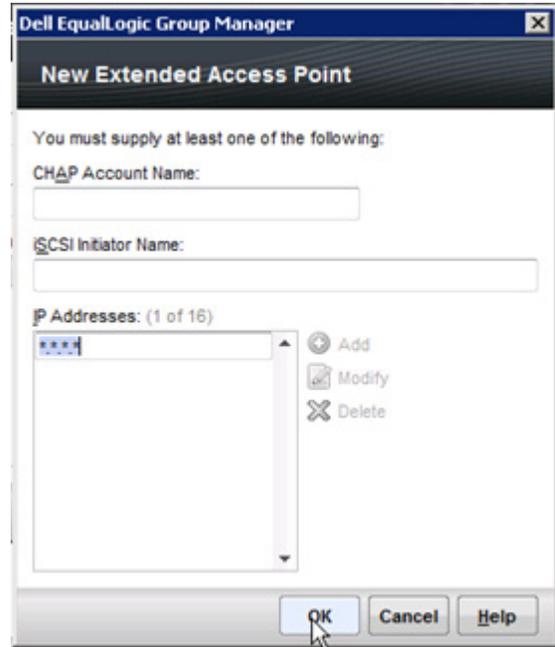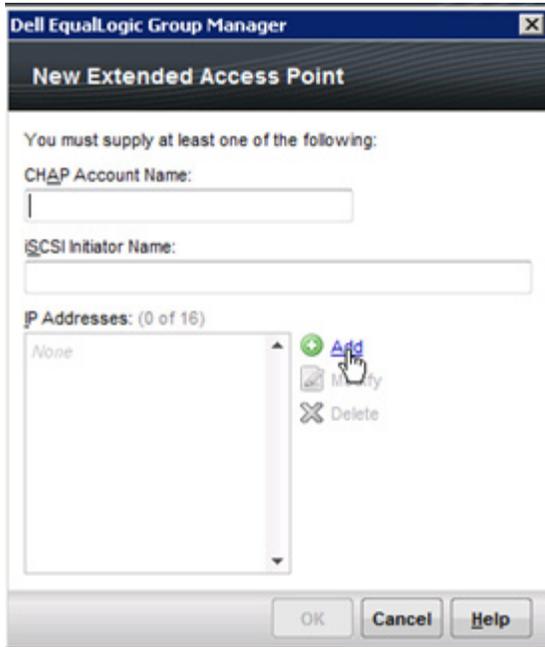
4. Clone the previous volume 7 times to create volumes **spc2** through **spc8** for ASU-1 and ASU-2. See the **Cloning a Volume** section for details of cloning a volume.

5. The capacity is different for ASU-3 volumes, so follow steps #2 and #3 above to create the two 285.04 GB volumes for **spc9** and **spc10**.

## Cloning a Volume *(logical units 2 through 10)*

1. Right click on the volume that is to be cloned and select **Clone** as illustrated below.
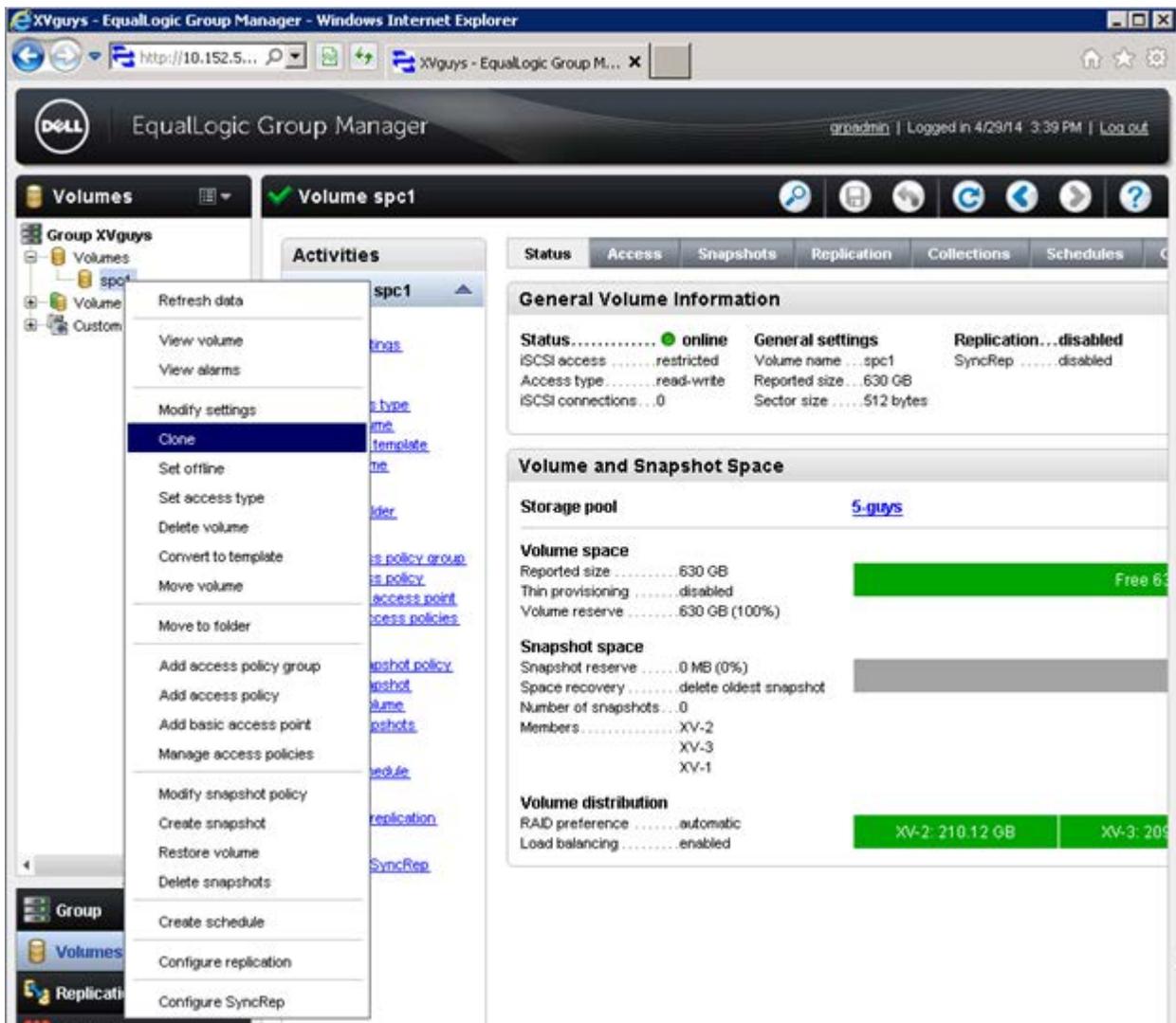
2. Enter volume name **spc2** and click **Next**. The volume size if fixed to be same as the original, so just click **Next**. Those two operations are illustrated in the two screenshots below.
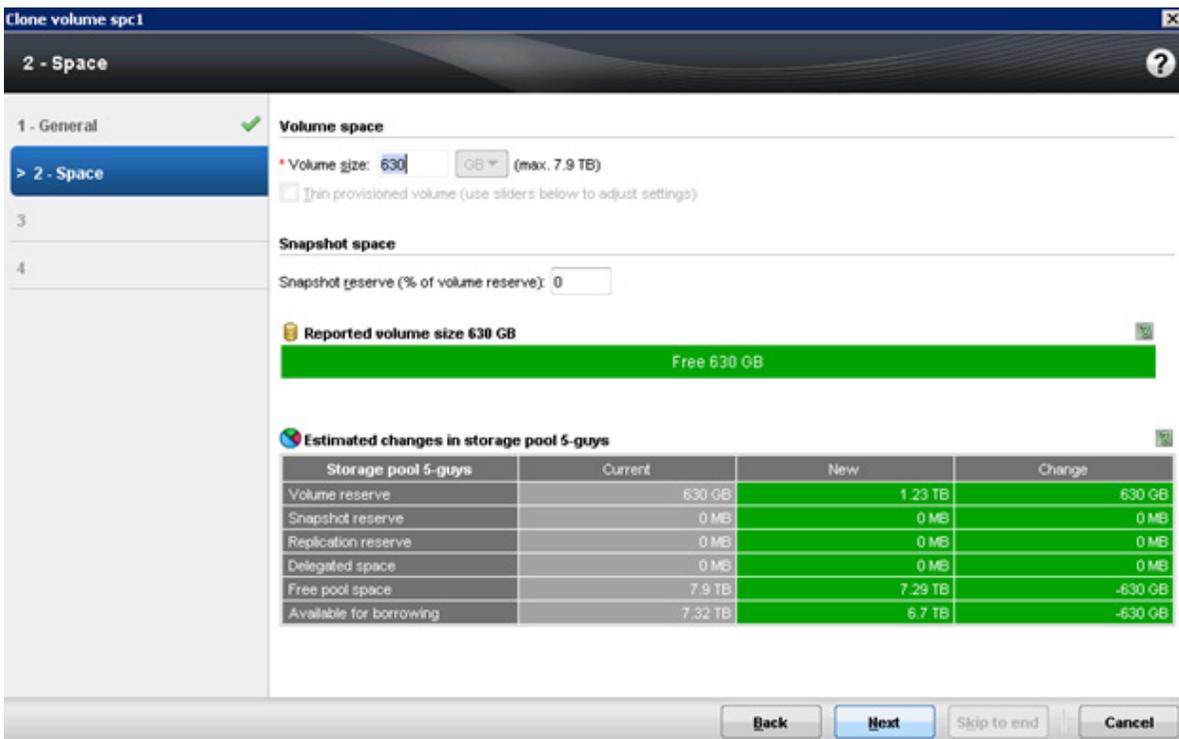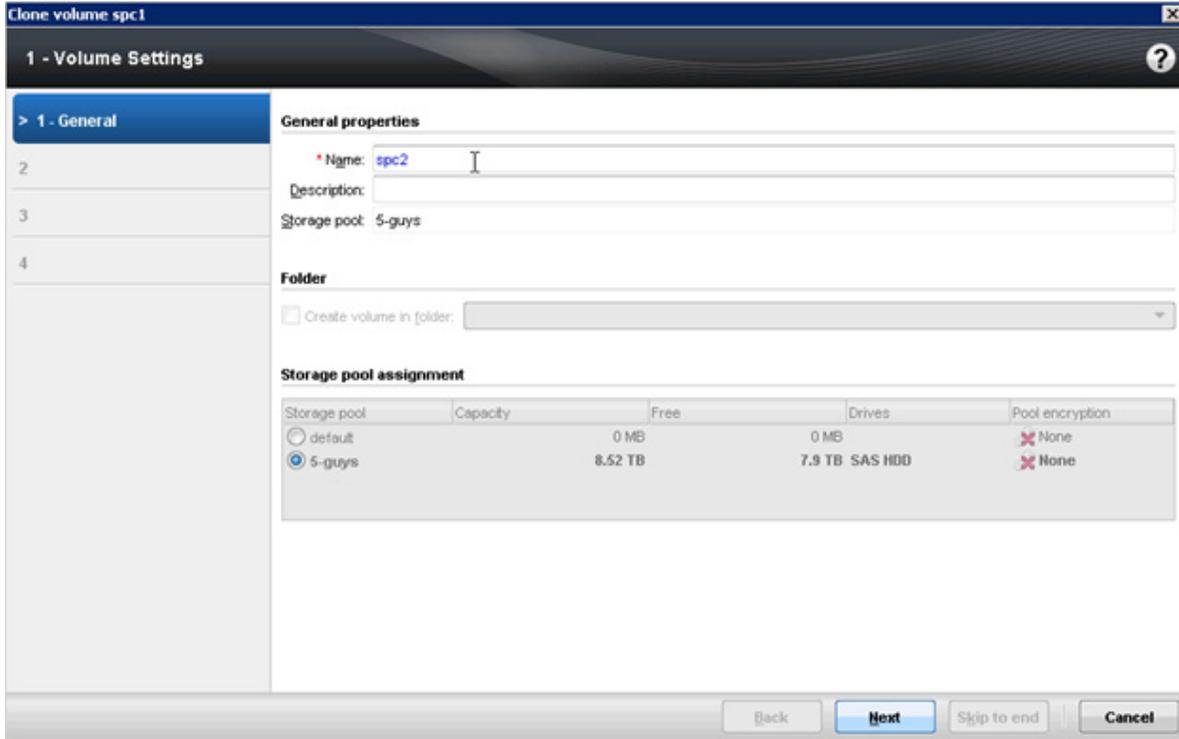
3. Select the **Copy access controls from another volume** and select **spc1** volume and
    click **Next**. At the Summary click **Finish** to create the clone. Those two operations are
    illustrated in the two screenshots below.
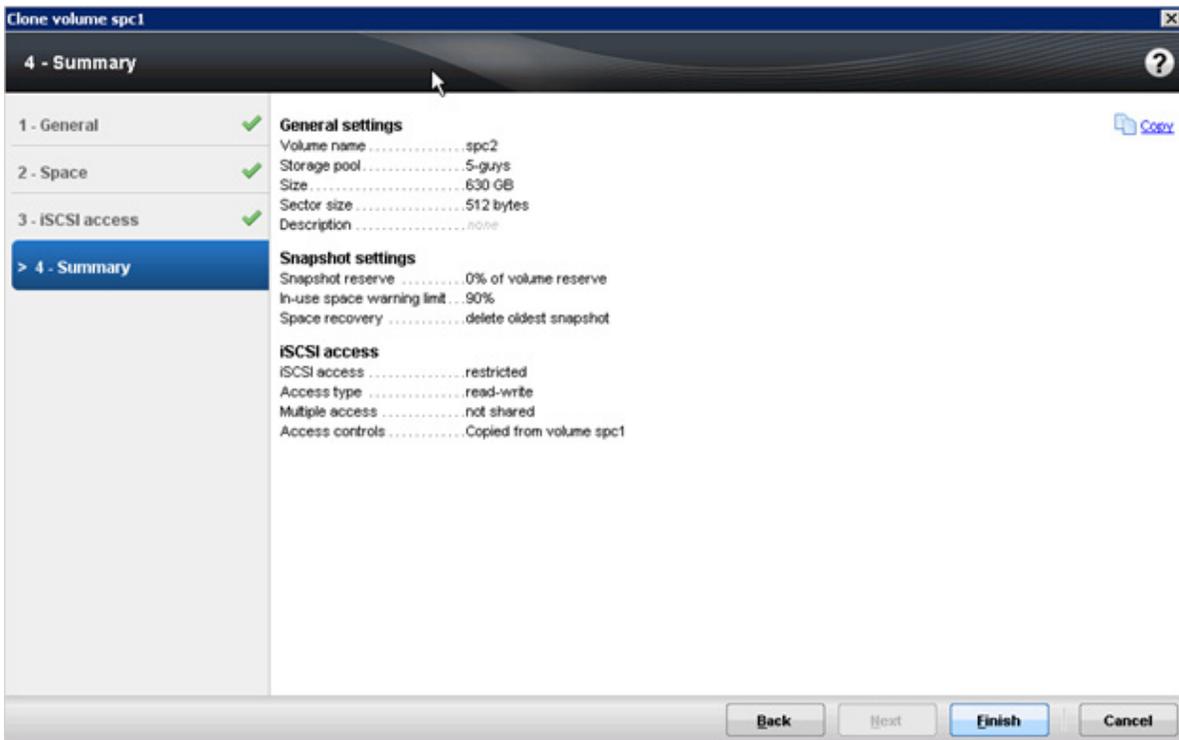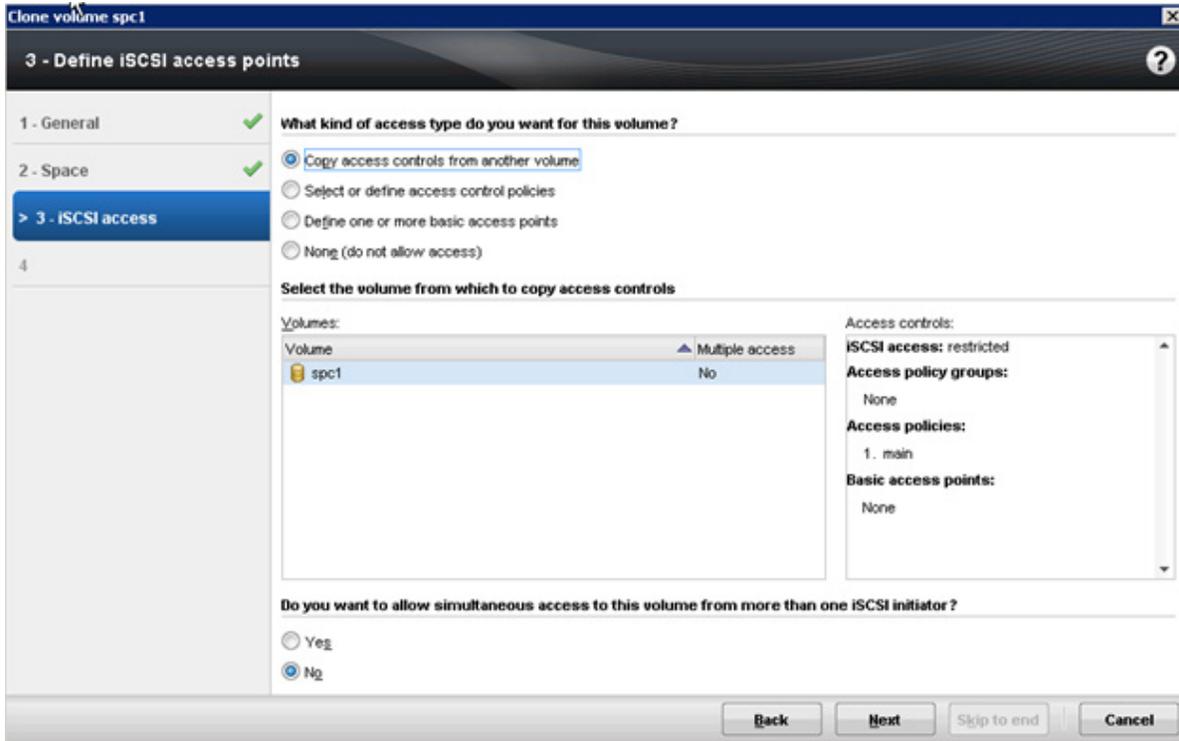
Preparing the Volumes on the single Host System

1. On the Host System, open **iSCSI Initiator Properties** window and under **Targets** tab, connect all the Inactive targets for the volumes **spc1** through **spc10.**

2. Select **Enable multi-path** and click **OK**.

The above operations are illustrated below two screen shots.
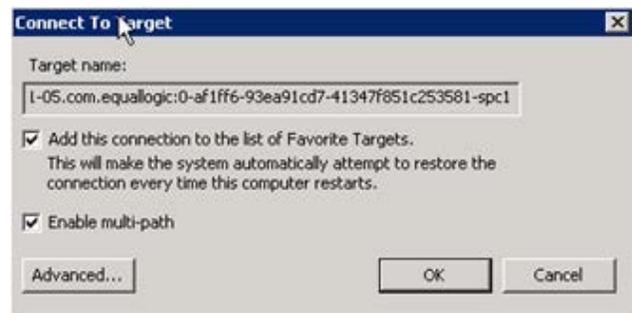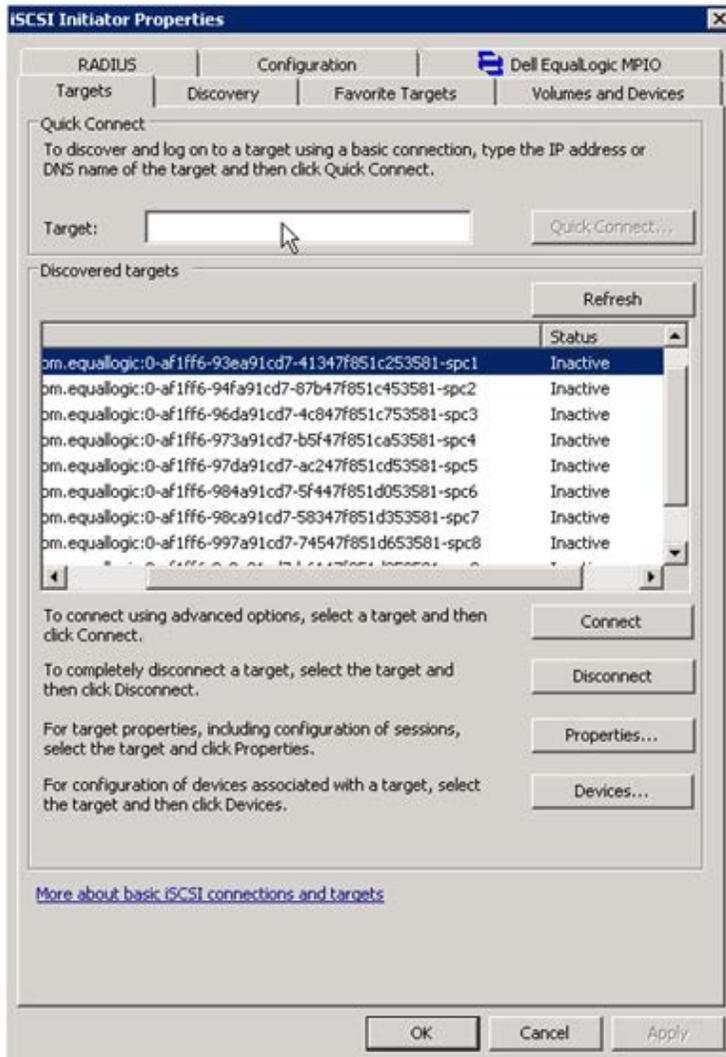
3. Use the Windows Disk Management utility to bring all the Windows "disks" online and initialized as illustrated below.

4. Reboot the Host System.

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

ASU Pre-Fill

The content of command and parameter file, used in this benchmark to execute the required ASU pre-fill, is listed below.

```
* This will produce a random data pattern of the entire LBA range using LSFR 32bit
compratio=1
*
*
* The first SPC-1/SPC-1C Logical Volume (LUN) for ASU-1
* or the first SPC-2/SPC-2C LUN for the single SPC-2/SPC-2/C ASU
*
sd=sd1,lun=\\.\PhysicalDrive1,threads=32
sd=sd2,lun=\\.\PhysicalDrive2,threads=32
sd=sd3,lun=\\.\PhysicalDrive3,threads=32
sd=sd4,lun=\\.\PhysicalDrive4,threads=32
sd=sd5,lun=\\.\PhysicalDrive5,threads=32
sd=sd6,lun=\\.\PhysicalDrive6,threads=32
sd=sd7,lun=\\.\PhysicalDrive7,threads=32
sd=sd8,lun=\\.\PhysicalDrive8,threads=32
sd=sd9,lun=\\.\PhysicalDrive9,threads=32
sd=sd10,lun=\\.\PhysicalDrive10,threads=32
wd=wd1,sd=sd1,rdpct=0,seekpct=-1,xfersize=128K
wd=wd2,sd=sd2,rdpct=0,seekpct=-1,xfersize=128K
wd=wd3,sd=sd3,rdpct=0,seekpct=-1,xfersize=128K
wd=wd4,sd=sd4,rdpct=0,seekpct=-1,xfersize=128K
wd=wd5,sd=sd5,rdpct=0,seekpct=-1,xfersize=128K
wd=wd6,sd=sd6,rdpct=0,seekpct=-1,xfersize=128K
wd=wd7,sd=sd7,rdpct=0,seekpct=-1,xfersize=128K
wd=wd8,sd=sd8,rdpct=0,seekpct=-1,xfersize=128K
wd=wd9,sd=sd9,rdpct=0,seekpct=-1,xfersize=128K
wd=wd10,sd=sd10,rdpct=0,seekpct=-1,xfersize=128K

*
* Repeat the above until all of the LUNs for all the ASUs have been specified.
* Use the same "lun=" entry as used in the SPC-1/SPC-1C/SPC-2/SPC-2C configuration
file.
*

rd=asu_prefill,wd=wd*,iorate=max,elapsed=50000,interval=10
*
* The above "elapsed=36000" may have to be increased to ensure
* that the pre-fill will reach the end of the LUN ("seek=-1")
* prior to the end of the specified elapsed time
```

Primary Metrics, Repeatability and SPC-1 Persistence Tests

The content of SPC-1 Workload Generator command and parameter file used in this benchmark to execute the Primary Metrics *(Sustainability Test Phase, IOPS Test Phase, and Response Time Ramp Test Phase)*, Repeatability *(Repeatability Test Phase 1 and Repeatability Test Phase 2)*, and SPC-1 Persistence Tests is listed below.

```
sd=asu1_1,lun=\\.\PHYSICALDRIVE1
sd=asu1_2,lun=\\.\PHYSICALDRIVE2
sd=asu1_3,lun=\\.\PHYSICALDRIVE3
sd=asu1_4,lun=\\.\PHYSICALDRIVE4
sd=asu2_1,lun=\\.\PHYSICALDRIVE5
sd=asu2_2,lun=\\.\PHYSICALDRIVE6
sd=asu2_3,lun=\\.\PHYSICALDRIVE7
sd=asu2_4,lun=\\.\PHYSICALDRIVE8
sd=asu3_1,lun=\\.\PHYSICALDRIVE9
sd=asu3_2,lun=\\.\PHYSICALDRIVE10
```

APPENDIX E: SPC-1 WORKLOAD GENERATOR INPUT PARAMETERS

The following script calls the standard **vdbench.bat** script to execute the required ASU pre-fill and upon completion of that first step, invoke the commands to execute the Primary Metrics Test *(Sustainability Test Phase, IOPS Test Phase, and Response Time Ramp Test Phase)*, the Repeatability Test *(Repeatability Test Phase 1 and Repeatability Test Phase 2)*, and SPC-1 Persistence Test Run 1 *(write phase)* in an uninterrupted sequence.

```
call C:\spc\spcPrefill\SPC_ASU-Prefill\503RC11\vdbench503rc11\vdbench.bat -f
C:\spc\spcPrefill\SPC_ASU-Prefill\503RC11\vdbench503rc11\prefill.parm -o
503BSUPreFill-%time:~0,2%.%time:~3,2%
C:\java7u5164\bin\java.exe metrics -b 503 -s 3000:180 -t 28800
C:\java7u5164\bin\java.exe repeat1 -b 503
C:\java7u5164\bin\java.exe repeat2 -b 503
C:\java7u5164\bin\java.exe persist1 -b 503
```

SPC-1 Persistence Test Run 2

The following script is executed to invoke the SPC-1 Persistence Test Run 2 *(read phase)* after completion of the required TSC power off/power on cycle.

```
C:\java7u5164\bin\java.exe persist2
```