SPC BENCHMARK 1/ENERGY™ FULL DISCLOSURE REPORT

IBM CORPORATION
IBM FLASHSYSTEM® 900

SPC-1/E V1.14

Submitted for Review: October 30, 2015
Submission Identifier: AE00008
Revised: November 16, 2015

First Edition – October 2015

Trademarks

Table of Contents

AUDIT CERTIFICATION

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

November 16, 2015

The SPC Benchmark 1/Energy™ Reported Data listed below for the IBM FlashSystem® 900 was produced in compliance with the SPC Benchmark 1/Energy™ v1.14 Remote Audit requirements.

SPC Benchmark 1/Energy™ v1.14 Reported Data	
Tested Storage Product (TSP) Name: IBM FlashSystem® 900	
Metric	**Reported Result**
SPC-1 IOPS™	440,011.00
SPC-1 Price-Performance	$1.61/SPC-1 IOPS™
Total ASU Capacity	34,39.738 GB
Data Protection Level	Protected 1 *(RAID-5)*
Total Price (including three-year maintenance)	$708,701.76
Currency Used	U.S. Dollars
Target Country for availability, sales and support	USA

Power Environment

Average RMS Voltage: 207.34 **Average Power Factor:** 0.977

Usage Profile

	Hours of Use per Day			Nominal	Nominal	Nominal	Nominal
	Heavy	Moderate	Idle	Power, W	Traffic, IOPS	IOPS/W	Heat, BTU/hr
Low Daily Usage:	0	8	16	790.10	73325.65	92.80	2,695.92
Medium Daily Usage:	4	14	6	817.79	186983.13	228.64	2,790.38
High Daily Usage:	18	6	0	850.12	318978.86	375.22	2,900.69
			Composite Metrics:	819.34	193,095.88	235.67	

Annual Energy Use, kWh: 7,177.39
Energy Cost, $/kWh: $ 0.12 **Annual Energy Cost, $:** $ 861.29

Storage Performance Council
643 Bair Island Road, Suite 103
Redwood City, CA 94062
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AUDIT CERTIFICATION *(CONT.)*

IBM FlashSystem® 900
SPC-1/E Audit Certification

Page 2

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

- A Letter of Good Faith, signed by a senior executive.
- The following Data Repository storage items were verified by visual inspection and 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.
- 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).
- Visual 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 visual inspection and 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 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 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:
  - ✓ Idle Test
    - Conditioning Phase
    - Application Idle Phase
    - Recovery Phase
  - ✓ Primary Metrics Test:
    - Sustainability Test Phase
    - IOPS Test Phase
    - Response Time Ramp Test Phase
  - ✓ Repeatability Test
  - ✓ Data Persistence Test
- The Yokogawa WT1800 Digital Power Meter, used to record power consumption, was verified as an SPC approved "Power Extension apparatus" with a current calibration certificate.

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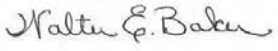
AUDIT CERTIFICATION *(CONT.)*

- All power supplies present in the Tested Storage Configuration were verified as active
- IBM Corporation provided documentation of the following:
  - ✓ Voltage *(220)*, amperage *(30)*, and phase characteristics *(single)* of the AC inputs used for powering the Tested Storage Configuration.
  - ✓ The configured power supplies were configured for mutual failover.
- Concurrent power measurements were taken at each active AC input so that the total power requirement of the Tested Storage Configuration was recorded.
- The ambient temperature was recorded at the following times in near proximity to the Tested Storage configuration with a precision of at least ±0.1°C:
  - ✓ During the first one minute of the Idle Test *(Initial Energy Extension temperature)*.
  - ✓ During the last one minute of the Primary Metrics Test *(Final Energy Extension temperature)*.
- The Benchmark Configuration/Tested Storage Configuration diagram included the electrical metering, which illustrates the measurement apparatus used and the relationship between the active AC inputs and the associated measurement apparatus inputs.
- 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
SPC Auditor

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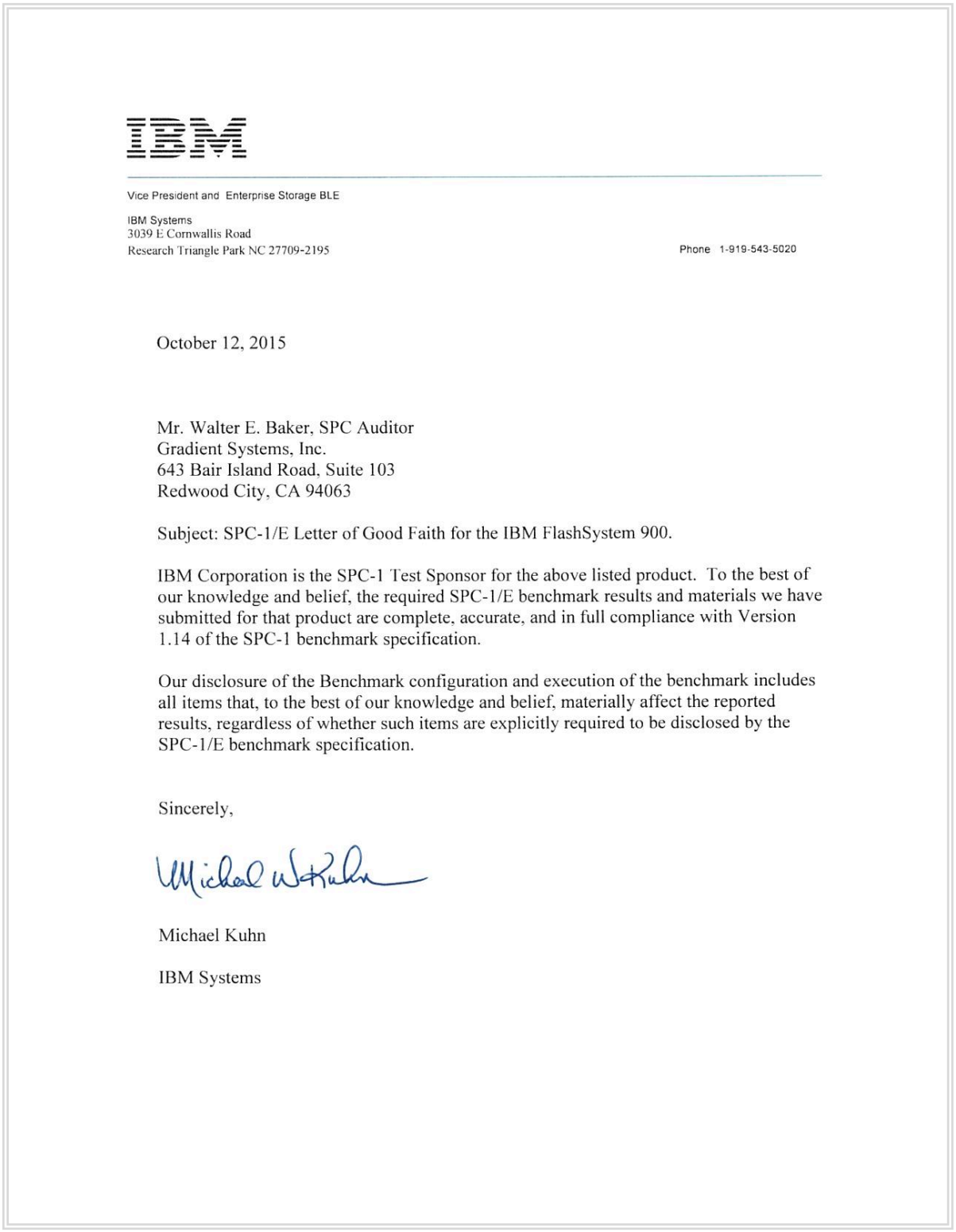
LETTER OF GOOD FAITH



IBM

Vice President and Enterprise Storage BLE

IBM Systems
3039 E Cornwallis Road
Research Triangle Park NC 27709-2195

Phone 1-919-543-5020

October 12, 2015

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

Subject: SPC-1/E Letter of Good Faith for the IBM FlashSystem 900.

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/E benchmark results and materials we have submitted for that product are complete, accurate, and in full compliance with Version 1.14 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/E benchmark specification.

Sincerely,

Michael Kuhn

IBM Systems

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 IBM ARC 650 Harry Road San Jose, CA 95120 Phone: (408) 927-2717 FAX: (408) 927-2050
Test Sponsor Alternate Contact	IBM Corporation – http://www.ibm.com Andrew Lin – awlin@us.ibm.com 9000 Rita Road IBM Mail Drop 9042-2 Tucson, AZ 85744 Phone: (520) 799-2358 FAX: (520)799-2009
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	V1.14
SPC-1 Workload Generator revision number	V2.3.0
Date Results were first used publicly	October 30, 2015
Date the FDR was submitted to the SPC	October 30, 2015
Date the revised FDR was submitted to the SPC Revised pricing *(page 25)* resulting in revised SPC-1 Price-Performance.*(page 13)* Revisions highlighted in red. Revised Audit Certification letter to reflect the pricing revisions. **Revision History** 16 November 2015 – reised pricing as described above	16 November 2015
Date the Priced Storage Configuration is available for shipment to customers	currently available
Date the TSC completed audit certification	October 29, 2015

Tested Storage Product (TSP) Description

IBM FlashSystem 900 is designed to deliver high performance, efficiency, and reliability for shared enterprise storage environments, helping clients around the world address performance issues with their most critical applications and infrastructure. FlashSystem 900 may be used as data storage for important applications that need high performance and low latency. Such applications include databases supporting line of business applications, as well as virtualization platforms such as virtual servers and VDI. FlashSystem 900 can also be used as the top tier of storage alongside traditional arrays in tiered storage architectures, such as the IBM Easy Tier functionality available in IBM System Storage SAN Volume Controller and Storwize® V7000 storage virtualization platforms.

Summary of Results

SPC-1 Reported Data	
Tested Storage Product (TSP) Name: IBM FlashSystem® 900	
Metric	**Reported Result**
SPC-1 IOPS™	440,011.00
SPC-1 Price-Performance™	**$1.61**/SPC-1 IOPS™
Total ASU Capacity	34,359.738 GB
Data Protection Level	Protected 1 *(RAID-5)*
Total Price	**$708,701.76**
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 1** using ***RAID-5***, which distributes check data corresponding to user data across multiple disks in the form of bit-by-bit parity.

> ***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.*

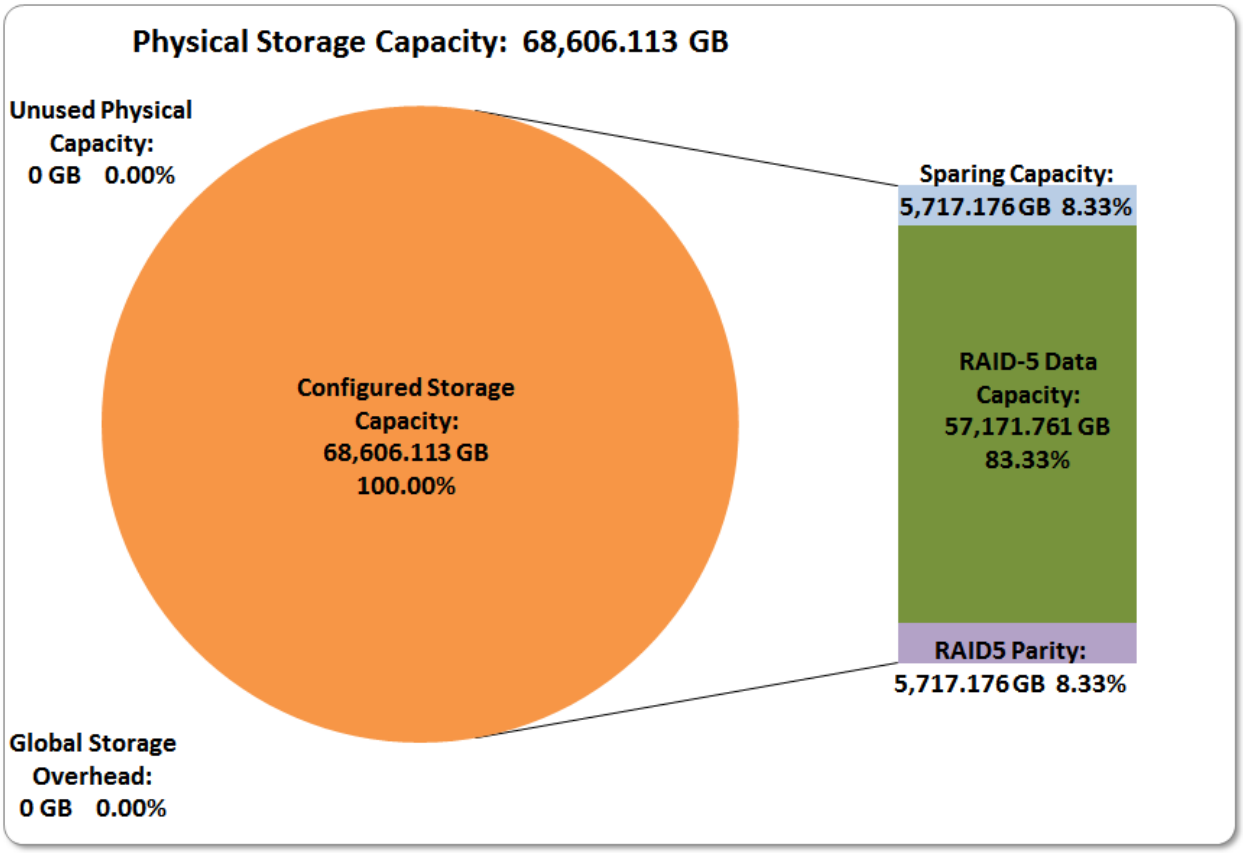
Total Price includes the cost of the Priced Storage Configuration plus three years of hardware maintenance and software support as detailed on page 25.

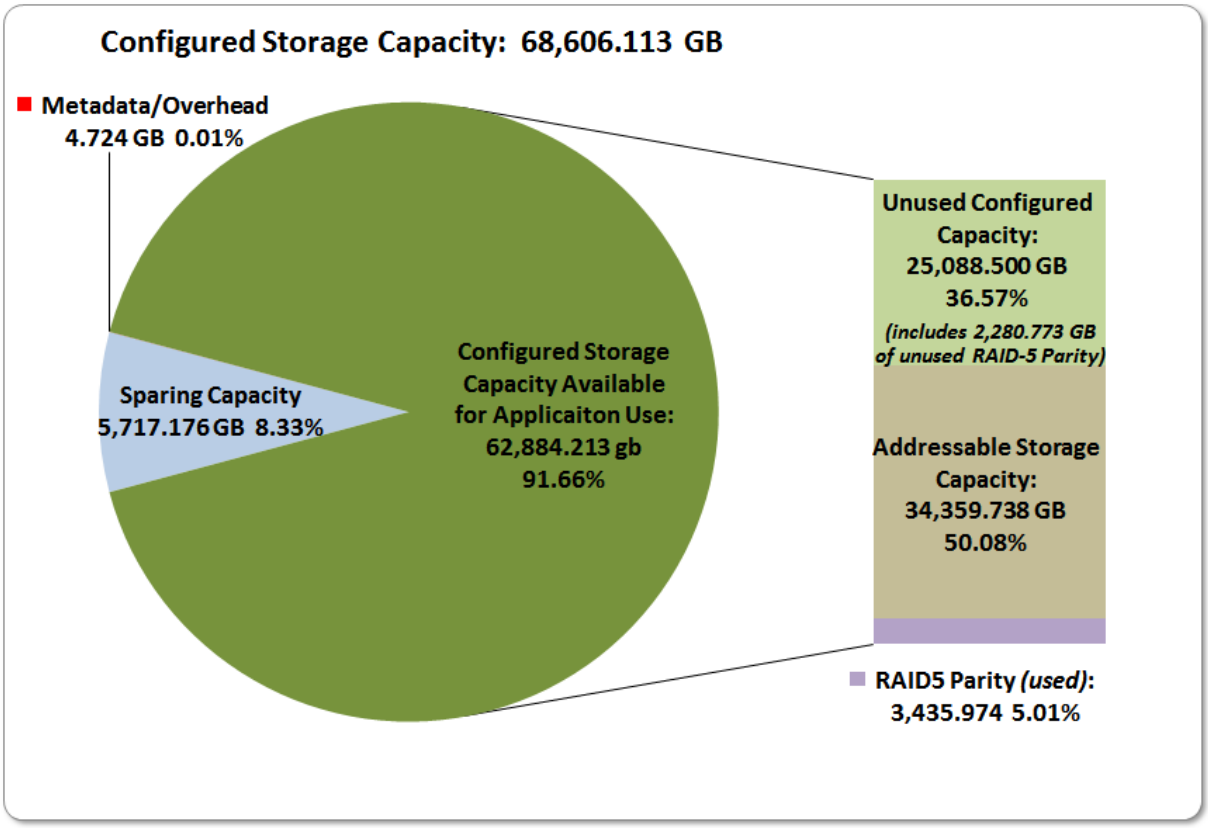
Currency Used is formal name for the currency used in calculating the **Total Price** and **SPC-1 Price-Performance™**. That currency may be the local currency of the **Target Country** or the currency of a difference country *(non-local currency)*.

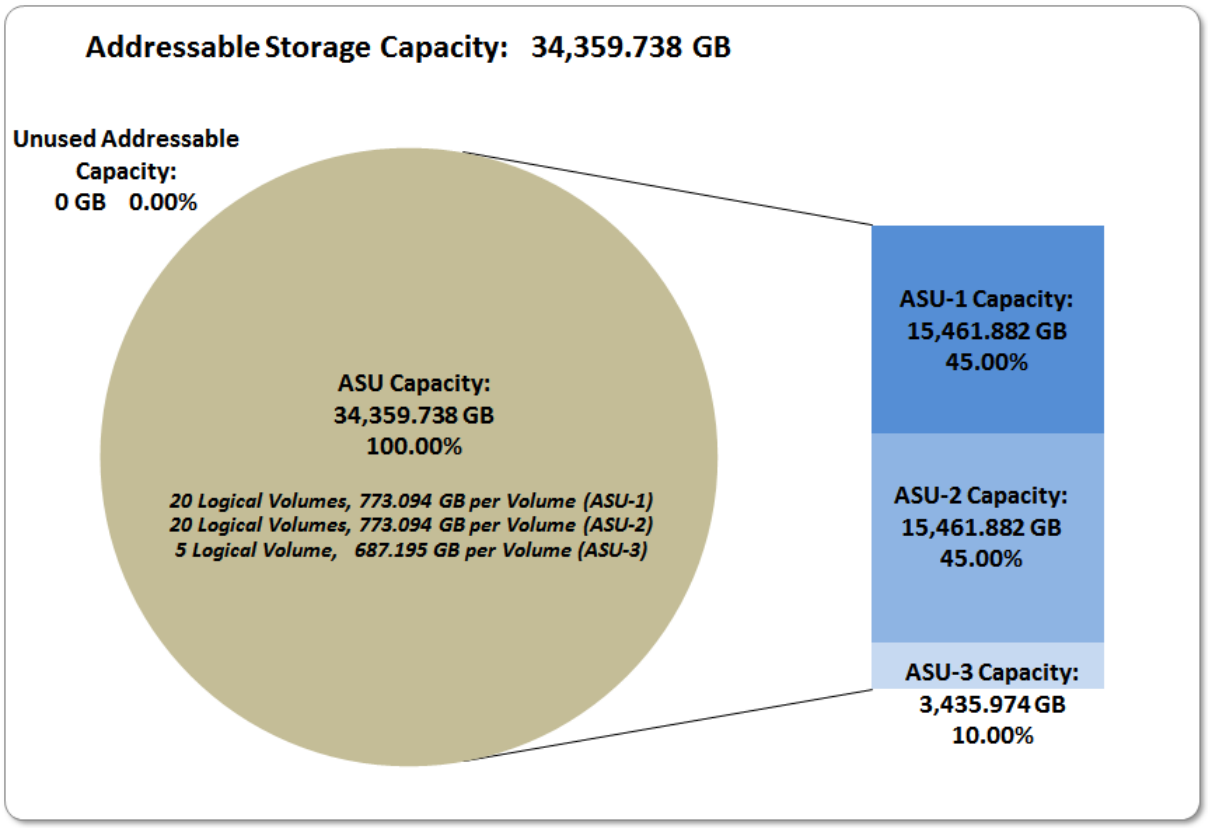
The **Target Country** is the country in which the Priced Storage Configuration is available for sale and in which the required hardware maintenance and software support is provided either directly from the Test Sponsor or indirectly via a third-party supplier.

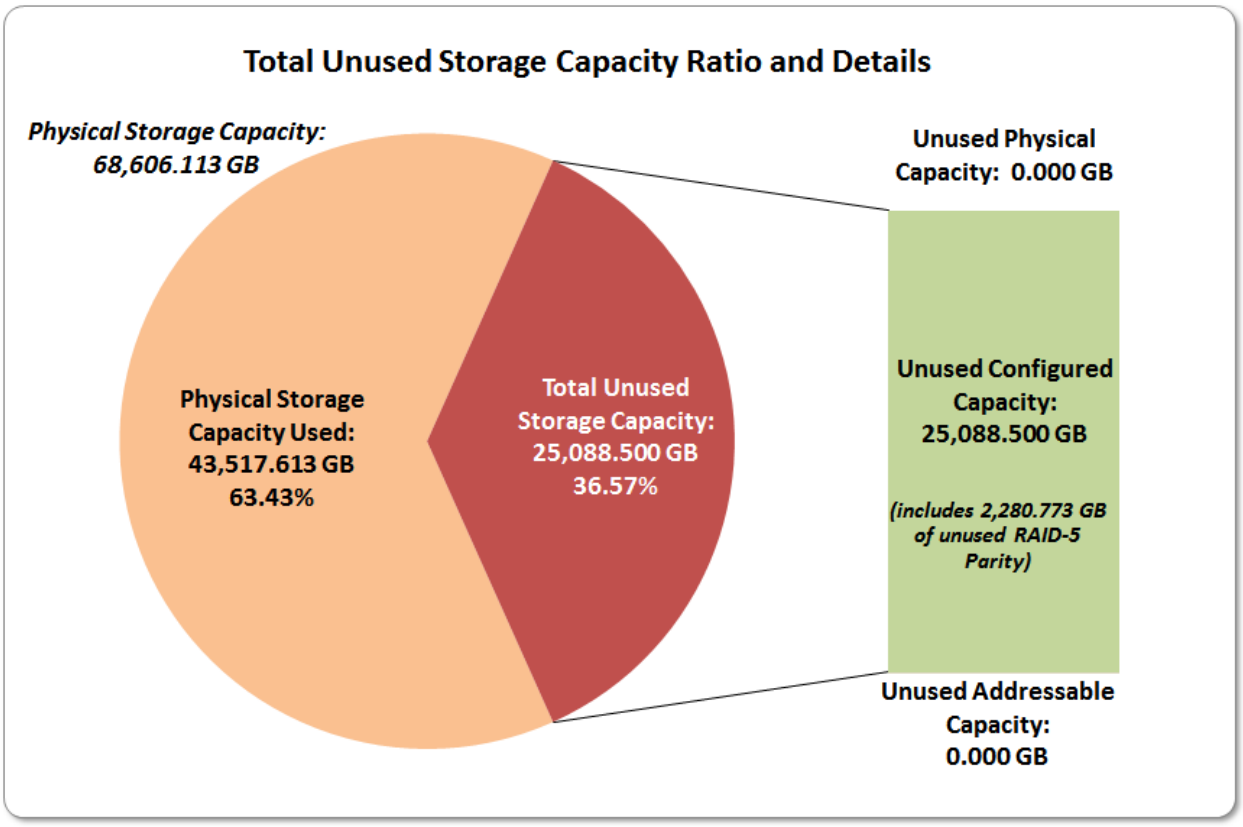
Storage Capacities, Relationships, and Utilization

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.




Configured Storage Capacity: 68,606.113 GB
Metadata/Overhead
4.724 GB 0.01%
Sparing Capacity
5,717.176 GB 8.33%
Configured Storage Capacity Available for Applicaiton Use:
62,884.213 gb
91.66%
Unused Configured Capacity:
25,088.500 GB
36.57%
(includes 2,280.773 GB of unused RAID-5 Parity)
Addressable Storage Capacity:
34,359.738 GB
50.08%
RAID5 Parity (used):
3,435.974 5.01%


Addressable Storage Capacity: 34,359.738 GB
Unused Addressable Capacity:
0 GB 0.00%
ASU Capacity:
34,359.738 GB
100.00%
20 Logical Volumes, 773.094 GB per Volume (ASU-1)
20 Logical Volumes, 773.094 GB per Volume (ASU-2)
5 Logical Volume, 687.195 GB per Volume (ASU-3)
ASU-1 Capacity:
15,461.882 GB
45.00%
ASU-2 Capacity:
15,461.882 GB
45.00%
ASU-3 Capacity:
3,435.974 GB
10.00%



SPC-1 Storage Capacity Utilization	
Application Utilization	50.08%
Protected Application Utilization	55.09%
Unused Storage Ratio	36.57%

Application Utilization: Total ASU Capacity *(34,359.738 GB)* divided by Physical Storage Capacity *(68,606.113 GB)*.

Protected Application Utilization: (Total ASU Capacity *(34,359.738 GB)* plus total Data Protection Capacity *(5,717.176 GB)* minus unused Data Protection Capacity *(2,280.773 GB)*) divided by Physical Storage Capacity *(68,606.113 GB)*.

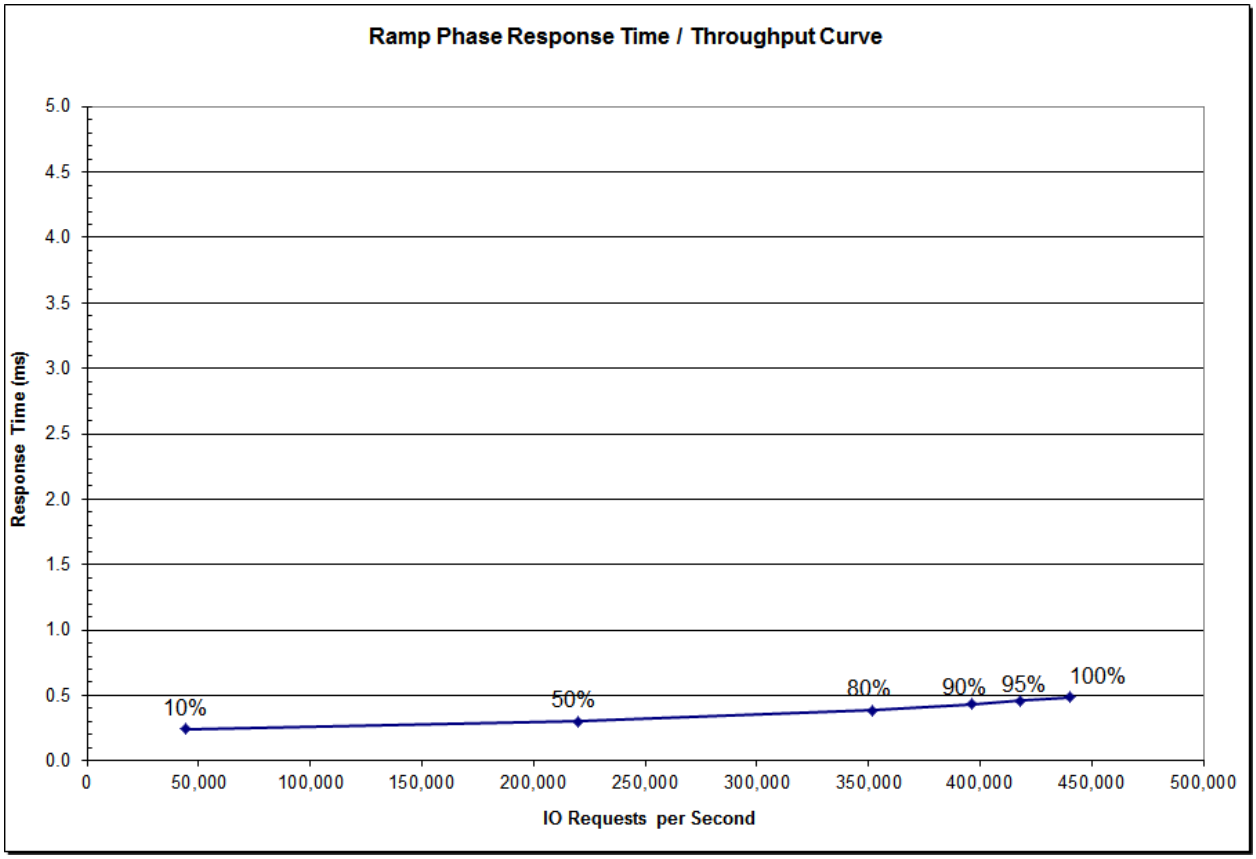
Unused Storage Ratio: Total Unused Capacity *(25,088.500 GB)* divided by Physical Storage Capacity *(68,606.113 GB)* and may not exceed 45%.

Detailed information for the various storage capacities and utilizations is available on pages 32-33.

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	43,986.34	219,976.95	351,979.49	395,987.29	417,979.06	440,011.00
Average Response Time (ms):						
All ASUs	0.24	0.30	0.39	0.43	0.46	0.49
ASU-1	0.26	0.33	0.42	0.47	0.49	0.52
ASU-2	0.26	0.34	0.43	0.48	0.51	0.54
ASU-3	0.20	0.23	0.29	0.34	0.36	0.38
Reads	0.33	0.44	0.57	0.63	0.66	0.69
Writes	0.18	0.21	0.27	0.31	0.33	0.35

SPC-1/E Reported Data

The initial SPC-1/E energy extension temperature, recorded during the first one minute of the Idle Test was 64F. The final SPC-1/E energy extension temperature, recorded during the last one minute of the Primary Metrics Test was 64F.

Power Environment

Average RMS Voltage:	**207.34**	**Average Power Factor:**	**0.977**

Usage Profile

	Hours of Use per Day			Nominal	Nominal	Nominal	Nominal
	Heavy	Moderate	Idle	Power, W	Traffic, IOPS	IOPS/W	Heat, BTU/hr
Low Daily Usage:	0	8	16	**790.10**	**73325.65**	**92.80**	**2,695.92**
Medium Daily Usage:	4	14	6	**817.79**	**186983.13**	**228.64**	**2,790.38**
High Daily Usage:	18	6	0	**850.12**	**318978.86**	**375.22**	**2,900.69**
			Composite Metrics:	**819.34**	**193,095.88**	**235.67**	

Annual Energy Use, kWh:	**7,177.39**		
Energy Cost, $/kWh:	$ 0.12	**Annual Energy Cost, $:**	**$ 861.29**

The above usage profile describes conditions in environments that respectively impose light ("low"), moderate ("medium"), and extensive ("high") demands on the Tested Storage Configuration (TSC).

HEAVY SPC-1 Workload: 858.25W at 80% of maximum reported performance *(351,979.49 SPC-1 IOPS)*.

MODERATE SPC-1 Workload: 825.73W at 50% of maximum reported performance *(219,976.95 SPC-1 IOPS)*.

IDLE SPC-1 Workload: 772.29W at 0% of maximum reported performance *(0.00 SPC-1 IOPS)*.

AVERAGE RMS VOLTAGE: The average supply voltage applied to the Tested Storage Product (TSP) as measured during the Measurement Intervals of the SPC-1/E Tests.

AVERAGE POWER FACTOR: The ratio of average real power, in watts, to the average apparent power, in volt-amps flowing into the Tested Storage Product (TSP) during the Measurement Intervals of the SPC-1/E Tests.

NOMINAL POWER, W: The average power consumption over the course of a day *(24 hours)*, taking into account hourly load variations.

NOMINAL TRAFFIC, IOPS: The average level of I/O requests over the course of a day *(24 hours)*, taking into account hourly load variations.

NOMINAL IOPS/W: The overall efficiency with which I/O requests can be supported, reflected by the ratio of **NOMINAL TRAFFIC** versus the **NOMINAL POWER**.

NOMINAL HEAT, BTU/HR: The average amount of heat required to be dissipated over the course of a day *(24 hours)*, taking into account hourly load variations. *(1 watt = 3.412 BTU/hr)*

COMPOSITE METRICS: The aggregated **NOMINAL POWER**, **NOMINAL TRAFFIC**, and **NOMINAL IOPS/W** for all three environments: **LOW**, **MEDIUM**, and **HIGH DAILY USAGE**.

ANNUAL ENERGY USE, KWH: An estimate of the average energy use across the three environments over the course of a year and computed as (**NOMINAL POWER** * 24 *0.365).

ENERGY COST, $/KWH: A standardized energy cost per kilowatt hour.

ANNUAL ENERGY COST: An estimate of the annual energy use across the three environments over the course of a year and computed as (**ANNUAL ENERGY USE * ENERGY COST**).

SPC-1/E Power/Performance Profiles

The following table provides a report for each SPC-1/E execution component. The power consumption for each execution component is reported and, where appropriate the measured SPC-1 performance *(SPC-1 IOPS™)* is also reported.

The **Load Level** value in the table represents the percentage of the maximum, specified offered load that was used for a specific execution component.

SPC-1/E Power/Performance Profile Data

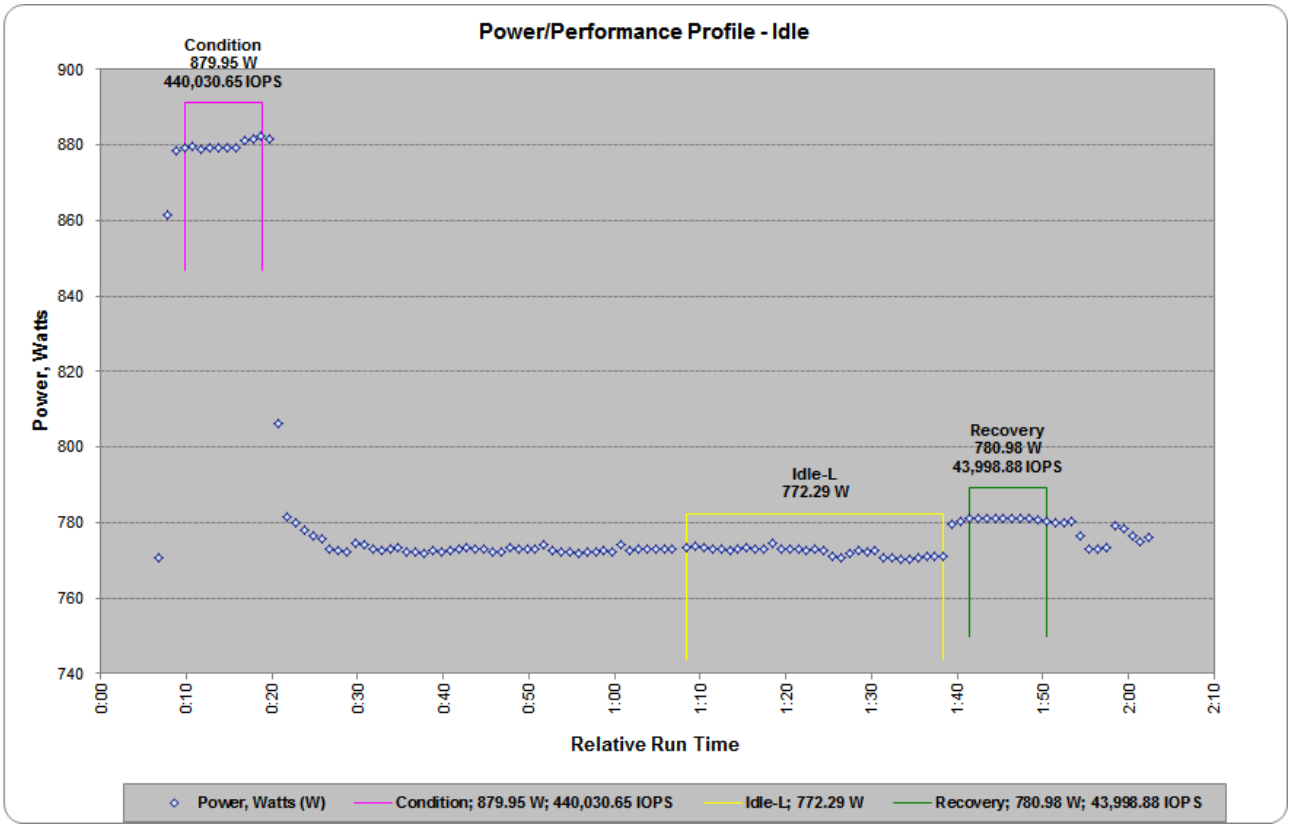
Execution Component	Load Level	SPC-1 IOPS™	Power (W)
Idle – Conditioning ***(Condition)***	100%	440,030.65	879.95
Idle ***(Idle-L)***	0%	-	772.29
Idle - Recovery ***(Recovery)***	10%	43,998.88	780.98
Sustainability ***(Sustain)***	100%	439,994.71	883.86
IOPS ***(100%)***	100%	440,011.00	882.38
Ramp95 ***(95%)***	95%	417,979.06	875.14
Ramp90 ***(90%)***	90%	395,987.29	869.71
Ramp80 ***(80%)***	80%	351,979.49	858.25
Ramp50 ***(50%)***	50%	219,976.95	825.73
Ramp10 ***(10%)***	10%	43,986.34	782.93
Repeat1 LRT ***(10%)***	10%	43,995.57	782.98
Repeat1 IOPS ***(100%)***	100%	440,002.07	880.94
Repeat2 LRT ***(10%)***	10%	43,994.06	781.94
Repeat2 IOPS ***(100%)***	100%	439,978.06	881.32

SPC-1/E Power/Performance Profile Charts and Tables

The following four SPC-1/E Power/Performance Profile charts and tables provide a complete "at a glance" illustration and report for each SPC-1/E execution component. The power consumption at each step is reported and, where appropriate the measured SPC-1 performance *(SPC-1 IOPS™)* is also reported.

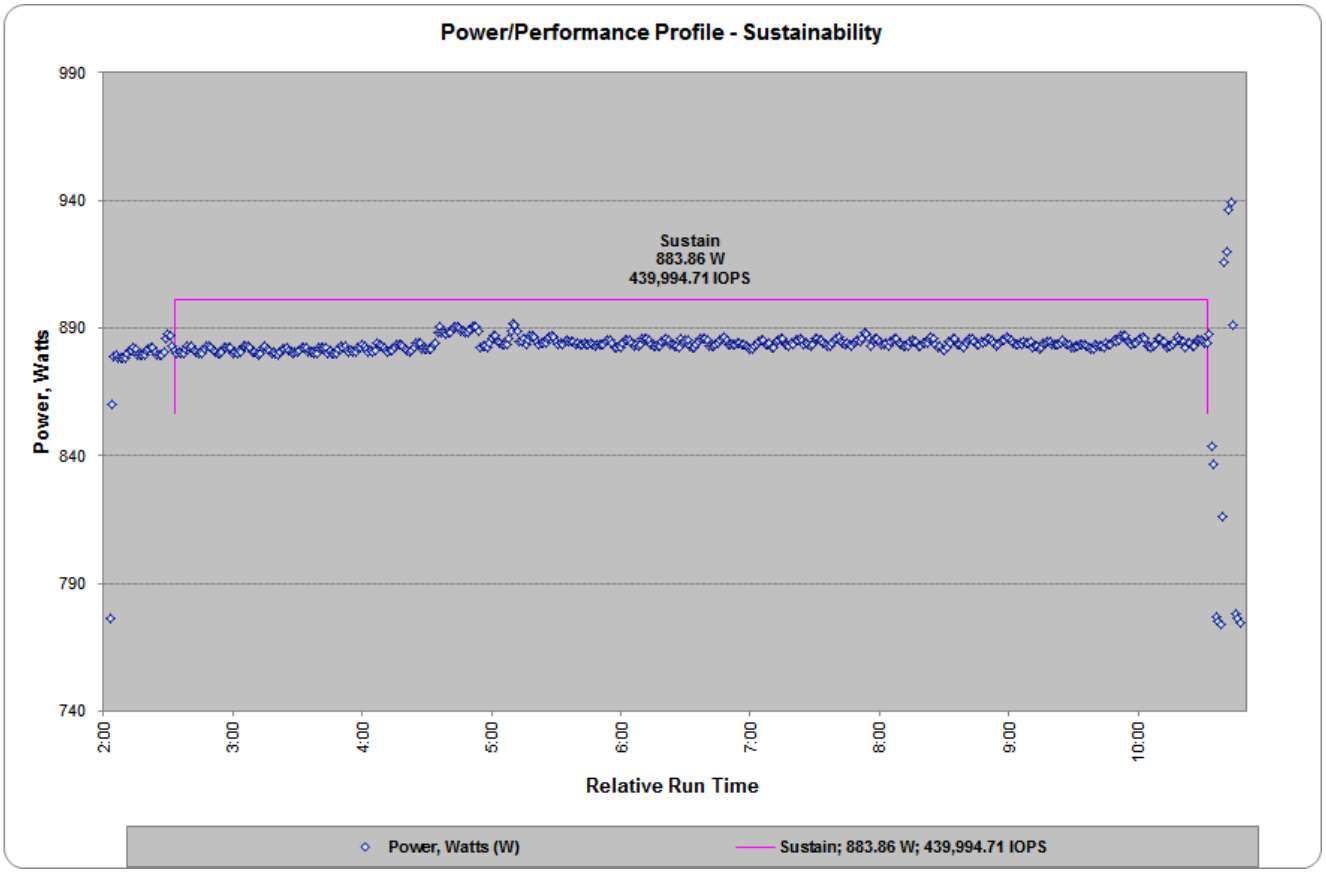
The **Load Level** value in the table represents the percentage of the maximum, specified offered load that was used for a specific execution component. Each **Execution Component** entry includes the acronym, in parenthesis, which is used in the corresponding chart to identify the execution component.

Power/Performance Profile – Idle Test



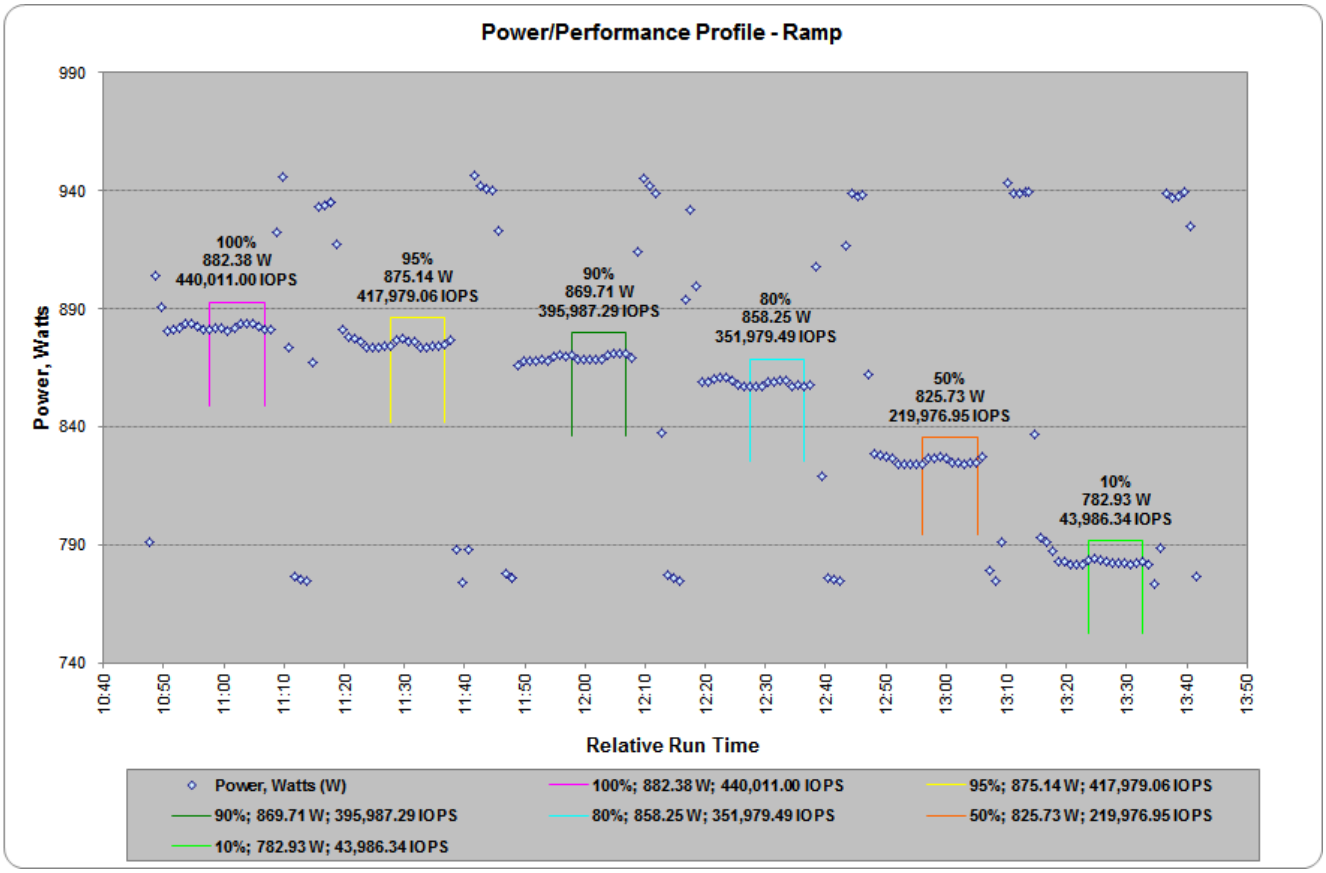
Execution Component	Load Level	SPC-1 IOPS™	Power (W)
Idle – Conditioning ***(Condition)***	100%	440,030.65	879.95
Idle ***(Idle-L)***	0%	-	772.29
Idle - Recovery ***(Recovery)***	10%	43,998.88	780.98

Power/Performance Profile – Sustainability Test Run



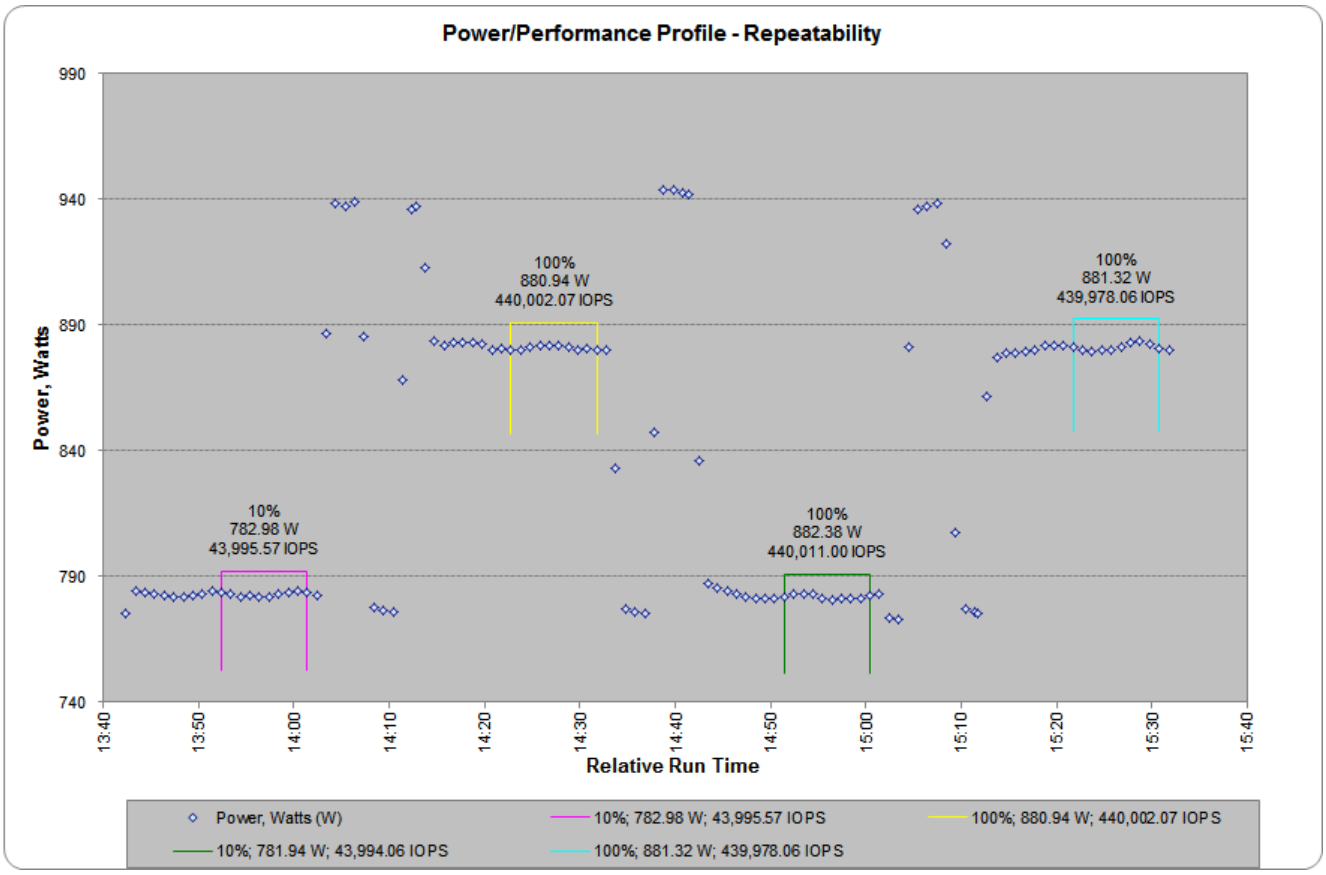
Execution Component	Load Level	SPC-1 IOPS™	Power (W)
Sustainability (***Sustain***)	100%	439,994.71	883.86

Power/Performance Profile – IOPS and Response Time Ramp Test Runs



Execution Component	Load Level	SPC-1 IOPS™	Power (W)
IOPS *(**100%**)*	100%	440,011.00	882.38
Ramp95 *(**95%**)*	95%	417,979.06	875.14
Ramp90 *(**90%**)*	90%	395,987.29	869.71
Ramp80 *(**80%**)*	80%	351,979.49	858.25
Ramp50 *(**50%**)*	50%	219,976.95	825.73
Ramp10 *(**10%**)*	10%	43,986.34	782.93

Power/Performance Profile – Repeatability Test *(two phases)*



Execution Component	Load Level	SPC-1 IOPS™	Power (W)
Repeat1 LRT ***(10%)***	10%	43,995.57	782.98
Repeat1 IOPS ***(100%)***	100%	440,002.07	880.94
Repeat2 LRT ***(10%)***	10%	43,994.06	781.94
Repeat2 IOPS ***(100%)***	100%	439,978.06	881.32

Priced Storage Configuration Pricing

Component	Quantity	Unit Price	Unit Maint	List w/ Maint	% discount	Total Price
FlashSystem 900 (9840-AE2) w/ 8 x 16 Gb SFP, 1 year warranty	1	53,000.00	6,240.00	59,240.00	39	36,136.40
5.7 TB microlatency module (-AF25)	12	**74,800.00**	**7,248.00**	**984,576.00**	39	**600,591.36**
5m fibre channel cable (-3701)	24	75.00	0.00	1,800.00	30	1,260.00
2498-F48 16 Gbps FC switch w/ 24 port activation, 24x16 Gbps SFPs	1	43,068.00	10,800.00	53,868.00	30	37,707.60
16 Gbps dual port FC adapter (9179-EN0A)	8	5,894.00	0.00	47,152.00	30	33,006.40
Total Price						**708,701.76**

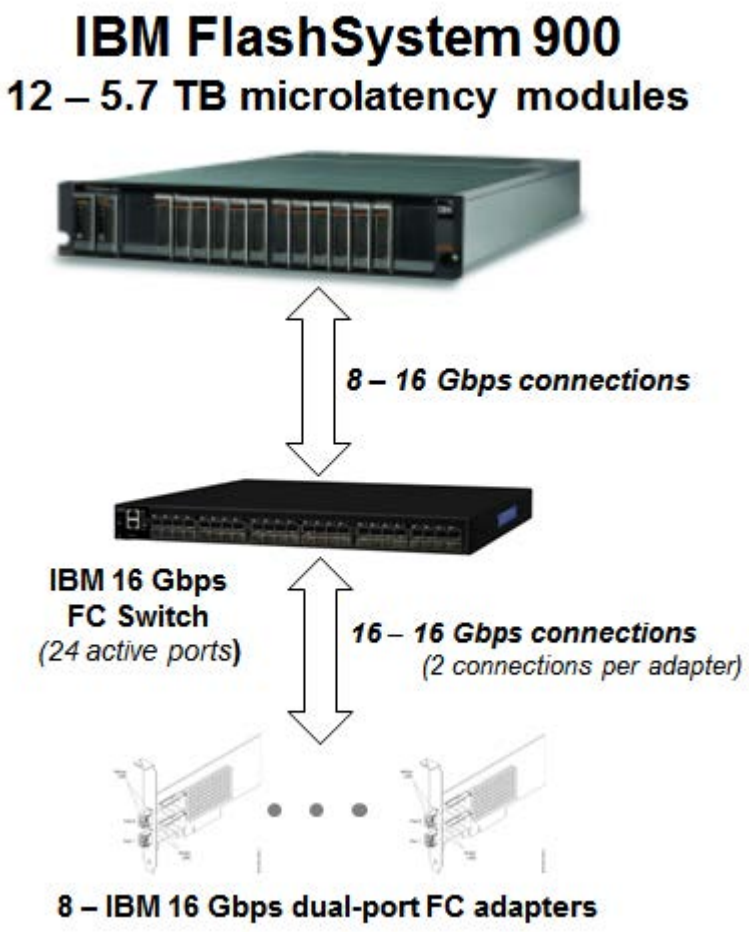
The above pricing includes hardware maintenance and software support for three years, 7 days per week, 24 hours per day. The hardware maintenance and software support provides the following:

- 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

There were no differences between the TSC and the Priced Storage Configuration.

Priced Storage Configuration Diagram



Priced Storage Configuration Components

Priced Storage Configuration
8 – IBM 16 Gbps dual-port FC adapters
IBM FlashSystem® 900 Dual controllers 8 – 16 Gbps FC front-end connections *(w/8 SFPs)* *(8 connections used)* 40 – SAMNet backend lanes available and used *(proprietary interconnect similar to PCIe)*
1 – IBM 16 Gbps FC switch w/24 active ports
12 – 5.7 TB microlatency modules

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 28 *(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 28 *(Benchmark Configuration/Tested Storage Configuration Diagram)*.

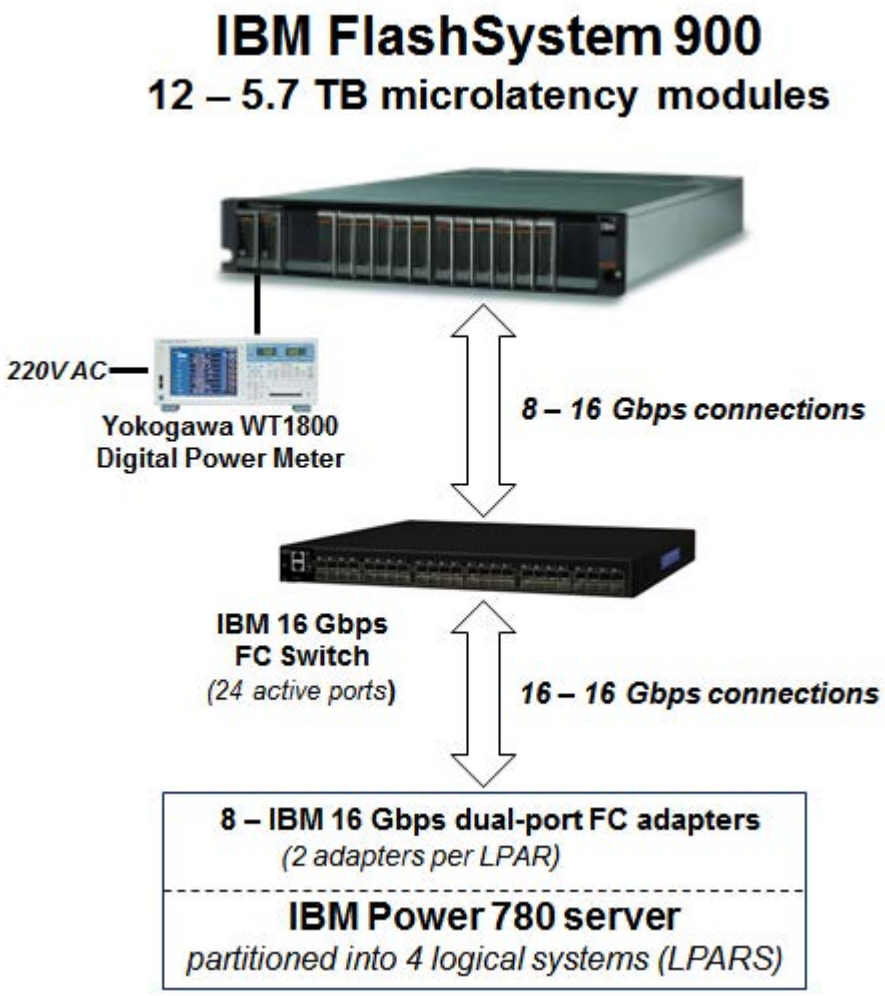
Host System(s) and Tested Storage Configuration (TSC) Table of Components

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 29 *(Host System and Tested Storage Configuration Components)*.

Benchmark Configuration/Tested Storage Configuration Diagram



Host System and Tested Storage Configuration Components

Host System
IBM Power 780 server partitioned into 4 logical systems (LPARS) each with: 4 – Power 7+ processor modules 4 – 3.1 GHz processor cores per module 256 KB L2 cache per core 4 MB L3 cache per core 128 GB main memory AIX 7.1 PCIe
Priced Storage Configuration
8 – IBM 16 Gbps dual-port FC adapters
IBM FlashSystem® 900 Dual controllers 8 – 16 Gbps FC front-end connections *(w/8 SFPs)* *(8 connections used)* 40 – SAMNet backend lanes available and used *(proprietary interconnect similar to PCIe)*
1 – IBM 16 Gbps FC switch w/24 active ports
12 – 5.7 TB microlatency modules

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 73 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 74 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 76.

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 76.

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 69 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 68,606.113 GB distributed over 12 solid state devices (SSDs) each with a formatted capacity of 5,717.176 GB per SSD. There was 0.00 GB (0.00%) of Unused Storage within the Physical Storage Capacity. Global Storage Overhead consisted of 0.00 GB (0.00%) of the Physical Storage Capacity. There was 25,088.500 GB (36.57%) of Unused Storage within the Configured Storage Capacity. The Total ASU Capacity utilized 100% of the Addressable Storage Capacity resulting in 0.00 GB (0.00%) of Unused Storage within the Addressable Storage Capacity. The Data Protection *(RAID-5)* capacity was 5,717.176 GB of which 3,436.403 GB was utilized. The total Unused Storage capacity was 25,088.500 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.

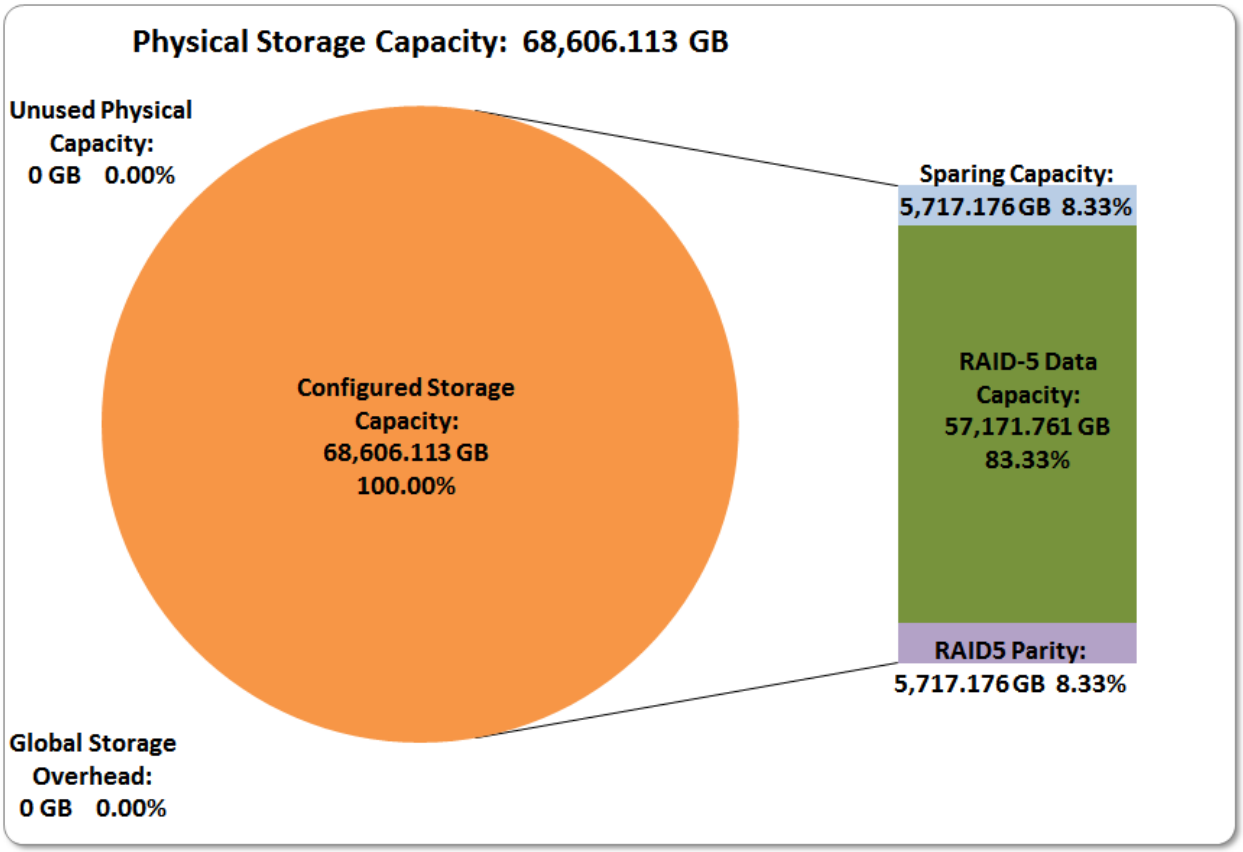
SPC-1 Storage Capacities

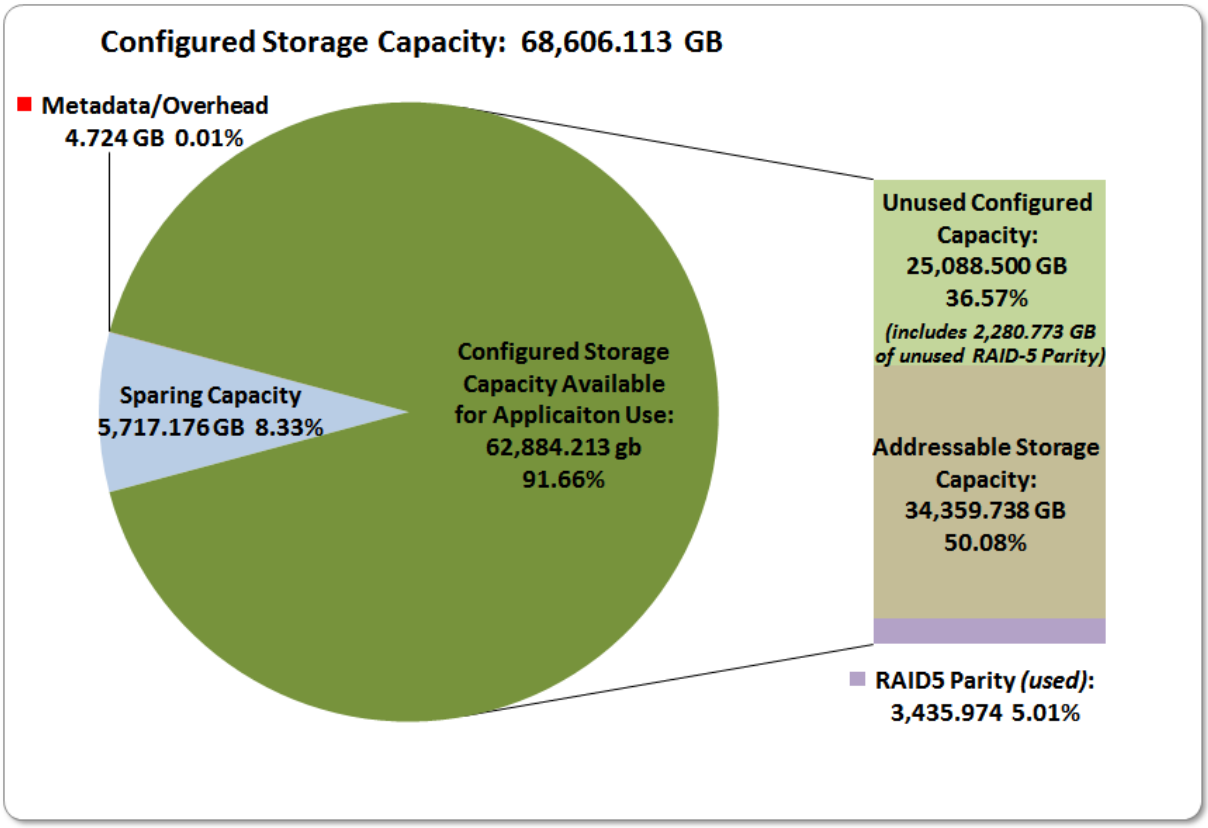
Storage Hierarchy Component	Units	Capacity
Total ASU Capacity	Gigabytes (GB)	34,359.738
Addressable Storage Capacity	Gigabytes (GB)	34,359.738
Configured Storage Capacity	Gigabytes (GB)	68,606.113
Physical Storage Capacity	Gigabytes (GB)	68,606.113
Data Protection *(RAID-5)*	Gigabytes (GB)	5,717.176
Required Storage *(sparing, metadata)*	Gigabytes (GB)	5,721.901
Global Storage Overhead	Gigabytes (GB)	0.000
Total Unused Storage	Gigabytes (GB)	25,088.500

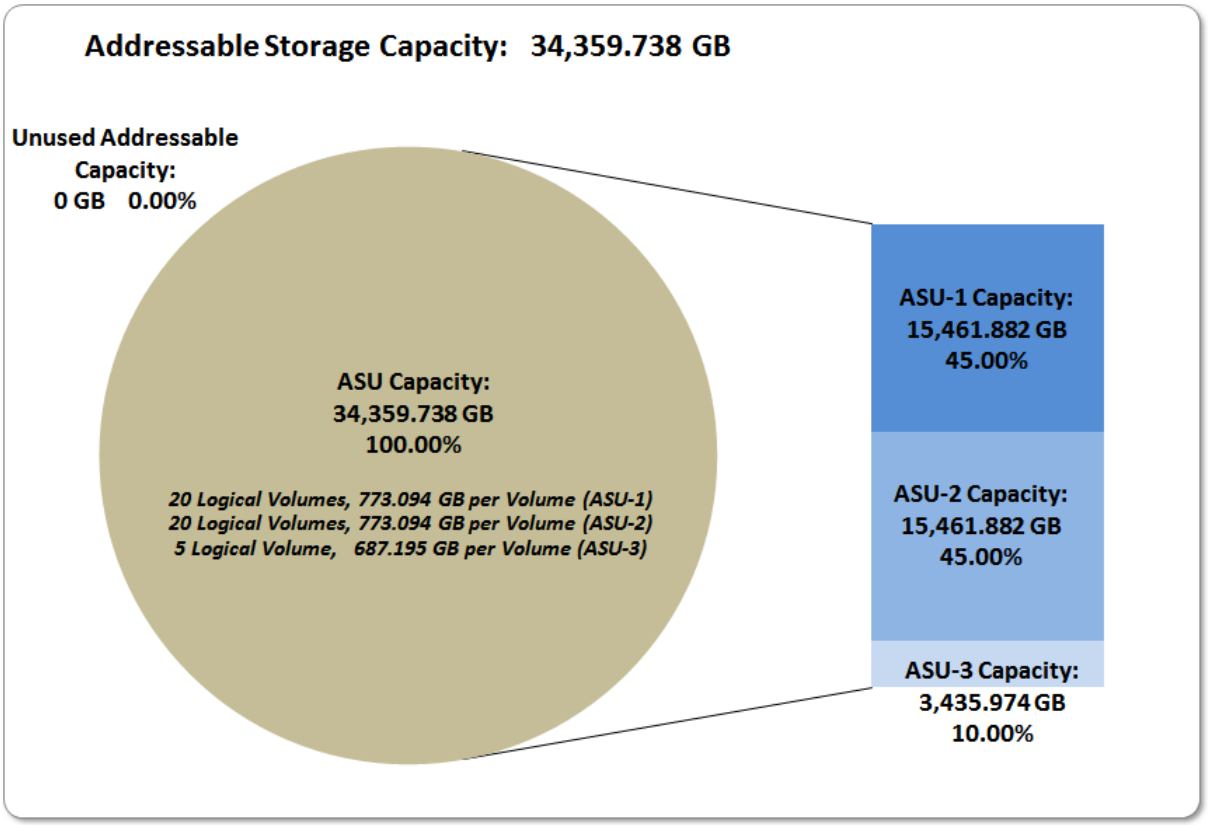
SPC-1 Storage Hierarchy Ratios

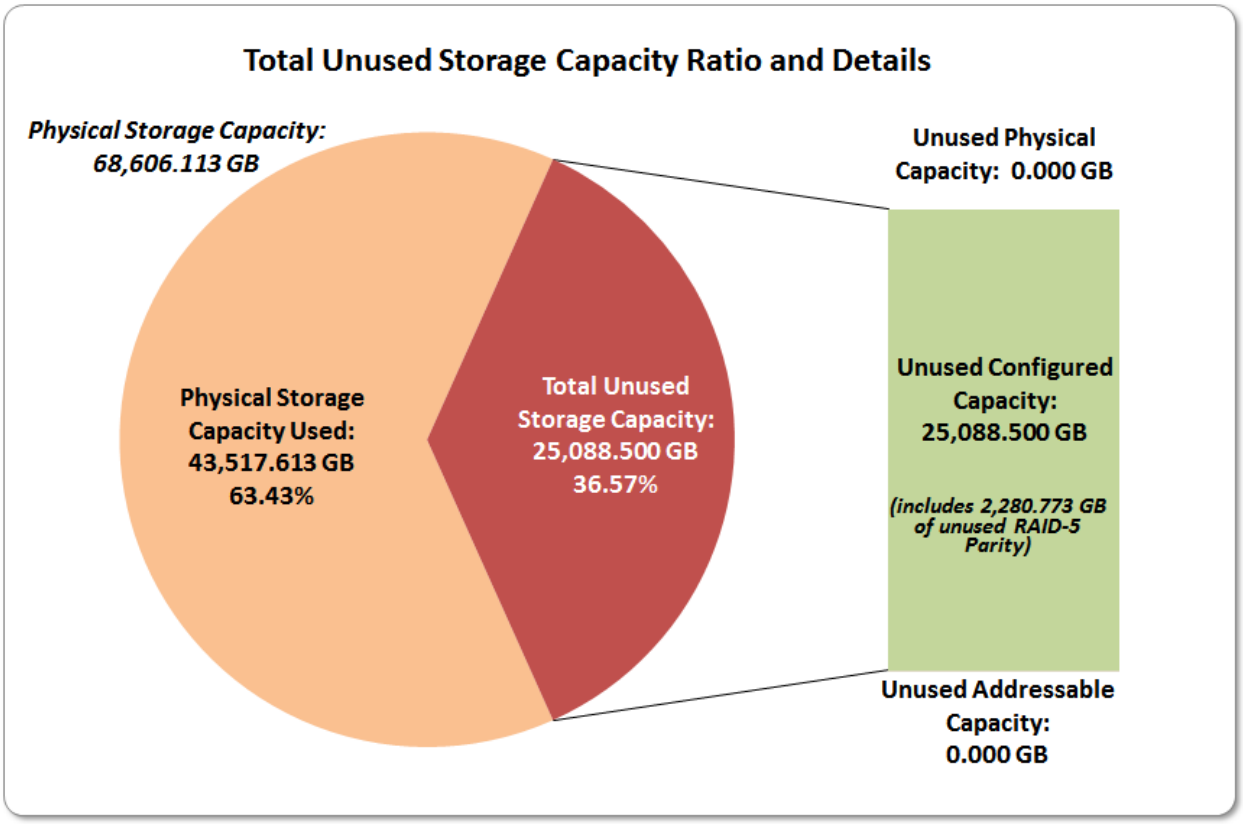
	Addressable Storage Capacity	Configured Storage Capacity	Physical Storage Capacity
Total ASU Capacity	100.00%	50.08%	50.08%
Required for Data Protection *(RAID-5)*		8.33%	8.33%
Addressable Storage Capacity		50.08%	50.08%
Required Storage *(sparing, metadata)*		8.34%	8.34%
Configured Storage Capacity			100.00%
Global Storage Overhead			0.00%
Unused Storage:			
Addressable	0,00%		
Configured		36.57%	
Physical			0.00%

SPC-1 Storage Capacity Charts




Configured Storage Capacity: 68,606.113 GB
Metadata/Overhead
4.724 GB 0.01%
Sparing Capacity
5,717.176 GB 8.33%
Configured Storage Capacity Available for Applicaiton Use:
62,884.213 gb
91.66%
Unused Configured Capacity:
25,088.500 GB
36.57%
(includes 2,280.773 GB of unused RAID-5 Parity)
Addressable Storage Capacity:
34,359.738 GB
50.08%
RAID5 Parity (used):
3,435.974 5.01%


Addressable Storage Capacity: 34,359.738 GB
Unused Addressable Capacity:
0 GB 0.00%
ASU Capacity:
34,359.738 GB
100.00%
20 Logical Volumes, 773.094 GB per Volume (ASU-1)
20 Logical Volumes, 773.094 GB per Volume (ASU-2)
5 Logical Volume, 687.195 GB per Volume (ASU-3)
ASU-1 Capacity:
15,461.882 GB
45.00%
ASU-2 Capacity:
15,461.882 GB
45.00%
ASU-3 Capacity:
3,435.974 GB
10.00%



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	50.08%
Protected Application Utilization	55.09%
Unused Storage Ratio	36.57%

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 (15,461.882 GB)	**ASU-2 (15,461.882 GB)**	**ASU-3 (3,435.974 GB)**
20 Logical Volume 773.094 GB per Logical Volume (773.094 GB used per Logical Volume)	20 Logical Volume 773.094 GB per Logical Volume (773.094 GB used per Logical Volume)	5 Logical Volumes 687.195 GB per Logical Volume (687.195 GB used per Logical Volume)

The Data Protection Level used for all Logical Volumes was **Protected 1** using ***RAID-5*** as described on page 13. 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 69 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.

"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.

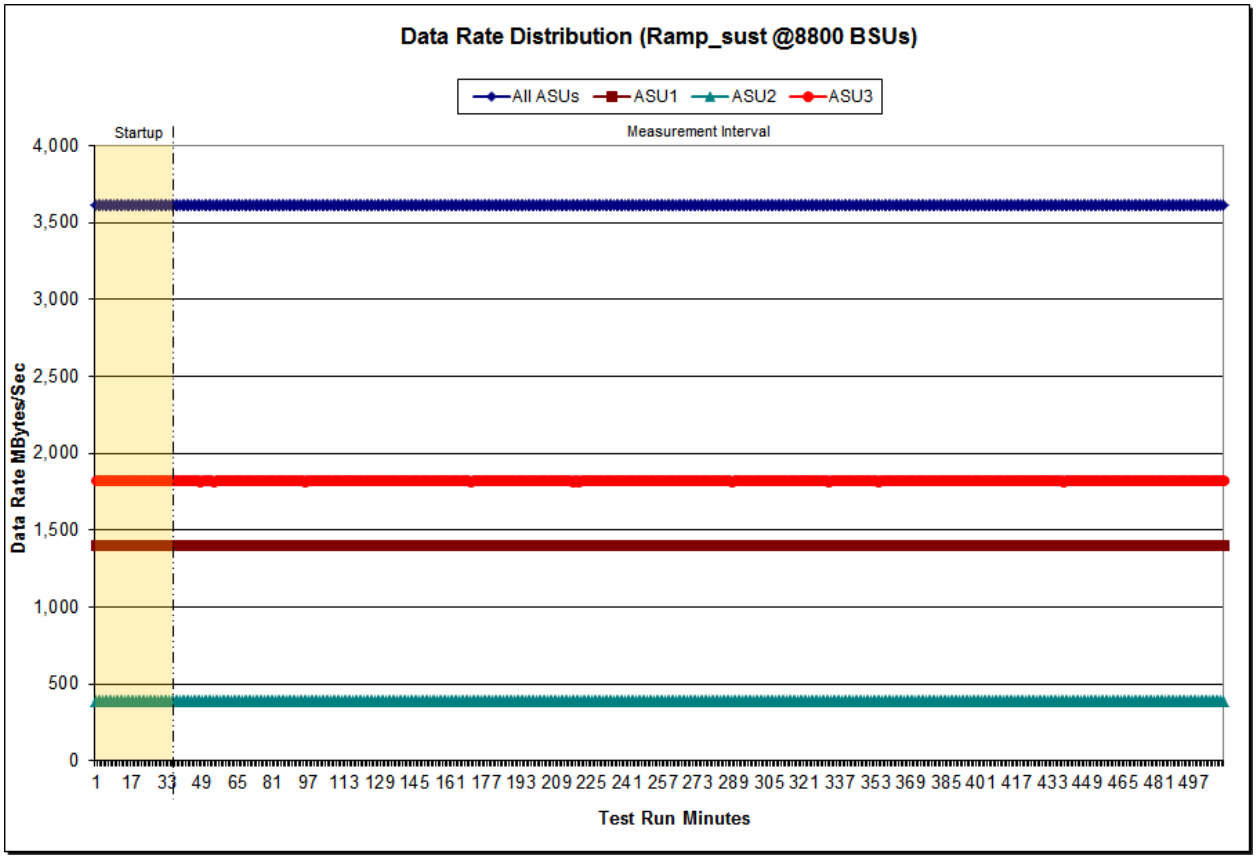
Sustainability Test Results File

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

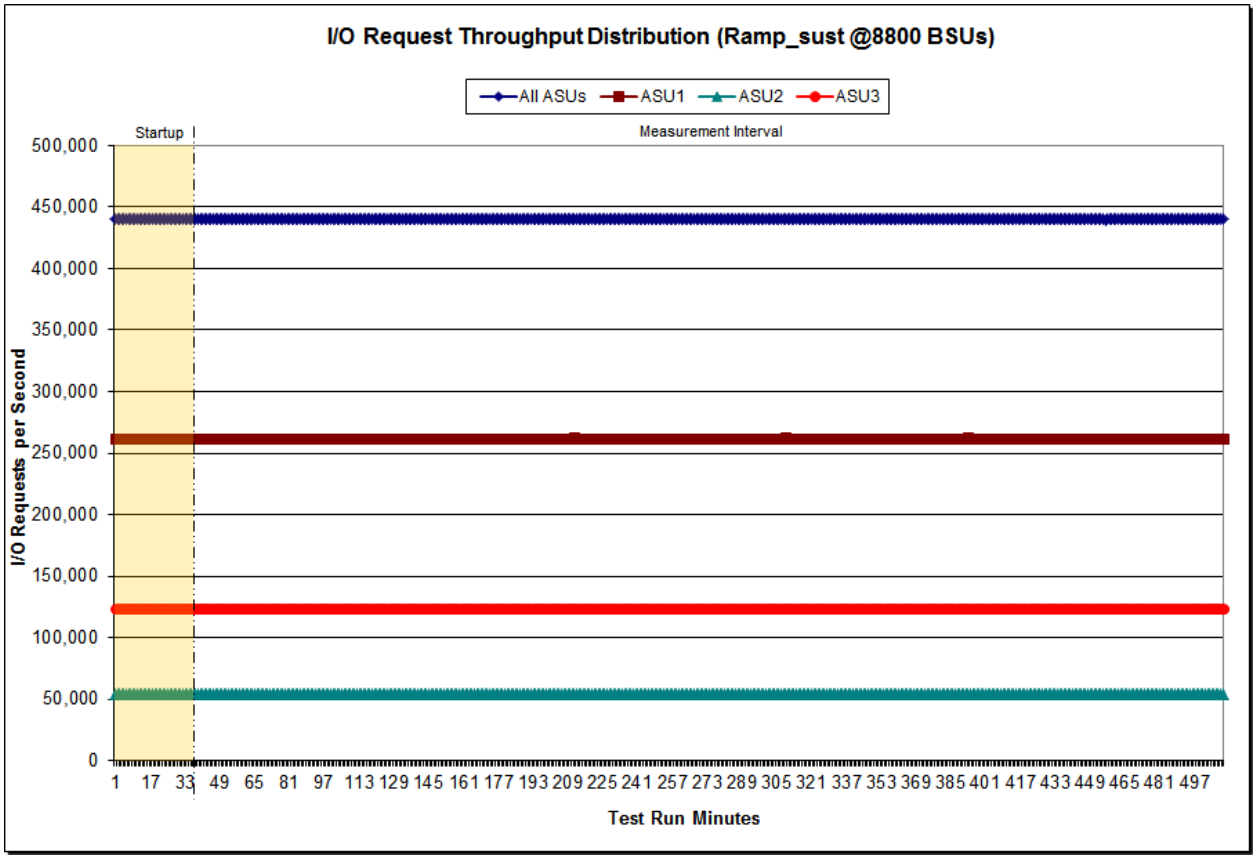


Sustainability – I/O Request Throughput Distribution Data

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

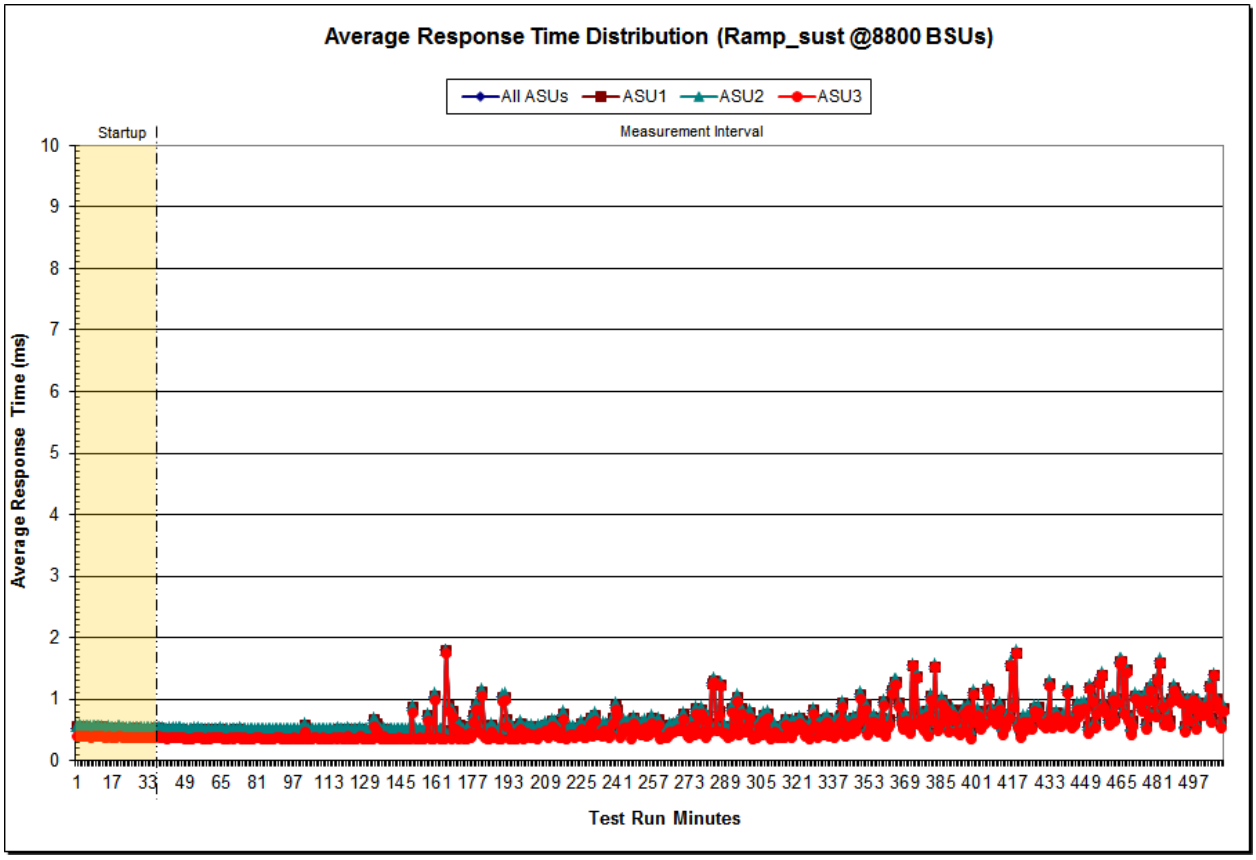


Sustainability – Average Response Time (ms) Distribution Data

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

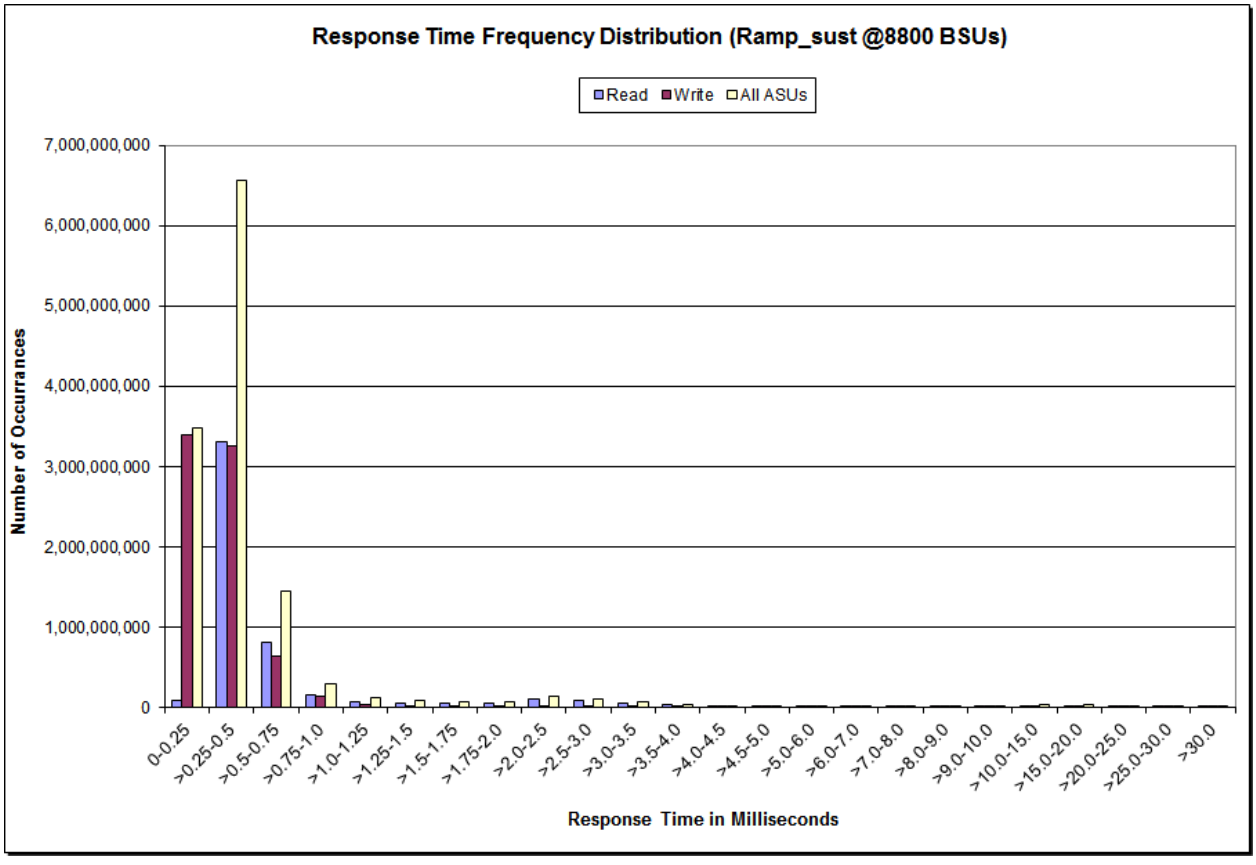
Sustainability – Average Response Time (ms) Distribution Graph



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	85,928,169	3,313,664,218	810,916,907	155,109,337	77,272,200	62,588,008	58,557,749	57,053,944
Write	3,402,096,991	3,257,413,025	637,001,125	145,651,651	45,300,160	22,718,244	16,002,295	12,953,922
All ASUs	3,488,025,160	6,571,077,243	1,447,918,032	300,760,988	122,572,360	85,306,252	74,560,044	70,007,866
ASU1	1,704,886,321	4,161,504,610	923,538,231	181,463,543	78,225,960	57,433,871	51,416,318	48,851,497
ASU2	392,248,157	794,173,642	190,900,405	39,159,902	17,803,411	13,582,565	12,463,417	12,069,552
ASU3	1,390,890,682	1,615,398,991	333,479,396	80,137,543	26,542,989	14,289,816	10,680,309	9,086,817
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	113,862,978	92,303,974	55,474,585	34,576,469	21,005,338	8,824,753	4,649,705	3,096,709
Write	20,980,482	15,096,069	9,554,116	6,393,377	4,371,750	2,788,213	3,797,475	3,410,648
All ASUs	134,843,460	107,400,043	65,028,701	40,969,846	25,377,088	11,612,966	8,447,180	6,507,357
ASU1	95,073,191	75,876,789	45,650,283	28,559,470	17,550,088	7,839,676	5,327,462	4,010,199
ASU2	24,158,703	19,884,327	12,112,063	7,674,552	4,747,537	2,036,010	1,162,894	842,945
ASU3	15,611,566	11,638,927	7,266,355	4,735,824	3,079,463	1,737,280	1,956,824	1,654,213
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	2,577,061	2,346,948	2,468,662	17,969,201	8,854,195	3,012,014	1,560,787	3,962,002
Write	3,329,507	3,270,370	3,163,930	17,950,925	20,968,312	9,776,665	3,380,735	6,841,472
All ASUs	5,906,568	5,617,318	5,632,592	35,920,126	29,822,507	12,788,679	4,941,522	10,803,474
ASU1	3,581,937	3,375,608	3,440,848	22,989,823	16,481,764	6,503,550	2,643,224	6,180,633
ASU2	745,226	701,842	704,887	4,617,470	3,563,342	1,430,121	566,374	1,296,875
ASU3	1,579,405	1,539,868	1,486,857	8,312,833	9,777,401	4,855,008	1,731,924	3,325,966

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	0.2810	0.0700	0.2100	0.0180	0.0700	0.0350	0.2810
COV	0.001	0.000	0.001	0.000	0.001	0.001	0.001	0.000

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

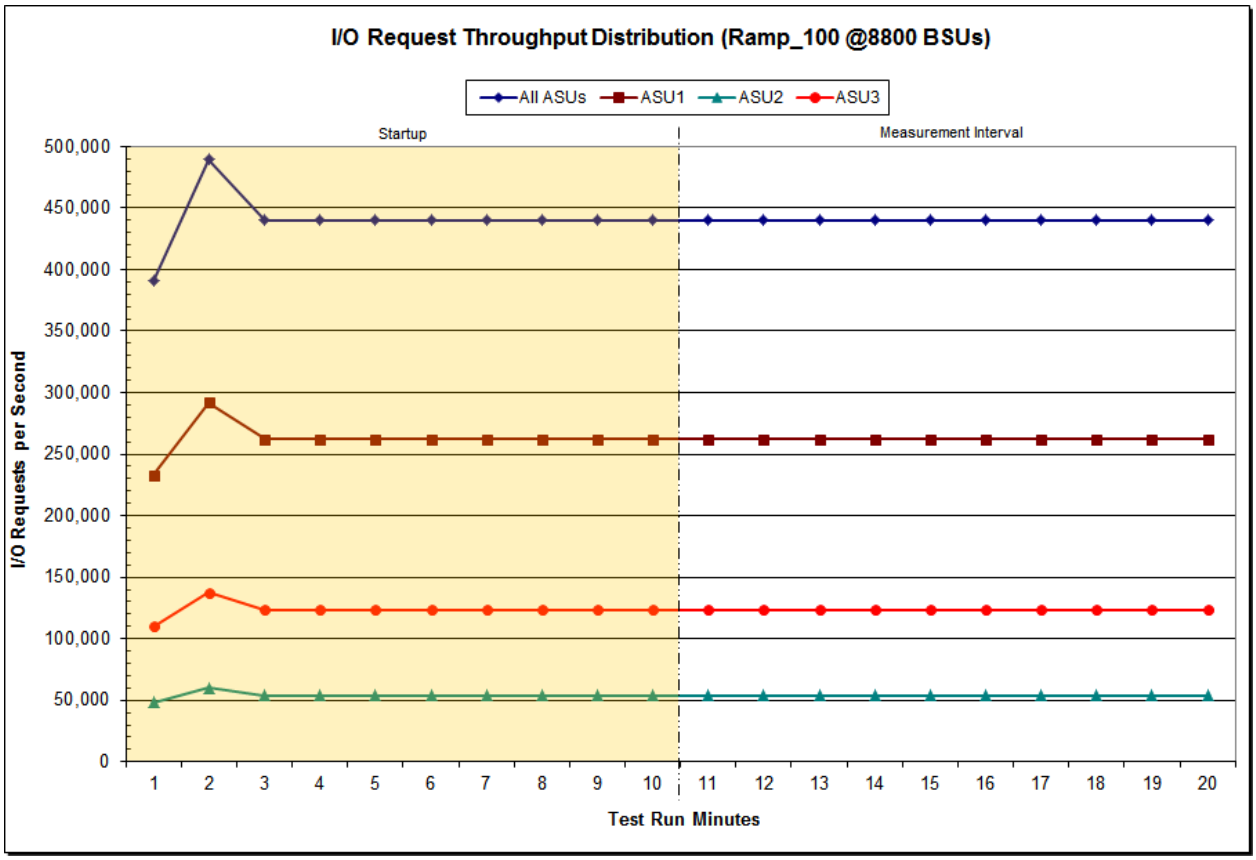
A link to the test results file generated from the IOPS Test Run is listed below.

IOPS Test Results File

IOPS Test Run – I/O Request Throughput Distribution Data

8,800 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	4:07:43	4:17:44	0-9	0:10:01
Measurement Interval	4:17:44	4:27:45	9-19	0:10:01
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	390,859.17	232,968.88	48,047.90	109,842.38
1	489,392.95	291,649.73	60,179.98	137,563.23
2	440,028.63	262,306.42	54,082.18	123,640.03
3	440,030.23	262,213.62	54,143.28	123,673.33
4	440,031.68	262,249.77	54,090.65	123,691.27
5	439,879.12	262,223.37	54,080.43	123,575.32
6	439,958.57	262,225.63	54,119.48	123,613.45
7	440,083.37	262,339.13	54,064.67	123,679.57
8	440,043.13	262,245.85	54,127.97	123,669.32
9	439,921.72	262,222.30	54,086.10	123,613.32
10	439,977.55	262,222.78	54,140.07	123,614.70
11	440,127.85	262,356.93	54,129.07	123,641.85
12	439,917.37	262,150.00	54,096.18	123,671.18
13	440,059.95	262,284.02	54,105.92	123,670.02
14	440,013.17	262,201.30	54,159.60	123,652.27
15	440,095.07	262,218.28	54,128.38	123,748.40
16	440,037.38	262,312.62	54,084.63	123,640.13
17	439,857.10	262,163.58	54,116.63	123,576.88
18	439,930.27	262,193.92	54,131.83	123,604.52
19	440,094.27	262,198.17	54,207.65	123,688.45
Average	***440,011.00***	***262,230.16***	***54,130.00***	***123,650.84***

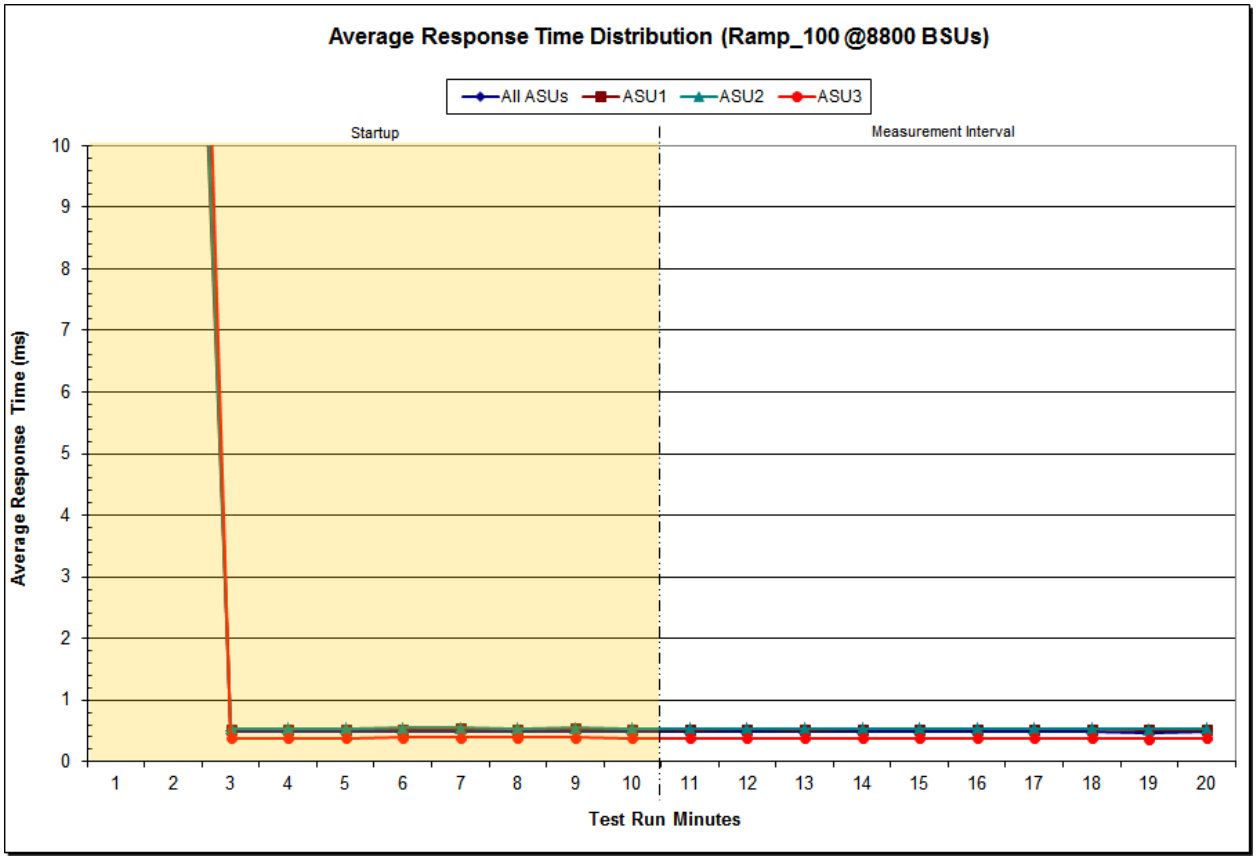
IOPS Test Run – I/O Request Throughput Distribution Graph



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

8,800 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	4:07:43	4:17:44	0-9	0:10:01
Measurement Interval	4:17:44	4:27:45	9-19	0:10:01
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	44.92	41.68	44.44	52.01
1	26.60	24.94	25.79	30.48
2	0.49	0.53	0.54	0.39
3	0.49	0.53	0.54	0.38
4	0.49	0.53	0.54	0.39
5	0.49	0.53	0.55	0.39
6	0.50	0.53	0.55	0.39
7	0.49	0.53	0.54	0.39
8	0.50	0.54	0.55	0.39
9	0.49	0.53	0.54	0.39
10	0.48	0.52	0.54	0.38
11	0.49	0.52	0.54	0.38
12	0.48	0.52	0.54	0.38
13	0.49	0.53	0.54	0.39
14	0.49	0.53	0.54	0.39
15	0.49	0.53	0.54	0.38
16	0.49	0.53	0.54	0.39
17	0.49	0.53	0.54	0.39
18	0.48	0.51	0.53	0.38
19	0.48	0.52	0.54	0.38
Average	***0.49***	***0.52***	***0.54***	***0.38***

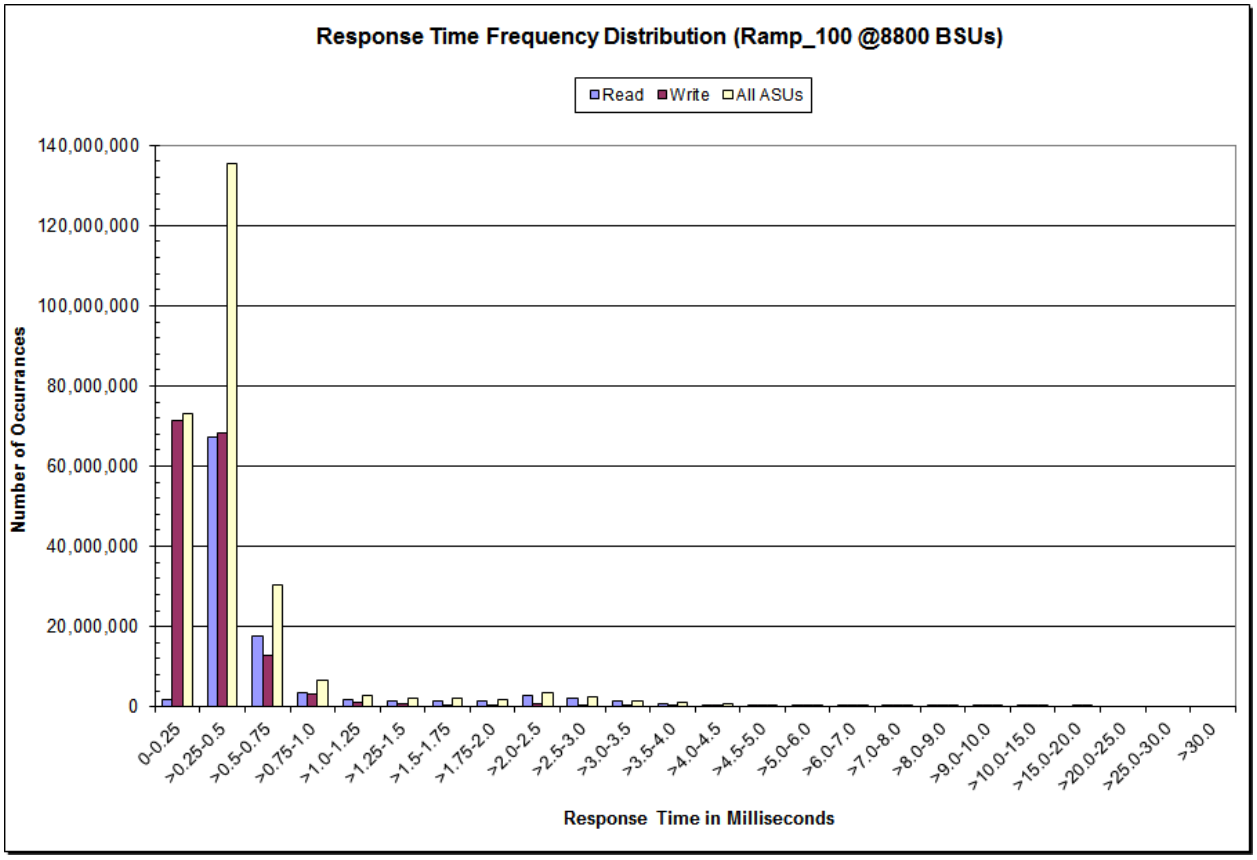
IOPS Test Run – Average Response Time (ms) Distribution Graph



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	1,622,297	67,133,700	17,575,597	3,475,483	1,839,468	1,547,587	1,448,791	1,394,643
Write	71,477,275	68,244,694	12,858,570	2,993,911	1,119,867	694,642	522,481	417,434
All ASUs	73,099,572	135,378,394	30,434,167	6,469,394	2,959,335	2,242,229	1,971,272	1,812,077
ASU1	35,563,416	85,093,823	19,751,236	3,999,377	1,910,454	1,503,892	1,351,132	1,261,079
ASU2	8,224,735	16,530,663	3,940,738	818,257	409,924	331,413	302,744	288,006
ASU3	29,311,421	33,753,908	6,742,193	1,651,760	638,957	406,924	317,396	262,992
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	2,728,587	2,158,374	1,338,307	841,473	512,179	245,401	159,494	60,562
Write	623,434	389,462	228,859	139,166	82,269	41,441	32,635	13,045
All ASUs	3,352,021	2,547,836	1,567,166	980,639	594,448	286,842	192,129	73,607
ASU1	2,374,300	1,832,218	1,129,796	705,551	428,070	208,639	140,167	52,997
ASU2	558,551	436,635	269,468	170,814	103,552	46,923	28,379	11,000
ASU3	419,170	278,983	167,902	104,274	62,826	31,280	23,583	9,610
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	23,481	8,130	2,354	1,049	10	-	-	-
Write	6,168	2,125	907	917	38	-	-	-
All ASUs	29,649	10,255	3,261	1,966	48	-	-	-
ASU1	21,120	7,287	2,224	1,121	13	-	-	-
ASU2	4,178	1,392	372	204	4	-	-	-
ASU3	4,351	1,576	665	641	31	-	-	-

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
264,006,307	264,006,307	0

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	0.2810	0.0700	0.2100	0.0180	0.0700	0.0350	0.2810
COV	0.001	0.000	0.000	0.000	0.001	0.001	0.001	0.000

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 17.

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 - 8,800 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	4:07:43	4:17:44	0-9	0:10:01
Measurement Interval	4:17:44	4:27:45	10-19	0:10:01
(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3
0	390,859.17	232,968.88	48,047.90	109,842.38
1	489,392.95	291,649.73	60,179.98	137,563.23
2	440,028.63	262,306.42	54,082.18	123,640.03
3	440,030.23	262,213.62	54,143.28	123,673.33
4	440,031.68	262,249.77	54,090.65	123,691.27
5	439,879.12	262,223.37	54,080.43	123,575.32
6	439,958.57	262,225.63	54,119.48	123,613.45
7	440,083.37	262,339.13	54,064.67	123,679.57
8	440,043.13	262,245.85	54,127.97	123,669.32
9	439,921.72	262,222.30	54,086.10	123,613.32
10	439,977.55	262,222.78	54,140.07	123,614.70
11	440,127.85	262,356.93	54,129.07	123,641.85
12	439,917.37	262,150.00	54,096.18	123,671.18
13	440,059.95	262,284.02	54,105.92	123,670.02
14	440,013.17	262,201.30	54,159.60	123,652.27
15	440,095.07	262,218.28	54,128.38	123,748.40
16	440,037.38	262,312.62	54,084.63	123,640.13
17	439,857.10	262,163.58	54,116.63	123,576.88
18	439,930.27	262,193.92	54,131.83	123,604.52
19	440,094.27	262,198.17	54,207.65	123,688.45
Average	***440,011.00***	***262,230.16***	***54,130.00***	***123,650.84***

95% Load Level - 8,360 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	4:37:45	4:47:46	0-9	0:10:01
Measurement Interval	4:47:46	4:57:47	10-19	0:10:01
(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3
0	407,645.77	242,998.68	50,156.30	114,490.78
1	428,592.37	255,488.27	52,654.88	120,449.22
2	417,914.22	249,085.02	51,426.83	117,402.37
3	418,072.60	249,176.43	51,427.40	117,468.77
4	417,980.20	249,154.80	51,396.13	117,429.27
5	418,036.60	249,187.72	51,386.87	117,462.02
6	417,899.10	249,043.03	51,454.82	117,401.25
7	418,042.37	249,100.68	51,431.57	117,510.12
8	417,867.50	248,983.12	51,412.40	117,471.98
9	418,068.27	249,117.55	51,419.77	117,530.95
10	418,006.00	249,072.27	51,409.75	117,523.98
11	418,034.07	249,075.52	51,421.32	117,537.23
12	417,964.80	249,135.27	51,397.52	117,432.02
13	417,977.60	249,029.20	51,430.53	117,517.87
14	417,857.33	249,106.93	51,368.12	117,382.28
15	418,018.78	249,071.85	51,457.57	117,489.37
16	418,020.30	249,116.83	51,419.27	117,484.20
17	418,022.43	249,076.85	51,467.10	117,478.48
18	417,979.27	249,006.58	51,471.97	117,500.72
19	417,910.03	249,070.55	51,388.93	117,450.55
Average	***417,979.06***	***249,076.19***	***51,423.21***	***117,479.67***

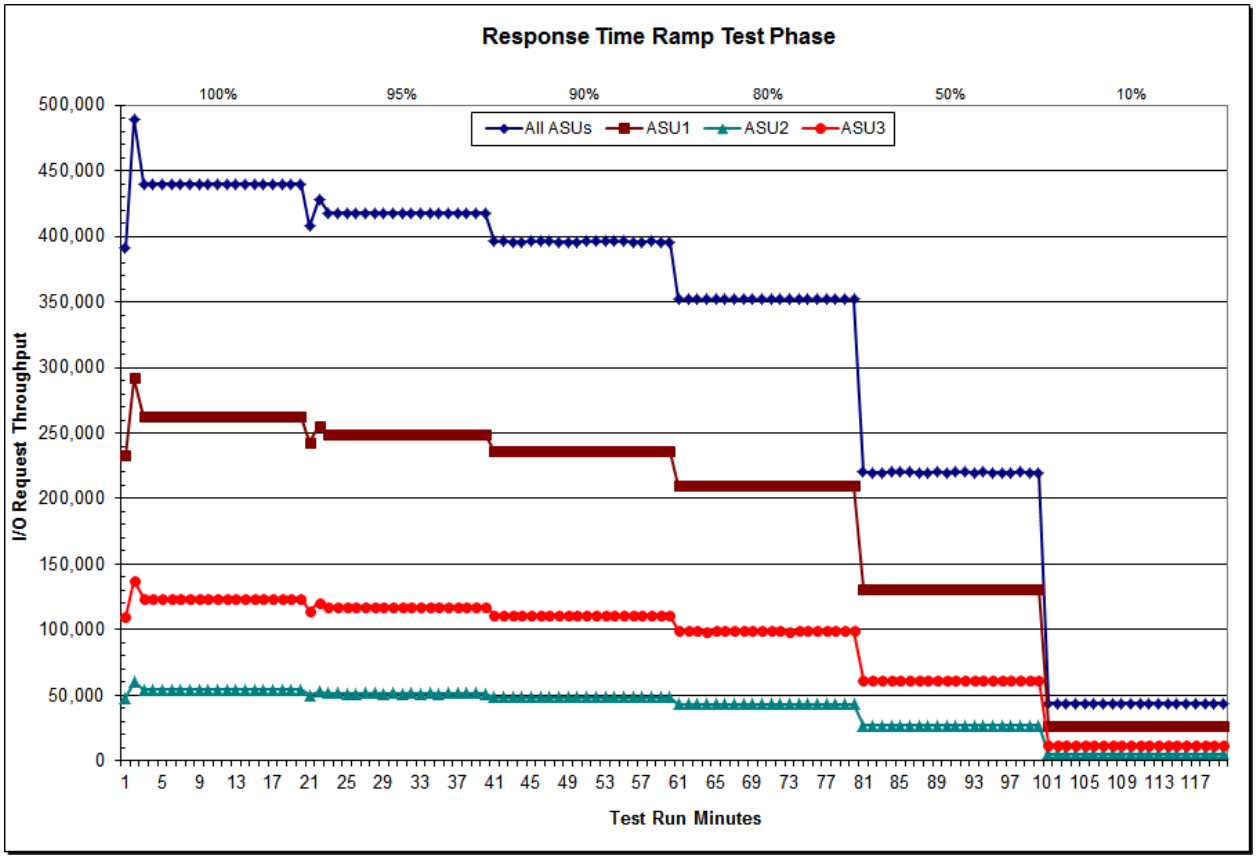
90% Load Level - 7,920 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	5:07:48	5:17:49	0-9	0:10:01
Measurement Interval	5:17:49	5:27:50	10-19	0:10:01
(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3
0	396,253.52	236,097.67	48,718.75	111,437.10
1	396,074.95	236,073.90	48,734.50	111,266.55
2	395,890.05	236,009.68	48,673.08	111,207.28
3	395,937.95	236,007.73	48,719.88	111,210.33
4	396,091.68	236,014.22	48,731.42	111,346.05
5	396,013.73	236,004.03	48,722.37	111,287.33
6	396,021.45	236,010.62	48,724.88	111,285.95
7	395,899.88	235,966.42	48,696.10	111,237.37
8	395,929.35	236,097.02	48,632.40	111,199.93
9	395,947.25	235,971.47	48,658.93	111,316.85
10	396,046.22	235,968.70	48,720.38	111,357.13
11	396,132.55	236,121.93	48,729.85	111,280.77
12	395,977.25	235,924.72	48,738.00	111,314.53
13	396,070.73	236,087.90	48,738.80	111,244.03
14	396,129.10	236,054.73	48,736.87	111,337.50
15	395,830.88	235,959.53	48,662.15	111,209.20
16	395,893.52	235,962.22	48,716.52	111,214.78
17	395,973.58	236,062.20	48,693.90	111,217.48
18	395,897.38	235,953.65	48,727.33	111,216.40
19	395,921.65	235,944.47	48,693.25	111,283.93
Average	***395,987.29***	***236,004.01***	***48,715.71***	***111,267.58***

80% Load Level - 7,040 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	5:37:23	5:47:24	0-9	0:10:01
Measurement Interval	5:47:24	5:57:25	10-19	0:10:01
(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3
0	352,130.05	209,879.05	43,317.02	98,933.98
1	352,010.28	209,823.18	43,331.13	98,855.97
2	351,934.12	209,788.95	43,303.60	98,841.57
3	351,835.62	209,705.93	43,301.62	98,828.07
4	352,062.53	209,878.68	43,265.38	98,918.47
5	352,017.77	209,819.02	43,304.87	98,893.88
6	351,918.82	209,721.68	43,274.33	98,922.80
7	352,015.13	209,819.88	43,278.18	98,917.07
8	352,004.70	209,792.33	43,313.50	98,898.87
9	351,945.70	209,730.32	43,298.83	98,916.55
10	351,920.95	209,719.47	43,301.72	98,899.77
11	352,127.17	209,864.87	43,306.37	98,955.93
12	351,848.00	209,715.20	43,316.67	98,816.13
13	352,090.07	209,805.28	43,311.98	98,972.80
14	352,044.63	209,830.52	43,302.30	98,911.82
15	352,081.40	209,897.38	43,254.63	98,929.38
16	351,818.05	209,649.72	43,246.18	98,922.15
17	352,068.52	209,862.17	43,296.48	98,909.87
18	351,860.80	209,720.73	43,284.23	98,855.83
19	351,935.35	209,730.22	43,293.45	98,911.68
Average	***351,979.49***	***209,779.56***	***43,291.40***	***98,908.54***

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

50% Load Level - 4,400 BSUs	Start	Stop	Interval	Duration	10% Load Level - 800 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	6:06:07	6:16:08	0-9	0:10:01	Start-Up/Ramp-Up	6:33:38	6:43:39	0-9	0:10:01
Measurement Interval	6:16:08	6:26:09	10-19	0:10:01	Measurement Interval	6:43:39	6:53:40	10-19	0:10:01
(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3	*(60 second intervals)*	All ASUs	ASU-1	ASU-2	ASU-3
0	220,241.07	131,233.83	27,085.40	61,921.83	0	44,039.68	26,247.20	5,403.68	12,388.80
1	219,995.48	131,138.33	27,065.50	61,791.65	1	44,011.18	26,219.43	5,423.43	12,368.32
2	219,927.33	131,112.45	27,041.62	61,773.27	2	43,991.12	26,227.57	5,396.22	12,367.33
3	220,003.48	131,097.27	27,072.48	61,833.73	3	43,984.23	26,197.10	5,426.50	12,360.63
4	220,004.52	131,120.75	27,023.03	61,860.73	4	43,967.68	26,194.33	5,427.70	12,345.65
5	220,022.75	131,125.27	27,063.95	61,833.53	5	43,997.08	26,206.52	5,411.32	12,379.25
6	219,931.92	131,064.72	27,050.20	61,817.00	6	43,977.65	26,195.52	5,416.95	12,365.18
7	219,902.50	131,041.33	27,039.13	61,822.03	7	43,921.47	26,169.05	5,394.55	12,357.87
8	220,104.58	131,223.60	27,051.85	61,829.13	8	44,033.97	26,244.90	5,418.07	12,371.00
9	219,992.60	131,168.25	27,071.20	61,753.15	9	43,980.82	26,209.42	5,412.20	12,359.20
10	220,034.63	131,112.47	27,029.60	61,892.57	10	44,008.77	26,243.90	5,395.97	12,368.90
11	220,023.53	131,149.93	27,044.47	61,829.13	11	43,998.62	26,254.33	5,393.02	12,351.27
12	219,935.80	131,081.57	27,068.57	61,785.67	12	44,036.23	26,247.20	5,434.13	12,354.90
13	219,997.80	131,170.55	27,045.60	61,781.65	13	43,935.07	26,187.98	5,406.38	12,340.70
14	219,987.85	131,088.43	27,055.45	61,843.97	14	43,961.28	26,193.58	5,408.65	12,359.05
15	219,986.75	131,073.35	27,056.90	61,856.50	15	44,015.58	26,202.75	5,431.88	12,380.95
16	219,911.03	131,089.23	27,023.25	61,798.55	16	43,922.98	26,170.43	5,393.98	12,358.57
17	220,000.13	131,083.87	27,071.70	61,844.57	17	43,994.92	26,204.15	5,408.82	12,381.95
18	219,933.43	131,073.77	27,069.33	61,790.33	18	43,994.37	26,226.10	5,408.70	12,359.57
19	219,958.48	131,098.98	27,042.83	61,816.67	19	43,995.53	26,218.48	5,419.10	12,357.95
Average	***219,976.95***	***131,102.22***	***27,050.77***	***61,823.96***	***Average***	***43,986.34***	***26,214.89***	***5,410.06***	***12,361.38***

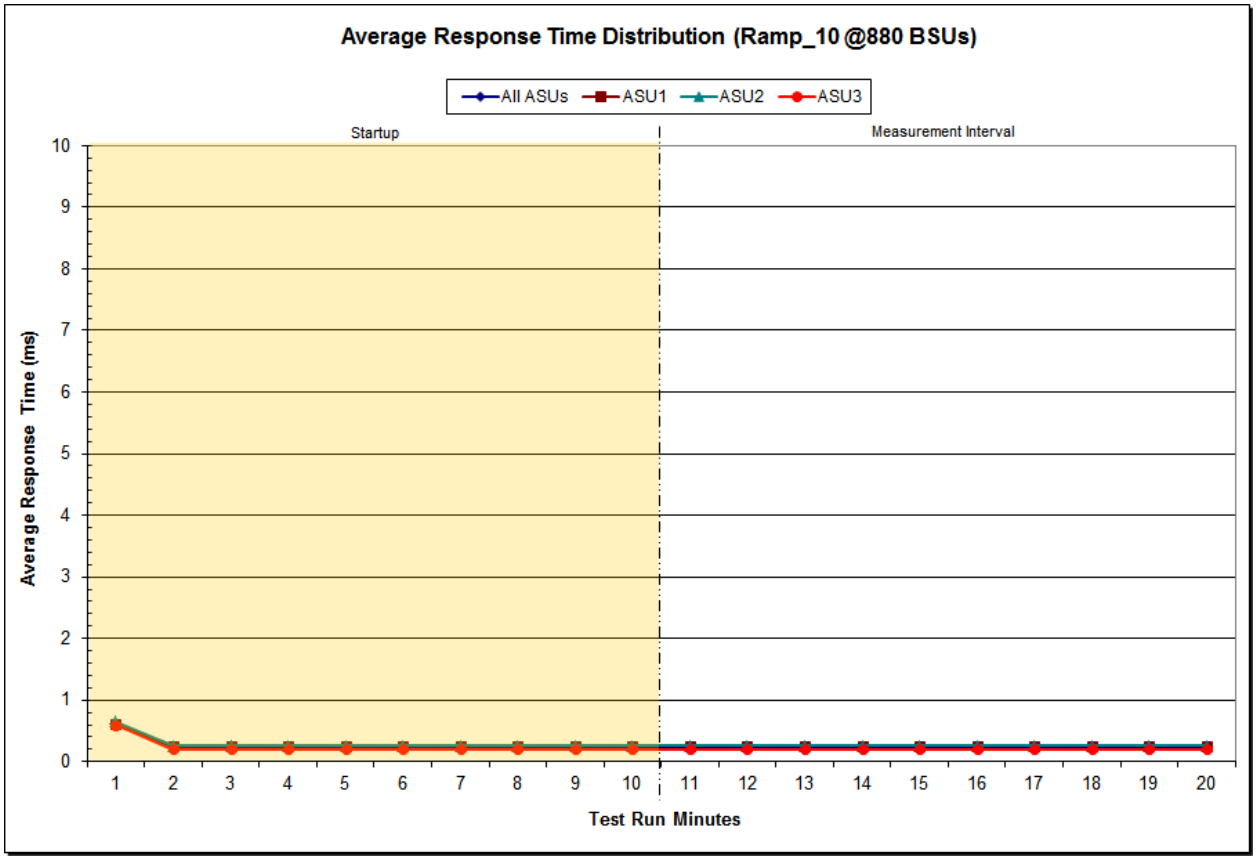
Response Time Ramp Distribution (IOPS) Graph



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

880 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	6:33:38	6:43:39	0-9	0:10:01
Measurement Interval	6:43:39	6:53:40	10-19	0:10:01
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	0.61	0.61	0.66	0.59
1	0.24	0.26	0.26	0.20
2	0.24	0.26	0.26	0.20
3	0.24	0.26	0.26	0.20
4	0.24	0.26	0.26	0.20
5	0.24	0.26	0.26	0.20
6	0.24	0.26	0.26	0.20
7	0.24	0.26	0.26	0.20
8	0.24	0.26	0.26	0.20
9	0.24	0.26	0.26	0.20
10	0.24	0.26	0.26	0.20
11	0.24	0.26	0.26	0.20
12	0.24	0.26	0.26	0.20
13	0.24	0.26	0.26	0.20
14	0.24	0.26	0.26	0.20
15	0.24	0.26	0.26	0.20
16	0.24	0.26	0.26	0.20
17	0.24	0.26	0.26	0.20
18	0.24	0.26	0.26	0.20
19	0.24	0.26	0.26	0.20
Average	***0.24***	***0.26***	***0.26***	***0.20***

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	0.0350	0.2810	0.0700	0.2100	0.0180	0.0700	0.0349	0.2810
COV	0.004	0.001	0.001	0.001	0.005	0.003	0.004	0.001

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	***440,011.00***
Repeatability Test Phase 1	440,002.07
Repeatability Test Phase 2	439,978.06

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	***0.24***
Repeatability Test Phase 1	0.24
Repeatability Test Phase 2	0.24

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).

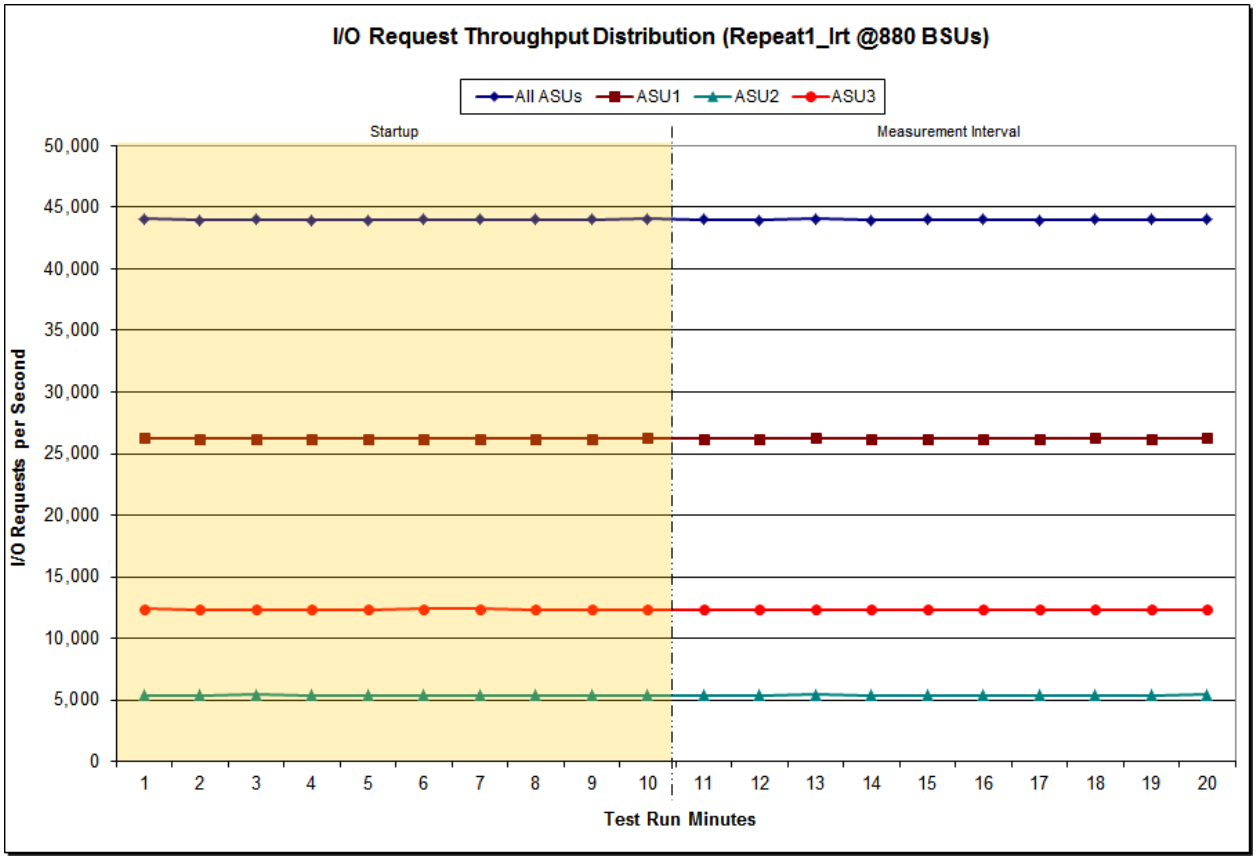
A link to the test result file generated from each Repeatability Test Run is listed below.

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

880 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	7:02:23	7:12:23	0-9	0:10:00
Measurement Interval	7:12:23	7:22:24	9-19	0:10:01
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	44,070.48	26,267.80	5,419.60	12,383.08
1	43,972.87	26,200.28	5,403.10	12,369.48
2	43,980.63	26,206.00	5,422.05	12,352.58
3	43,970.70	26,210.37	5,405.73	12,354.60
4	43,975.33	26,214.93	5,403.63	12,356.77
5	44,016.93	26,216.58	5,415.80	12,384.55
6	43,994.50	26,201.42	5,404.32	12,388.77
7	43,993.28	26,217.08	5,407.60	12,368.60
8	44,002.10	26,211.65	5,416.18	12,374.27
9	44,046.65	26,260.55	5,410.48	12,375.62
10	44,014.73	26,228.02	5,411.87	12,374.85
11	43,965.02	26,210.97	5,397.88	12,356.17
12	44,059.80	26,268.02	5,422.50	12,369.28
13	43,951.60	26,215.58	5,388.55	12,347.47
14	43,992.57	26,203.93	5,417.87	12,370.77
15	43,995.73	26,223.75	5,411.72	12,360.27
16	43,973.63	26,199.58	5,402.93	12,371.12
17	44,007.17	26,249.57	5,408.30	12,349.30
18	43,990.10	26,231.83	5,404.72	12,353.55
19	44,005.38	26,244.80	5,425.43	12,335.15
Average	***43,995.57***	***26,227.61***	***5,409.18***	***12,358.79***

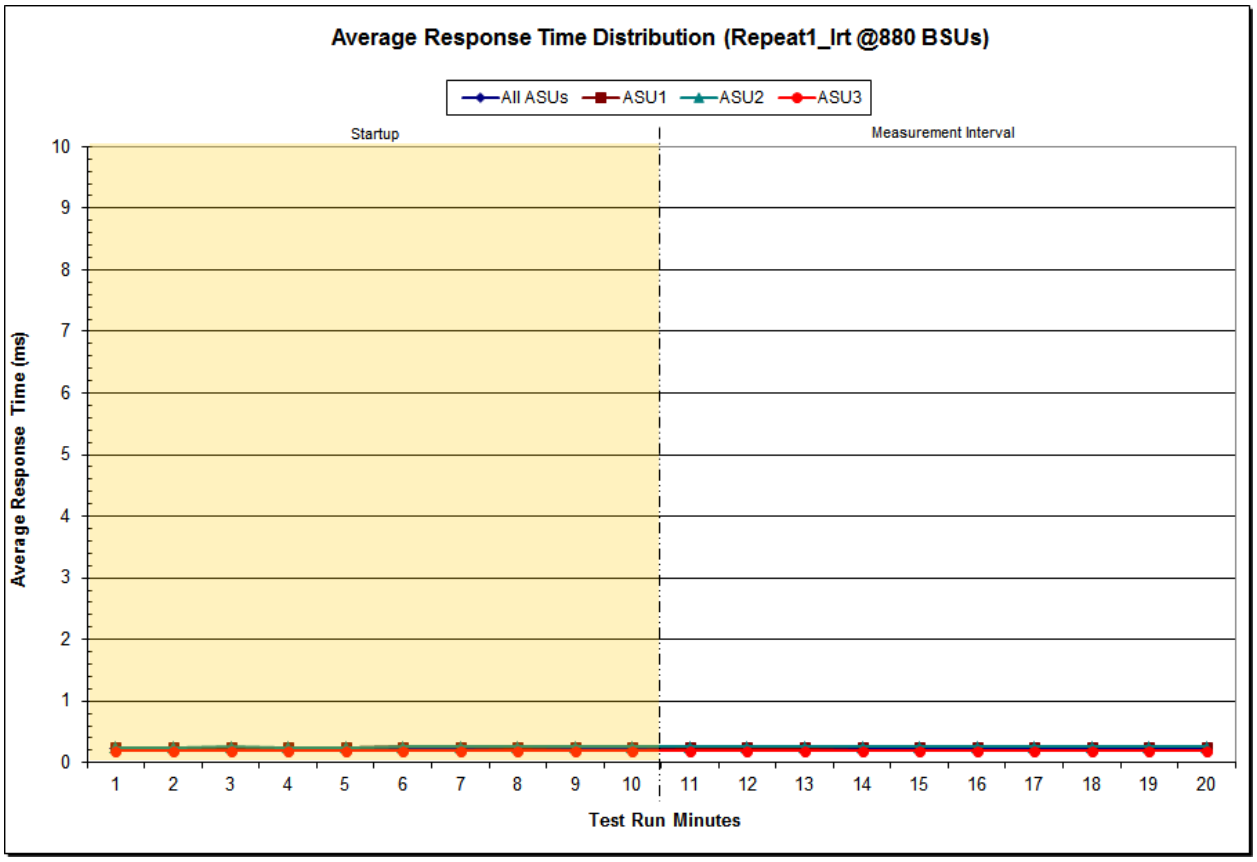
Repeatability 1 LRT – I/O Request Throughput Distribution Graph



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

880 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	7:02:23	7:12:23	0-9	0:10:00
Measurement Interval	7:12:23	7:22:24	9-19	0:10:01
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	0.23	0.25	0.25	0.19
1	0.23	0.25	0.25	0.19
2	0.24	0.25	0.25	0.19
3	0.24	0.25	0.25	0.19
4	0.24	0.25	0.25	0.19
5	0.24	0.25	0.25	0.19
6	0.24	0.25	0.26	0.19
7	0.24	0.25	0.26	0.19
8	0.24	0.25	0.26	0.19
9	0.24	0.25	0.26	0.19
10	0.24	0.25	0.26	0.19
11	0.24	0.25	0.25	0.19
12	0.24	0.25	0.25	0.19
13	0.24	0.25	0.25	0.19
14	0.24	0.26	0.26	0.20
15	0.24	0.26	0.26	0.20
16	0.24	0.26	0.26	0.20
17	0.24	0.26	0.26	0.20
18	0.24	0.26	0.26	0.20
19	0.24	0.25	0.26	0.20
Average	***0.24***	***0.25***	***0.26***	***0.19***

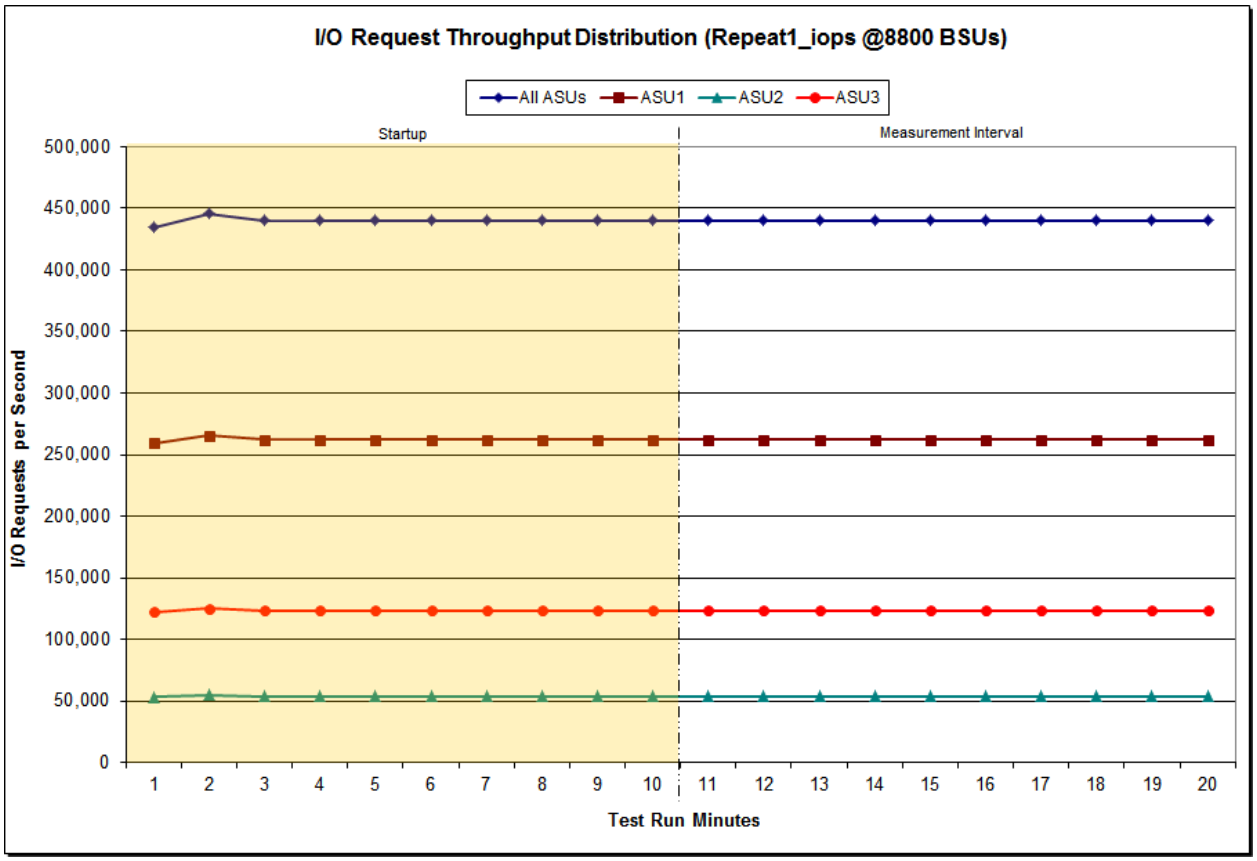
Repeatability 1 LRT –Average Response Time (ms) Distribution Graph



Repeatability 1 IOPS – I/O Request Throughput Distribution Data

8,800 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	7:32:46	7:42:47	0-9	0:10:01
Measurement Interval	7:42:47	7:52:48	9-19	0:10:01
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	434,706.82	259,110.98	53,463.30	122,132.53
1	445,728.43	265,591.48	54,856.30	125,280.65
2	439,979.32	262,258.98	54,141.55	123,578.78
3	439,932.62	262,245.93	54,112.22	123,574.47
4	440,070.02	262,272.45	54,123.02	123,674.55
5	440,191.18	262,245.95	54,216.13	123,729.10
6	440,012.23	262,224.35	54,136.85	123,651.03
7	439,885.08	262,182.93	54,143.00	123,559.15
8	439,941.43	262,268.12	54,115.78	123,557.53
9	440,018.92	262,303.87	54,097.38	123,617.67
10	439,883.93	262,227.32	54,036.60	123,620.02
11	439,986.43	262,212.13	54,106.22	123,668.08
12	439,950.50	262,221.00	54,111.98	123,617.52
13	439,947.47	262,204.25	54,108.73	123,634.48
14	439,843.55	262,162.35	54,135.10	123,546.10
15	440,141.18	262,298.13	54,127.63	123,715.42
16	440,052.60	262,304.92	54,126.75	123,620.93
17	440,073.07	262,275.35	54,093.45	123,704.27
18	440,096.13	262,380.08	54,063.53	123,652.52
19	440,045.83	262,289.82	54,076.32	123,679.70
Average	***440,002.07***	***262,257.54***	***54,098.63***	***123,645.90***

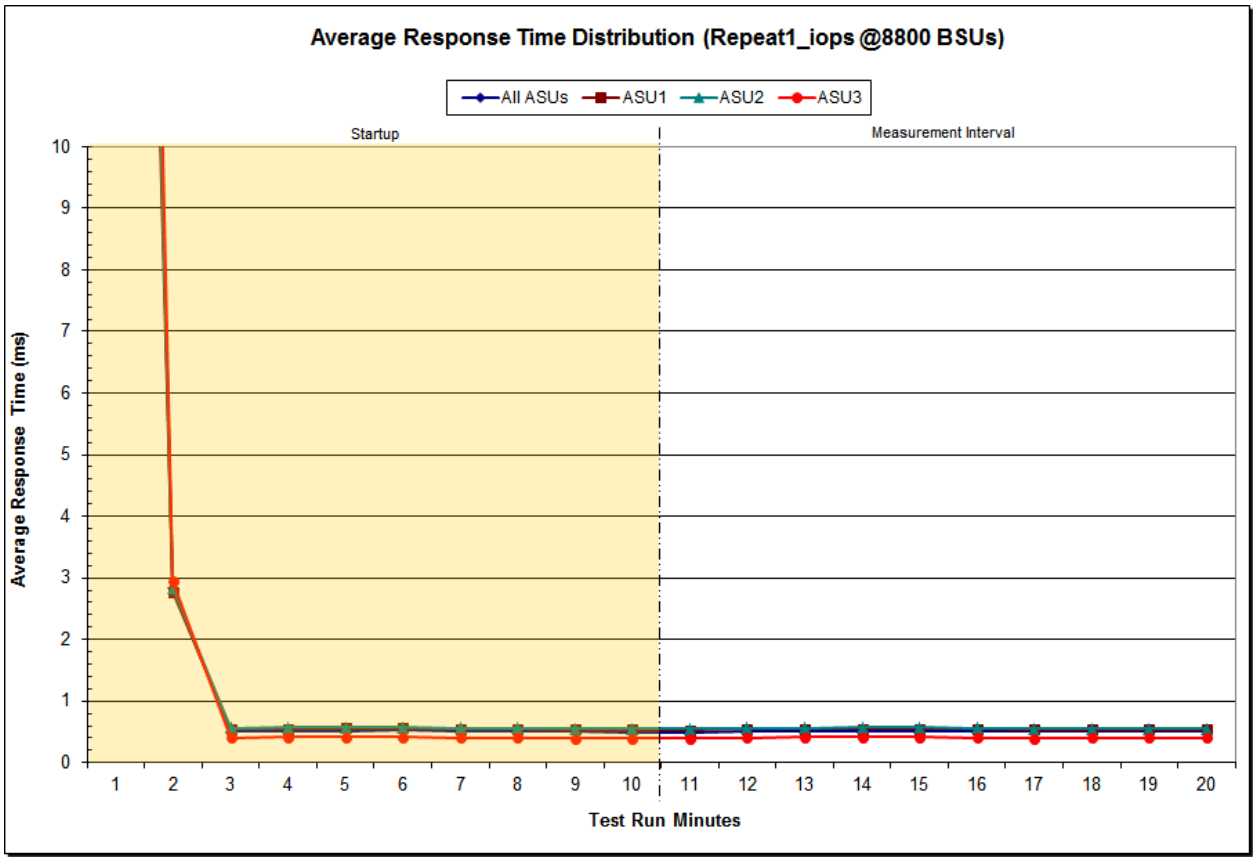
Repeatability 1 IOPS – I/O Request Throughput Distribution Graph



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

8,800 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	7:32:46	7:42:47	0-9	0:10:01
Measurement Interval	7:42:47	7:52:48	9-19	0:10:01
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	38.58	36.20	38.63	43.60
1	2.83	2.78	2.84	2.95
2	0.51	0.55	0.56	0.40
3	0.52	0.56	0.57	0.41
4	0.52	0.56	0.57	0.42
5	0.53	0.56	0.58	0.42
6	0.51	0.55	0.56	0.41
7	0.51	0.55	0.56	0.40
8	0.50	0.54	0.55	0.40
9	0.50	0.54	0.55	0.40
10	0.50	0.53	0.55	0.39
11	0.51	0.55	0.56	0.40
12	0.51	0.55	0.57	0.41
13	0.52	0.56	0.57	0.41
14	0.52	0.56	0.57	0.41
15	0.51	0.55	0.56	0.41
16	0.50	0.54	0.55	0.40
17	0.50	0.54	0.56	0.40
18	0.50	0.54	0.56	0.40
19	0.50	0.54	0.56	0.40
Average	***0.51***	***0.55***	***0.56***	***0.40***

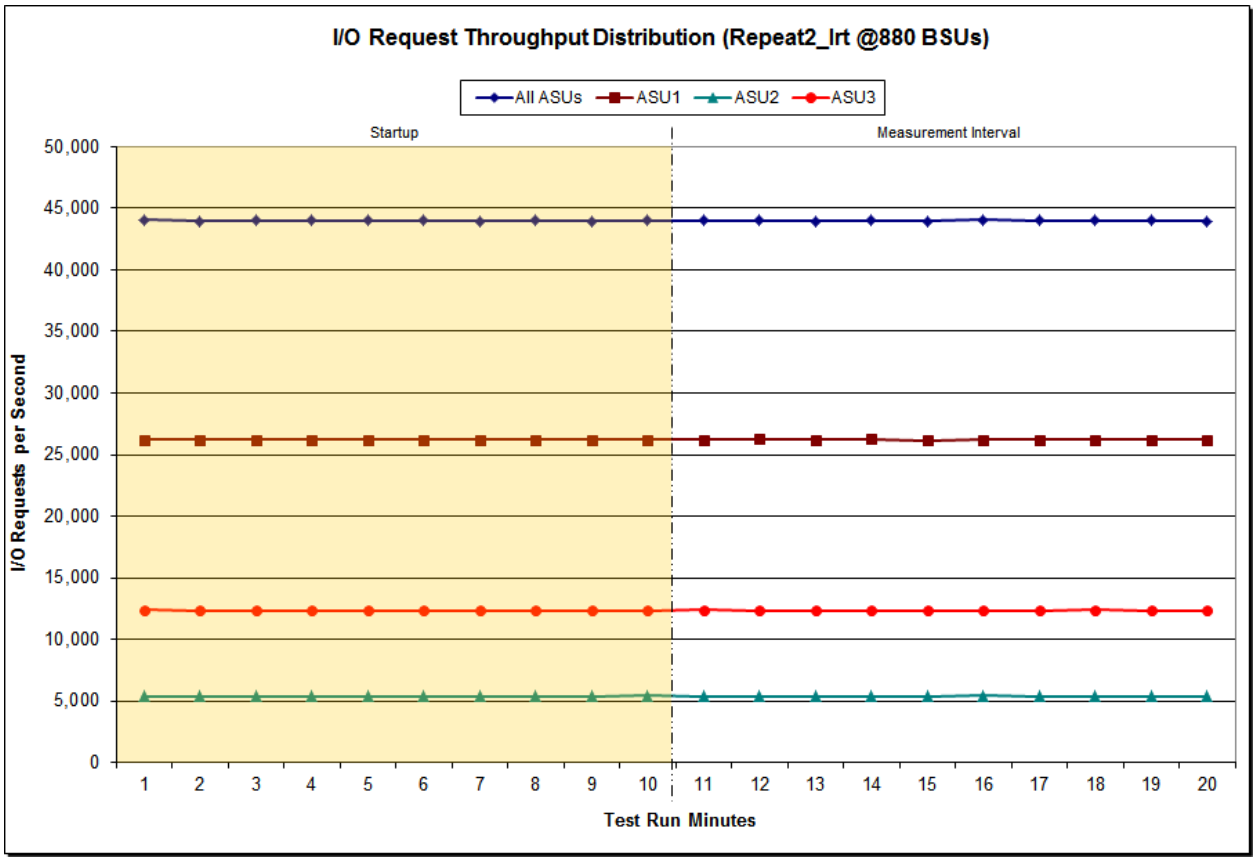
Repeatability 1 IOPS –Average Response Time (ms) Distribution Graph



Repeatability 2 LRT – I/O Request Throughput Distribution Data

880 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	8:01:27	8:11:27	0-9	0:10:00
Measurement Interval	8:11:27	8:21:28	9-19	0:10:01
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	44,039.40	26,222.90	5,417.53	12,398.97
1	43,952.12	26,196.48	5,404.80	12,350.83
2	44,008.17	26,237.38	5,420.82	12,349.97
3	43,983.92	26,231.92	5,414.73	12,337.27
4	43,984.52	26,198.35	5,417.07	12,369.10
5	43,986.80	26,218.18	5,392.67	12,375.95
6	43,968.00	26,201.67	5,409.72	12,356.62
7	44,010.80	26,231.60	5,415.32	12,363.88
8	43,976.32	26,204.45	5,404.33	12,367.53
9	44,030.92	26,231.92	5,424.52	12,374.48
10	43,992.75	26,190.53	5,419.62	12,382.60
11	44,023.17	26,242.92	5,405.53	12,374.72
12	43,961.65	26,196.33	5,412.40	12,352.92
13	44,010.15	26,243.30	5,408.80	12,358.05
14	43,928.58	26,156.08	5,410.05	12,362.45
15	44,033.17	26,236.62	5,423.47	12,373.08
16	44,009.02	26,222.42	5,406.62	12,379.98
17	44,024.27	26,225.02	5,412.22	12,387.03
18	44,008.55	26,223.02	5,421.10	12,364.43
19	43,949.27	26,200.05	5,389.42	12,359.80
Average	***43,994.06***	***26,213.63***	***5,410.92***	***12,369.51***

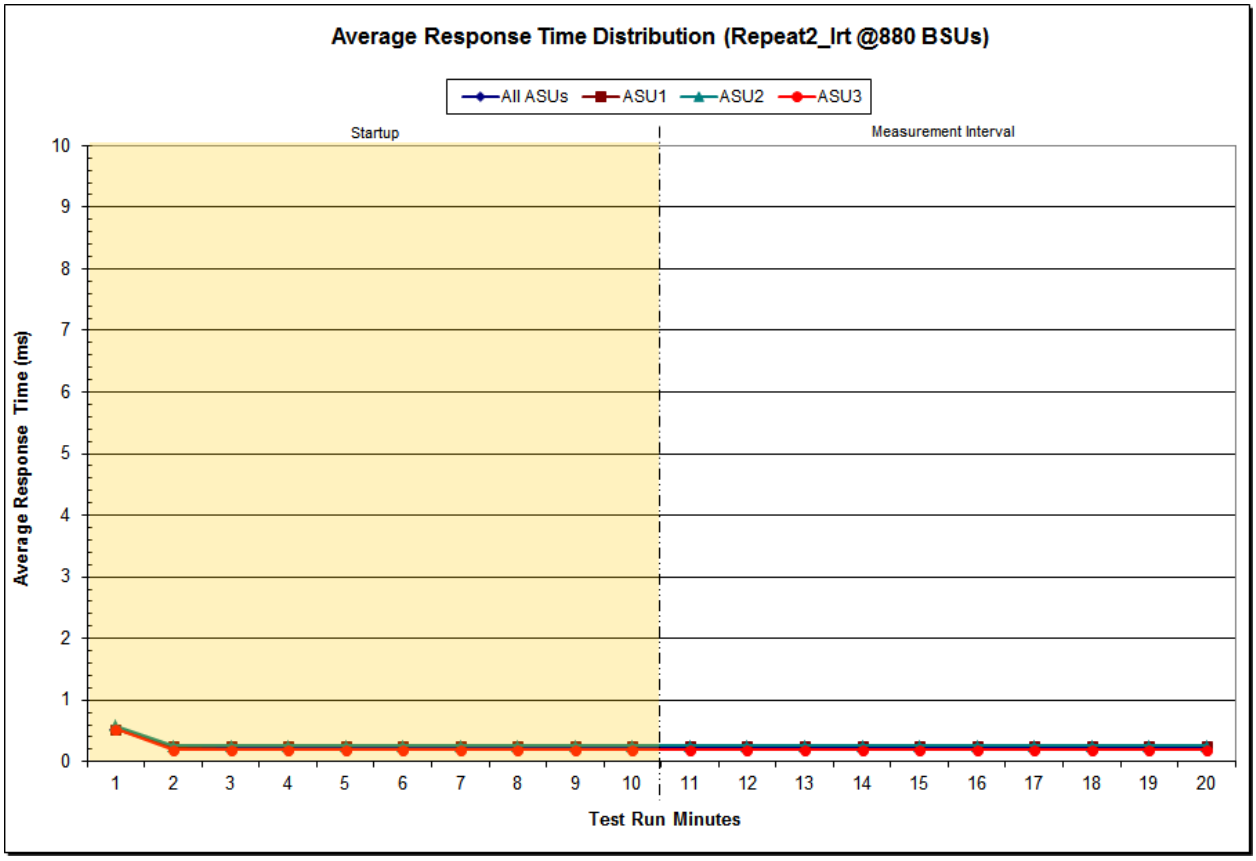
Repeatability 2 LRT – I/O Request Throughput Distribution Graph



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

880 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	8:01:27	8:11:27	0-9	0:10:00
Measurement Interval	8:11:27	8:21:28	9-19	0:10:01
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	0.53	0.53	0.59	0.53
1	0.24	0.25	0.25	0.19
2	0.24	0.25	0.26	0.19
3	0.24	0.25	0.25	0.19
4	0.24	0.25	0.26	0.19
5	0.24	0.25	0.26	0.19
6	0.24	0.25	0.26	0.19
7	0.24	0.25	0.26	0.19
8	0.24	0.25	0.26	0.19
9	0.24	0.26	0.26	0.19
10	0.24	0.25	0.26	0.19
11	0.24	0.26	0.26	0.19
12	0.24	0.26	0.26	0.19
13	0.24	0.26	0.26	0.19
14	0.24	0.26	0.26	0.20
15	0.24	0.26	0.26	0.20
16	0.24	0.26	0.26	0.20
17	0.24	0.26	0.26	0.20
18	0.24	0.26	0.26	0.20
19	0.24	0.26	0.26	0.20
Average	***0.24***	***0.26***	***0.26***	***0.20***

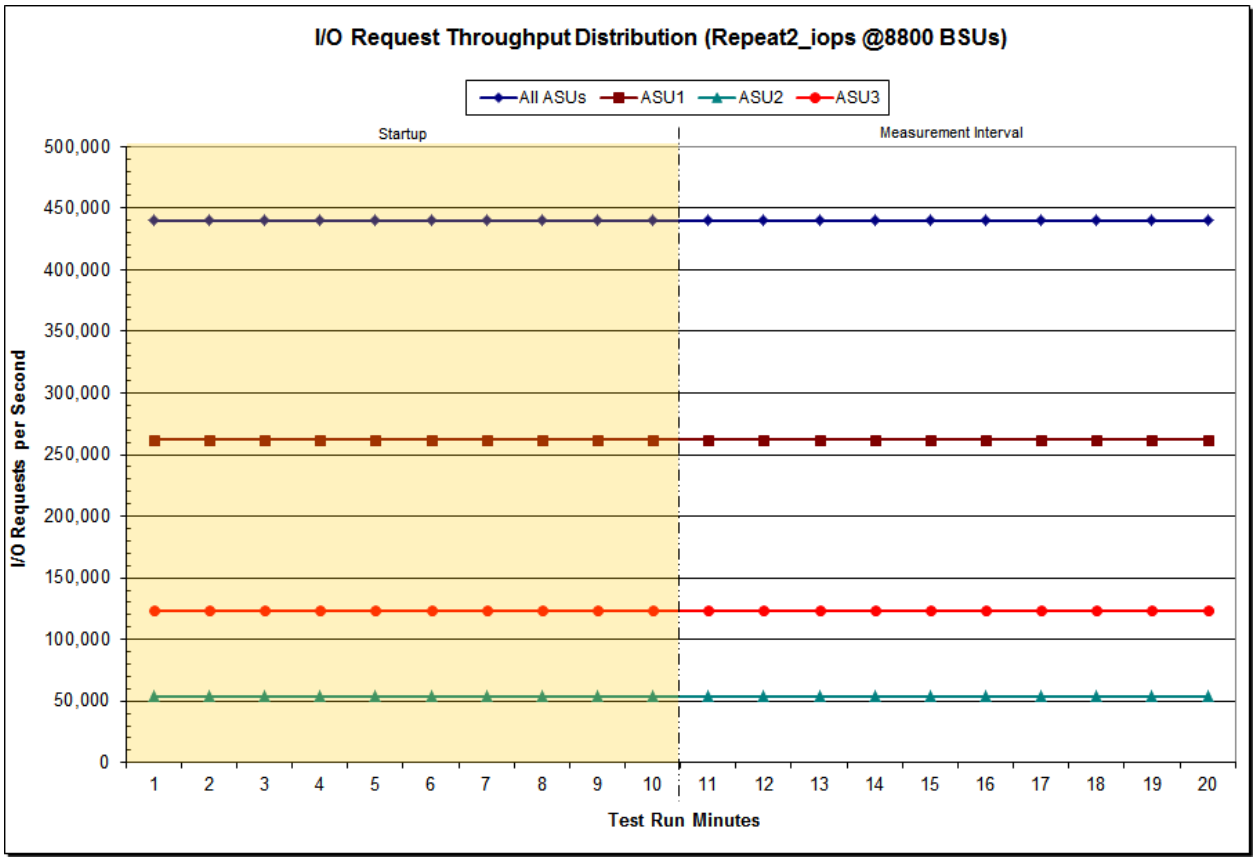
Repeatability 2 LRT –Average Response Time (ms) Distribution Graph



Repeatability 2 IOPS – I/O Request Throughput Distribution Data

8,800 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	8:31:45	8:41:46	0-9	0:10:01
Measurement Interval	8:41:46	8:51:47	9-19	0:10:01
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	440,166.92	262,325.95	54,124.02	123,716.95
1	439,882.10	262,136.73	54,129.00	123,616.37
2	440,116.72	262,255.08	54,170.70	123,690.93
3	440,060.92	262,339.87	54,104.57	123,616.48
4	439,966.57	262,257.88	54,117.65	123,591.03
5	440,010.02	262,281.63	54,085.00	123,643.38
6	440,140.17	262,382.63	54,078.55	123,678.98
7	440,057.10	262,199.02	54,178.72	123,679.37
8	440,065.12	262,284.43	54,117.63	123,663.05
9	439,962.30	262,261.25	54,109.95	123,591.10
10	439,943.17	262,207.17	54,107.85	123,628.15
11	439,784.27	262,022.17	54,109.03	123,653.07
12	440,003.53	262,215.25	54,118.20	123,670.08
13	440,038.48	262,284.08	54,073.50	123,680.90
14	440,055.77	262,303.43	54,106.53	123,645.80
15	440,153.62	262,410.95	54,101.70	123,640.97
16	439,912.40	262,189.42	54,115.67	123,607.32
17	439,961.82	262,199.87	54,118.80	123,643.15
18	439,941.97	262,226.52	54,106.78	123,608.67
19	439,985.57	262,248.15	54,092.27	123,645.15
Average	***439,978.06***	***262,230.70***	***54,105.03***	***123,642.33***

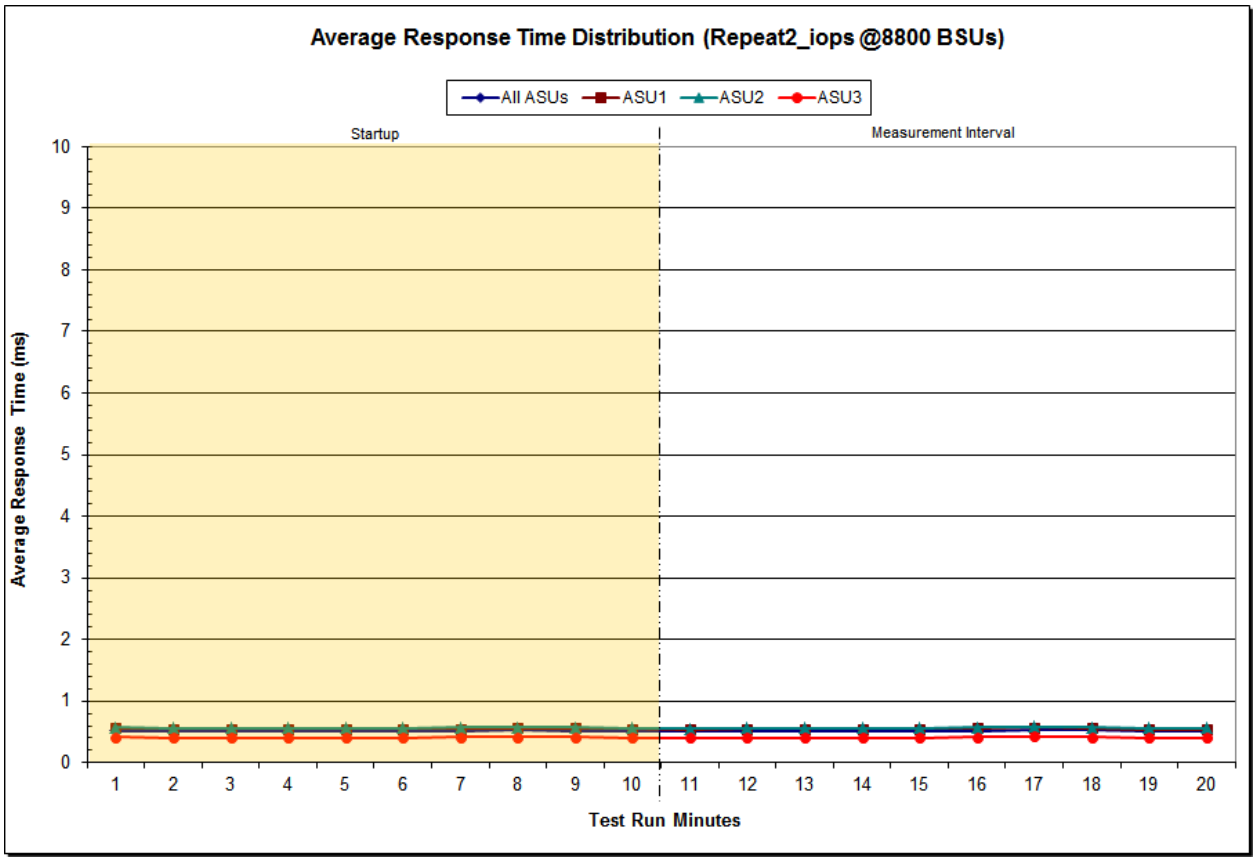
Repeatability 2 IOPS – I/O Request Throughput Distribution Graph



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

8,800 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	8:31:45	8:41:46	0-9	0:10:01
Measurement Interval	8:41:46	8:51:47	9-19	0:10:01
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	0.52	0.56	0.57	0.41
1	0.51	0.55	0.56	0.41
2	0.51	0.55	0.56	0.40
3	0.51	0.55	0.56	0.40
4	0.51	0.55	0.56	0.41
5	0.51	0.55	0.57	0.41
6	0.52	0.56	0.57	0.41
7	0.52	0.56	0.58	0.42
8	0.52	0.56	0.57	0.41
9	0.51	0.55	0.56	0.41
10	0.50	0.54	0.56	0.40
11	0.51	0.55	0.56	0.41
12	0.51	0.55	0.56	0.41
13	0.51	0.55	0.56	0.41
14	0.51	0.55	0.56	0.41
15	0.52	0.56	0.57	0.42
16	0.53	0.57	0.58	0.43
17	0.52	0.56	0.58	0.42
18	0.50	0.54	0.56	0.40
19	0.50	0.54	0.56	0.40
Average	***0.51***	***0.55***	***0.56***	***0.41***

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	0.0350	0.2812	0.0700	0.2099	0.0180	0.0699	0.0350	0.2809
COV	0.004	0.001	0.003	0.001	0.005	0.002	0.004	0.001

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	0.2100	0.0180	0.0700	0.0350	0.2810
COV	0.001	0.000	0.001	0.000	0.002	0.001	0.001	0.000

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	0.0350	0.2809	0.0700	0.2100	0.0180	0.0700	0.0350	0.2810
COV	0.004	0.001	0.002	0.001	0.004	0.002	0.004	0.001

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

	ASU1-1	ASU1-2	ASU1-3	ASU1-4	ASU2-1	ASU2-2	ASU2-3	ASU3-1
IM	***0.0350***	***0.2810***	***0.0700***	***0.2100***	***0.0180***	***0.0700***	***0.0350***	***0.2810***
MIM	0.0350	0.2810	0.0700	0.2100	0.0180	0.0700	0.0350	0.2810
COV	0.001	0.000	0.001	0.000	0.002	0.001	0.001	0.000

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	2,484,348
Total Number of Logical Blocks Verified	2,392,793
Total Number of Logical Blocks that Failed Verification	0
Time Duration for Writing Test Logical Blocks	5 minutes
Size in bytes of each Logical Block	1024
Number of Failed I/O Requests in the process of the Test	0

If approved by the SPC Auditor, the SPC-2 Persistence Test may be used to meet the SPC-1 persistence requirements. Both the SPC-1 and SPC-2 Persistence Tests provide the same level of functionality and verification of data integrity. The SPC-2 Persistence Test may be easily configured to address an SPC-1 storage configuration. The SPC-2 Persistence Test extends the size of storage configurations that may be tested and significantly reduces the test duration of such configurations.

The SPC-2 Persistence Test was approved for use in this set of audited measurements.

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 IBM FlashSystem® 900 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 18.

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 18.

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 FlashSystem® 900.

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.

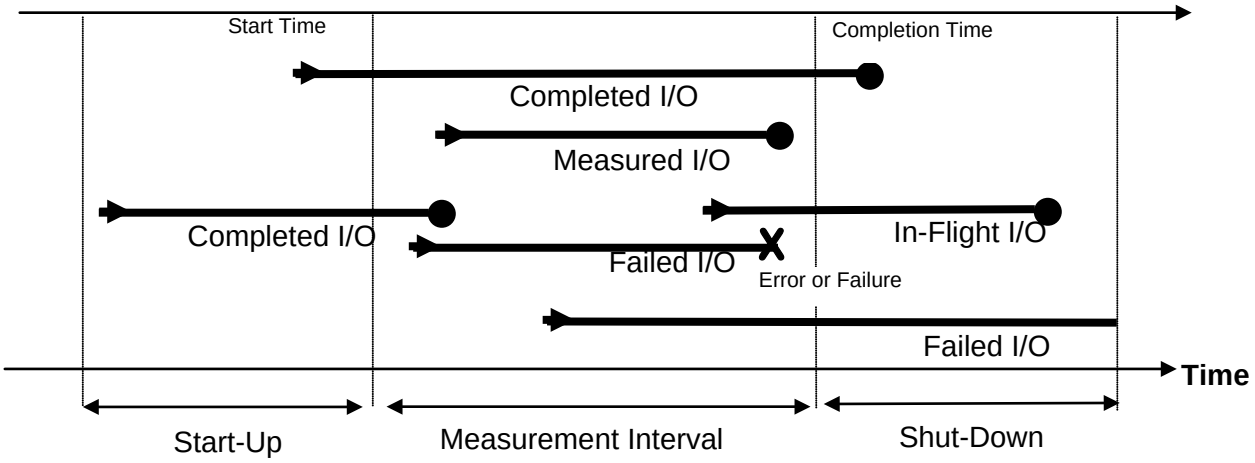
Steady State: The consistent and sustainable throughput of the TSC. During this period the load presented to the TSC by the Workload Generator is constant.

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

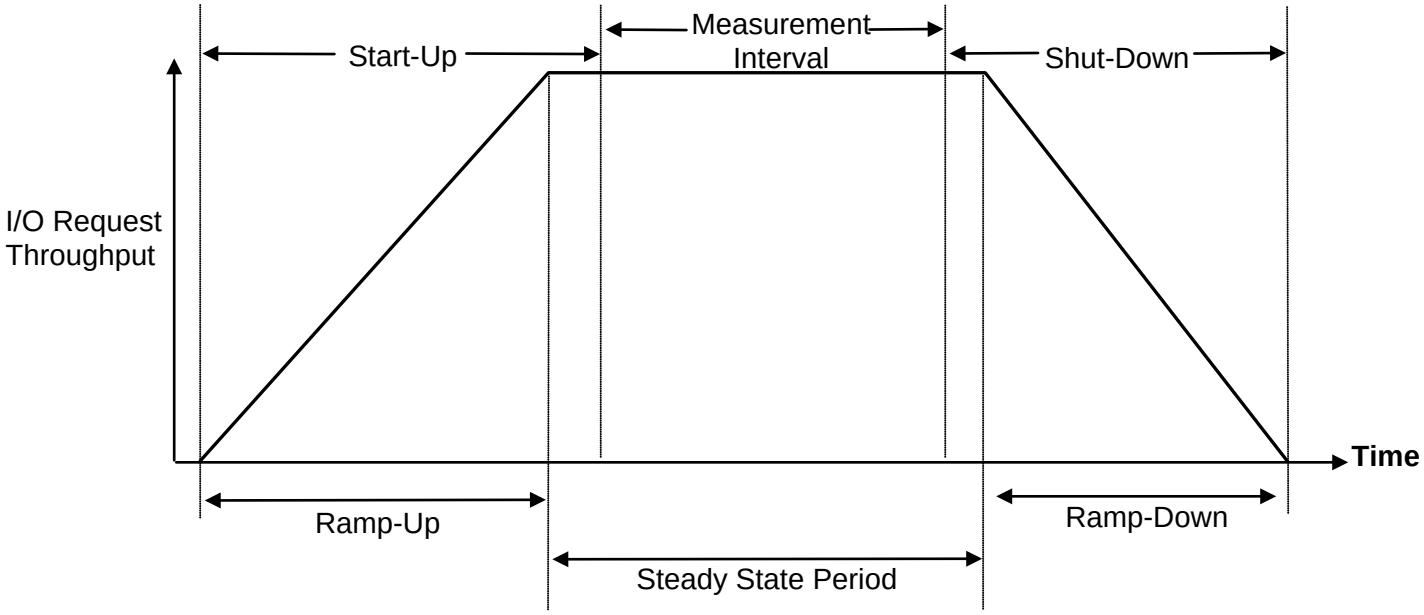
Test Run: The execution of SPC-1 for the purpose of producing or supporting an SPC-1 test result. SPC-1 Test Runs may have a finite and measured Ramp-Up period, Start-Up period, Shut-Down period, and Ramp-Down period as illustrated in the "SPC-1 Test Run Components" below. All SPC-1 Test Runs shall have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

The queue depth of each LUN (**queue_depth**) was set to 256 from a default value of 64. The maximum transfer size of each LUN (**max-transfer**) was explicitly set to 1 MiB, which is the default value of the parameter.

The two parameters were changed by execution of the commands documented in the **AIX Configuration** section on page 74.

A number of tuning steps were executed on the AIX Host System to allow a large number of IOPS when using a single AIX Host System. Each of those steps is documented with the command to change the value and a brief description in the **AIX Tuning Parameters** section on page 75

APPENDIX C: TESTED STORAGE CONFIGURATION (TSC) CREATION

FlashSystem 900 Configuration

The FlashSystem 900 was configured using CLI, which is a login shell interface accessed via PuTTY. The CLI has been ported from that provided by SVC but with some added commands useful for FlashSystem 900.

The first configuration step is the creation of the RAID-5 array of twelve 4TiB flashcards.

```
#create RAID-5 array, 11 members and 1 spare
mkarray –level raid5
```

Following creation of the array, 32 volumes (LUs) each of size 1082 GiB are created. The volumes were named **lun0, lun1**…**lun31**.

```
#create 32 X 1081GiB
let i=0;while ((i<32));do
mkvdisk -iogrp io_grp0 -mdiskgrp 0 -name lun_$i -size 1081 -unit gb
let i=i+1;done
```

The port topology was set to point-to-point, corresponding to host connections through a 48-port 16Gb switch.

```
#set port topology to point-to-point
let i=0;while ((i<8));do
chportfc –topology pp $i
let i=i+1;done
```

Open Access was enabled on the storage system. This is an alternative to manual mapping of LUs to host wwpns *(host mappings were managed by the system).*

```
#enable open access
chsystem –name bigtexan –openaccess on
```

AIX Configuration

The SPC-1 Logical Volumes, which comprised the three SPC-1 ASUs, were configured using an AIX command shell on the same AIX Host System.

The first step of configuring the volumes was to execute the command **cfgmgr**, causing 32 hdisks *(LUs created in the first configuration step)* named **hdisk2**, **hdisk3**…**hdisk33** to be discovered.

The queue depth and transfer size of each hdisk were set respectively to 256 and 1 MiB using the following commands:

```
#change IBM FlashSystem hdisk attributes
for i in $(lsdev -Cc disk | grep FlashSystem | awk '{print $1}');do
chdev -l $i -a queue_depth=256
chdev -l $i -a max_transfer=0x100000
done
```

The 32 volumes were then placed into a striped logical volume group (LVG) with the following commands:

```
#use 32 x 1081 GiB hdisks in an LVG with PP size 128 MiB, total 276736 PP
hfield=$(lsdev -Cc disk | grep 'MPIO' | awk '{print $1}')
mkvg -fy thinstripevg -S -P 2048 -s 128 $hfield
```

From the storage of the LVG, 40 logical volumes named **thin1**, **thin2** … **thin40** were created with a size of 5,760 PPs *(128 MiB per PP)* using the following commands:

```
#create 40 LVs, stripe across all hdisks with striped size 32MB
let i=1;while ((i<41));do
mklv -b n -y thin$i -x 32512 -u 32 -S 32M thinstripevg 5760
let i=i+1;done
```

Five additional logical volumes named **thin41**, **thin42** … **thin45** were created with a size of 5,120 PPs using the commands:

```
#create 5 LVs, stripe across all hdisks with striped size 32MB
let i=41;while ((i<46));do
mklv -b n -y thin$i -x 32512 -u 32 -S 32M thinstripevg 5120
let i=i+1;done
```

AIX Tuning Parameters

Tuning steps were taken to permit large levels of IOPS when running on an AIX host. The needed tuning was implemented with the following shell commands issued by the root user:

```
schedo -p -o vpm_fold_policy=0  #disable virtual processor management.
schedo -p -o smt_snooze_delay=-1  #disable snoozing while idle.
schedo -p -o smt_tertiary_snooze_delay=-1 #disable tertiary snoozing.
dscrctl -b -n -s 1 #disable stream prefetch
ioo –o spec_accessupdate=1 #disable raw device file access/update times.
```

The effects of these changes were then saved to the boot image with the command:

```
bosboot –a
```

The AIX Host System was then rebooted.

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
sd=default,threads=1

sd=sd1,size=773094113280,lun=/dev/rthin1
sd=sd2,size=773094113280,lun=/dev/rthin2
sd=sd3,size=773094113280,lun=/dev/rthin3
sd=sd4,size=773094113280,lun=/dev/rthin4
sd=sd5,size=773094113280,lun=/dev/rthin5
sd=sd6,size=773094113280,lun=/dev/rthin6
sd=sd7,size=773094113280,lun=/dev/rthin7
sd=sd8,size=773094113280,lun=/dev/rthin8
sd=sd9,size=773094113280,lun=/dev/rthin9
sd=sd10,size=773094113280,lun=/dev/rthin10
sd=sd11,size=773094113280,lun=/dev/rthin11
sd=sd12,size=773094113280,lun=/dev/rthin12
sd=sd13,size=773094113280,lun=/dev/rthin13
sd=sd14,size=773094113280,lun=/dev/rthin14
sd=sd15,size=773094113280,lun=/dev/rthin15
sd=sd16,size=773094113280,lun=/dev/rthin16
sd=sd17,size=773094113280,lun=/dev/rthin17
sd=sd18,size=773094113280,lun=/dev/rthin18
sd=sd19,size=773094113280,lun=/dev/rthin19
sd=sd20,size=773094113280,lun=/dev/rthin20
sd=sd21,size=773094113280,lun=/dev/rthin21
sd=sd22,size=773094113280,lun=/dev/rthin22
sd=sd23,size=773094113280,lun=/dev/rthin23
sd=sd24,size=773094113280,lun=/dev/rthin24
sd=sd25,size=773094113280,lun=/dev/rthin25
sd=sd26,size=773094113280,lun=/dev/rthin26
sd=sd27,size=773094113280,lun=/dev/rthin27
sd=sd28,size=773094113280,lun=/dev/rthin28
sd=sd29,size=773094113280,lun=/dev/rthin29
sd=sd30,size=773094113280,lun=/dev/rthin30
sd=sd31,size=773094113280,lun=/dev/rthin31
sd=sd32,size=773094113280,lun=/dev/rthin32
sd=sd33,size=773094113280,lun=/dev/rthin33
sd=sd34,size=773094113280,lun=/dev/rthin34
sd=sd35,size=773094113280,lun=/dev/rthin35
sd=sd36,size=773094113280,lun=/dev/rthin36
sd=sd37,size=773094113280,lun=/dev/rthin37
sd=sd38,size=773094113280,lun=/dev/rthin38
sd=sd39,size=773094113280,lun=/dev/rthin39
sd=sd40,size=773094113280,lun=/dev/rthin40
sd=sd41,size=687194767360,lun=/dev/rthin41
sd=sd42,size=687194767360,lun=/dev/rthin42
sd=sd43,size=687194767360,lun=/dev/rthin43
sd=sd44,size=687194767360,lun=/dev/rthin44
sd=sd45,size=687194767360,lun=/dev/rthin45

wd=default,rdpct=0,seek=-1,xfersize=256K
```

```
wd=wd1,sd=sd1
wd=wd2,sd=sd2
wd=wd3,sd=sd3
wd=wd4,sd=sd4
wd=wd5,sd=sd5
wd=wd6,sd=sd6
wd=wd7,sd=sd7
wd=wd8,sd=sd8
wd=wd9,sd=sd9
wd=wd10,sd=sd10
wd=wd11,sd=sd11
wd=wd12,sd=sd12
wd=wd13,sd=sd13
wd=wd14,sd=sd14
wd=wd15,sd=sd15
wd=wd16,sd=sd16
wd=wd17,sd=sd17
wd=wd18,sd=sd18
wd=wd19,sd=sd19
wd=wd20,sd=sd20
wd=wd21,sd=sd21
wd=wd22,sd=sd22
wd=wd23,sd=sd23
wd=wd24,sd=sd24
wd=wd25,sd=sd25
wd=wd26,sd=sd26
wd=wd27,sd=sd27
wd=wd28,sd=sd28
wd=wd29,sd=sd29
wd=wd30,sd=sd30
wd=wd31,sd=sd31
wd=wd32,sd=sd32
wd=wd33,sd=sd33
wd=wd34,sd=sd34
wd=wd35,sd=sd35
wd=wd36,sd=sd36
wd=wd37,sd=sd37
wd=wd38,sd=sd38
wd=wd39,sd=sd39
wd=wd40,sd=sd40
wd=wd41,sd=sd41
wd=wd42,sd=sd42
wd=wd43,sd=sd43
wd=wd44,sd=sd44
wd=wd45,sd=sd45

*==================================
* Use 20 hours as a maximum elapsed time,
* which should ensure the entire LBA range
* will be written before the time elapses
*==================================
*
rd=FILLIT,wd=wd*,iorate=max,elapsed=72000,interval=10
*
* The above "elapsed=72000" may have to be increased to ensure that the utility will
reach
* the end of the LUN ("seek=-1") prior to the end of the specified elapsed time
```

Common Command Lines – Primary Metrics, Repeatability and SPC-1 Persistence Test.

The following command lines appear in the command and parameter files for the Primary Metrics, Repeatability and reduced level SPC-1 Persistence Test. The command lines are only listed below to eliminate redundancy.

```
javaparms="-Xms1280m -Xmx1280m -Xss256k -Xgcpolicy:optavgpause"
sd=default
sd=asu1_1,size=773094113280,lun=/dev/rthin1
sd=asu1_2,size=773094113280,lun=/dev/rthin2
sd=asu1_3,size=773094113280,lun=/dev/rthin3
sd=asu1_4,size=773094113280,lun=/dev/rthin4
sd=asu1_5,size=773094113280,lun=/dev/rthin5
sd=asu1_6,size=773094113280,lun=/dev/rthin6
sd=asu1_7,size=773094113280,lun=/dev/rthin7
sd=asu1_8,size=773094113280,lun=/dev/rthin8
sd=asu1_9,size=773094113280,lun=/dev/rthin9
sd=asu1_10,size=773094113280,lun=/dev/rthin10
sd=asu1_11,size=773094113280,lun=/dev/rthin11
sd=asu1_12,size=773094113280,lun=/dev/rthin12
sd=asu1_13,size=773094113280,lun=/dev/rthin13
sd=asu1_14,size=773094113280,lun=/dev/rthin14
sd=asu1_15,size=773094113280,lun=/dev/rthin15
sd=asu1_16,size=773094113280,lun=/dev/rthin16
sd=asu1_17,size=773094113280,lun=/dev/rthin17
sd=asu1_18,size=773094113280,lun=/dev/rthin18
sd=asu1_19,size=773094113280,lun=/dev/rthin19
sd=asu1_20,size=773094113280,lun=/dev/rthin20
sd=asu2_1,size=773094113280,lun=/dev/rthin21
sd=asu2_2,size=773094113280,lun=/dev/rthin22
sd=asu2_3,size=773094113280,lun=/dev/rthin23
sd=asu2_4,size=773094113280,lun=/dev/rthin24
sd=asu2_5,size=773094113280,lun=/dev/rthin25
sd=asu2_6,size=773094113280,lun=/dev/rthin26
sd=asu2_7,size=773094113280,lun=/dev/rthin27
sd=asu2_8,size=773094113280,lun=/dev/rthin28
sd=asu2_9,size=773094113280,lun=/dev/rthin29
sd=asu2_10,size=773094113280,lun=/dev/rthin30
sd=asu2_11,size=773094113280,lun=/dev/rthin31
sd=asu2_12,size=773094113280,lun=/dev/rthin32
sd=asu2_13,size=773094113280,lun=/dev/rthin33
sd=asu2_14,size=773094113280,lun=/dev/rthin34
sd=asu2_15,size=773094113280,lun=/dev/rthin35
sd=asu2_16,size=773094113280,lun=/dev/rthin36
sd=asu2_17,size=773094113280,lun=/dev/rthin37
sd=asu2_18,size=773094113280,lun=/dev/rthin38
sd=asu2_19,size=773094113280,lun=/dev/rthin39
sd=asu2_20,size=773094113280,lun=/dev/rthin40
sd=asu3_1,size=687194767360,lun=/dev/rthin41
sd=asu3_2,size=687194767360,lun=/dev/rthin42
sd=asu3_3,size=687194767360,lun=/dev/rthin43
sd=asu3_4,size=687194767360,lun=/dev/rthin44
sd=asu3_5,size=687194767360,lun=/dev/rthin45
```

Primary Metrics and Repeatability 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)* and Repeatability *(Repeatability Test Phase 1 and Repeatability Test Phase 2)* Tests is listed below.

command command lines 1

```
host=master
slaves=(slav1,slav2,slav3,slav4,slav5,slav6,slav7,slav8,slav9,slav10,slav11,slav12,s
lav13,slav14,slav15,slav16,slav17,slav18,slav19,slav20,slav21,slav22,slav23,slav24,s
lav25,slav26,slav27,slav28,slav29,slav30,slav31,slav32,slav33,slav34,slav35,slav36,s
lav37,slav38,slav39,slav40,slav41,slav42,slav43,slav44,slav45,slav46,slav47,slav48,s
lav49,slav50,slav51,slav52,slav53,slav54,slav55,slav56,slav57,slav58,slav59,slav60,s
lav61,slav62,slav63,slav64,slav65,slav66,slav67,slav68,slav69,slav70,slav71,slav72,s
lav73,slav74,slav75,slav76,slav77,slav78,slav79,slav80,slav81,slav82,slav83,slav84,s
lav85,slav86,slav87,slav88)
```

SPC-1 Persistence

The content of SPC-1 Workload Generator command and parameter file, used in this benchmark to execute the reduced level SPC-1 Persistence Test, is listed below.

command command lines 1

SPC-2 Persistence Test

If approved by the SPC Auditor, the SPC-2 Persistence Test may be used to meet the SPC-1 persistence requirements. Both the SPC-1 and SPC-2 Persistence Tests provide the same level of functionality and verification of data integrity.

Common Command Lines – SPC-2 Persistence Test

The following command lines appear at the beginning of each command and parameter file for the two SPC-2 Persistence Test Runs. The command lines are only listed below to eliminate redundancy.

```
host=localhost,jvms=16,maxstreams=200

sd=default
sd=sd1,size=773094113280,lun=/dev/rthin1
sd=sd2,size=773094113280,lun=/dev/rthin2
sd=sd3,size=773094113280,lun=/dev/rthin3
sd=sd4,size=773094113280,lun=/dev/rthin4
sd=sd5,size=773094113280,lun=/dev/rthin5
sd=sd6,size=773094113280,lun=/dev/rthin6
sd=sd7,size=773094113280,lun=/dev/rthin7
sd=sd8,size=773094113280,lun=/dev/rthin8
sd=sd9,size=773094113280,lun=/dev/rthin9
sd=sd10,size=773094113280,lun=/dev/rthin10
sd=sd11,size=773094113280,lun=/dev/rthin11
sd=sd12,size=773094113280,lun=/dev/rthin12
sd=sd13,size=773094113280,lun=/dev/rthin13
sd=sd14,size=773094113280,lun=/dev/rthin14
sd=sd15,size=773094113280,lun=/dev/rthin15
```

```
sd=sd16,size=773094113280,lun=/dev/rthin16
sd=sd17,size=773094113280,lun=/dev/rthin17
sd=sd18,size=773094113280,lun=/dev/rthin18
sd=sd19,size=773094113280,lun=/dev/rthin19
sd=sd20,size=773094113280,lun=/dev/rthin20
sd=sd21,size=773094113280,lun=/dev/rthin21
sd=sd22,size=773094113280,lun=/dev/rthin22
sd=sd23,size=773094113280,lun=/dev/rthin23
sd=sd24,size=773094113280,lun=/dev/rthin24
sd=sd25,size=773094113280,lun=/dev/rthin25
sd=sd26,size=773094113280,lun=/dev/rthin26
sd=sd27,size=773094113280,lun=/dev/rthin27
sd=sd28,size=773094113280,lun=/dev/rthin28
sd=sd29,size=773094113280,lun=/dev/rthin29
sd=sd30,size=773094113280,lun=/dev/rthin30
sd=sd31,size=773094113280,lun=/dev/rthin31
sd=sd32,size=773094113280,lun=/dev/rthin32
sd=sd33,size=773094113280,lun=/dev/rthin33
sd=sd34,size=773094113280,lun=/dev/rthin34
sd=sd35,size=773094113280,lun=/dev/rthin35
sd=sd36,size=773094113280,lun=/dev/rthin36
sd=sd37,size=773094113280,lun=/dev/rthin37
sd=sd38,size=773094113280,lun=/dev/rthin38
sd=sd39,size=773094113280,lun=/dev/rthin39
sd=sd40,size=773094113280,lun=/dev/rthin40
sd=sd41,size=687194767360,lun=/dev/rthin41
sd=sd42,size=687194767360,lun=/dev/rthin42
sd=sd43,size=687194767360,lun=/dev/rthin43
sd=sd44,size=687194767360,lun=/dev/rthin44
sd=sd45,size=687194767360,lun=/dev/rthin45

maxlatestart=1
reportinginterval=5
segmentlength=512m
```

SPC-2 Persistence Test Run 1 *(write phase)*

```
* Persistence Test Run 1, maxstreams should be greater than target BSU divided by 30
common commands 2
rd=default,rampup=180,periods=90,measurement=300,runout=0,rampdown=0,buffers=1

common commands 2

rd=default,rdpct=0,xfersize=1024k
rd=TR1-5s_SPC-2-persist-w,streams=384
```

SPC-2 Persistence Test Run 2 *(read phase)*

```
* Persistence Test Run 2

common commands 2

maxpersistenceerrors=10
*corruptstreams=3

rd=default,buffers=1,rdpct=100,xfersize=1024k
rd=TR1-5s_SPC-2-persist-r
```

Slave JVMs

Each Slave JVM was invoked with a command and parameter file similar to the example listed below. The only difference in each file was **host** parameter value, which was unique to each Slave JVM, e.g. ***slav1…slav88***.

```
master=perfsh9a
host=slav1
sd=asu1_1,size=773094113280,lun=/dev/rthin1
sd=asu1_2,size=773094113280,lun=/dev/rthin2
sd=asu1_3,size=773094113280,lun=/dev/rthin3
sd=asu1_4,size=773094113280,lun=/dev/rthin4
sd=asu1_5,size=773094113280,lun=/dev/rthin5
sd=asu1_6,size=773094113280,lun=/dev/rthin6
sd=asu1_7,size=773094113280,lun=/dev/rthin7
sd=asu1_8,size=773094113280,lun=/dev/rthin8
sd=asu1_9,size=773094113280,lun=/dev/rthin9
sd=asu1_10,size=773094113280,lun=/dev/rthin10
sd=asu1_11,size=773094113280,lun=/dev/rthin11
sd=asu1_12,size=773094113280,lun=/dev/rthin12
sd=asu1_13,size=773094113280,lun=/dev/rthin13
sd=asu1_14,size=773094113280,lun=/dev/rthin14
sd=asu1_15,size=773094113280,lun=/dev/rthin15
sd=asu1_16,size=773094113280,lun=/dev/rthin16
sd=asu1_17,size=773094113280,lun=/dev/rthin17
sd=asu1_18,size=773094113280,lun=/dev/rthin18
sd=asu1_19,size=773094113280,lun=/dev/rthin19
sd=asu1_20,size=773094113280,lun=/dev/rthin20
sd=asu2_1,size=773094113280,lun=/dev/rthin21
sd=asu2_2,size=773094113280,lun=/dev/rthin22
sd=asu2_3,size=773094113280,lun=/dev/rthin23
sd=asu2_4,size=773094113280,lun=/dev/rthin24
sd=asu2_5,size=773094113280,lun=/dev/rthin25
sd=asu2_6,size=773094113280,lun=/dev/rthin26
sd=asu2_7,size=773094113280,lun=/dev/rthin27
sd=asu2_8,size=773094113280,lun=/dev/rthin28
sd=asu2_9,size=773094113280,lun=/dev/rthin29
sd=asu2_10,size=773094113280,lun=/dev/rthin30
sd=asu2_11,size=773094113280,lun=/dev/rthin31
sd=asu2_12,size=773094113280,lun=/dev/rthin32
sd=asu2_13,size=773094113280,lun=/dev/rthin33
sd=asu2_14,size=773094113280,lun=/dev/rthin34
sd=asu2_15,size=773094113280,lun=/dev/rthin35
sd=asu2_16,size=773094113280,lun=/dev/rthin36
sd=asu2_17,size=773094113280,lun=/dev/rthin37
sd=asu2_18,size=773094113280,lun=/dev/rthin38
sd=asu2_19,size=773094113280,lun=/dev/rthin39
sd=asu2_20,size=773094113280,lun=/dev/rthin40
sd=asu3_1,size=687194767360,lun=/dev/rthin41
sd=asu3_2,size=687194767360,lun=/dev/rthin42
sd=asu3_3,size=687194767360,lun=/dev/rthin43
sd=asu3_4,size=687194767360,lun=/dev/rthin44
sd=asu3_5,size=687194767360,lun=/dev/rthin45
```

APPENDIX E: SPC-1 WORKLOAD GENERATOR INPUT PARAMETERS

The following script was used to execute the required ASU pre-fill, SPC-1E Idle Test, 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)*, a reduced BSU level SPC-1 Persistence Test Run 1 *(write phase)* and SPC-2 Persistence Test Run 1 *(write phase)* in an uninterrupted sequence.

The script also included commands to capture various TSC profile listings used for audit documentation.

The, **runpersist2.sh**, script was used to execute the SPC-2 Persistence Test Run 2 *(read phase)* after completion of the required TSC power off/power on cycle.

runall.sh

```
rm -fr SPCOut
#Collect FS900 configuration details pre-run
getlvmdata.sh prerun
datestamp=$(date +%s)
echo "---- START PRELOG ----" $(date) | tee -a FS900.$datestamp.config.txt
echo "---- lsarray ---" >> FS900.$datestamp.config.txt
ssh -p 26 root@9.11.210.136 lsarray -bytes >> FS900.$datestamp.config.txt
echo "---- lsdrive ---" >> FS900.$datestamp.config.txt
ssh -p 26 root@9.11.210.136 lsdrive -bytes >> FS900.$datestamp.config.txt
echo "---- lsenclosure ---" >> FS900.$datestamp.config.txt
ssh -p 26 root@9.11.210.136 lsenclosure >> FS900.$datestamp.config.txt
echo "---- lsenclosurebattery ---" >> FS900.$datestamp.config.txt
ssh -p 26 root@9.11.210.136 lsenclosurebattery >> FS900.$datestamp.config.txt
echo "---- lsmdisk ---" >> FS900.$datestamp.config.txt
ssh -p 26 root@9.11.210.136 lsmdisk -bytes >> FS900.$datestamp.config.txt
echo "---- lsportfc ---" >> FS900.$datestamp.config.txt
ssh -p 26 root@9.11.210.136 lsportfc >> FS900.$datestamp.config.txt
echo "---- lssystem ---" >> FS900.$datestamp.config.txt
ssh -p 26 root@9.11.210.136 lssystem >> FS900.$datestamp.config.txt
echo "---- lsvdisk ---" >> FS900.$datestamp.config.txt
ssh -p 26 root@9.11.210.136 lsvdisk -bytes >> FS900.$datestamp.config.txt
echo "---- END PRELOG ----" $(date) | tee -a FS900.$datestamp.config.txt

rundir=`pwd`
cd Prefill_45LVM_texan
./runfill.sh
cd $rundir
#export PATH=$PATH:/usr/java6/bin
export PATH=$PATH:/usr/java6/jre/bin
export SPC1HOME=/perform/spc1install
export CLASSPATH=$SPC1HOME
export LIBPATH=$SPC1HOME
export IBM_JAVADUMP_OUTOFMEMORY=false
export IBM_HEAPDUMP_OUTOFMEMORY=false

#Energy measurement pre-condition
ksh allhost_jvmstart.sh
java -Xoptionsfile=javaopts.cfg range -b 8800 -t 600
ksh allhost_jvmstop.sh
rm -fr energy_precondition_100pct
mv rangetest energy_precondition_100pct
sleep 4200
ksh allhost_jvmstart.sh
java -Xoptionsfile=javaopts.cfg range -b 880 -t 600
```

```
ksh allhost_jvmstop.sh
rm -fr energy_precondition_10pct
mv rangetest energy_precondition_10pct

ksh allhost_jvmstart.sh
java -Xoptionsfile=javaopts.cfg metrics -b 8800 -s 1800:600 -t 28800
ksh allhost_jvmstop.sh
ksh allhost_jvmstart.sh
java -Xoptionsfile=javaopts.cfg repeat1 -b 8800 -s 600
ksh allhost_jvmstop.sh
ksh allhost_jvmstart.sh
java -Xoptionsfile=javaopts.cfg repeat2 -b 8800 -s 600
ksh allhost_jvmstop.sh

#singlehost persist test
rundir=`pwd`
cd OldPersist
./persistence1.sh
cd $rundir

#SPC2 persist test
rundir=`pwd`
cd Persist
./runpersist1.sh
cd $rundir

#Collect FS900 configuration details post-run
getlvmdata.sh postrun
datestamp=$(date +%s)
echo "---- START POSTLOG ----" $(date) | tee -a FS900.$datestamp.config.txt
echo "---- lsarray ---" >> FS900.$datestamp.config.txt
ssh -p 26 root@9.11.210.136 lsarray -bytes >> FS900.$datestamp.config.txt
echo "---- lsdrive ---" >> FS900.$datestamp.config.txt
ssh -p 26 root@9.11.210.136 lsdrive -bytes >> FS900.$datestamp.config.txt
echo "---- lsenclosure ---" >> FS900.$datestamp.config.txt
ssh -p 26 root@9.11.210.136 lsenclosure >> FS900.$datestamp.config.txt
echo "---- lsenclosurebattery ---" >> FS900.$datestamp.config.txt
ssh -p 26 root@9.11.210.136 lsenclosurebattery >> FS900.$datestamp.config.txt
echo "---- lsmdisk ---" >> FS900.$datestamp.config.txt
ssh -p 26 root@9.11.210.136 lsmdisk -bytes >> FS900.$datestamp.config.txt
echo "---- lsportfc ---" >> FS900.$datestamp.config.txt
ssh -p 26 root@9.11.210.136 lsportfc >> FS900.$datestamp.config.txt
echo "---- lssystem ---" >> FS900.$datestamp.config.txt
ssh -p 26 root@9.11.210.136 lssystem >> FS900.$datestamp.config.txt
echo "---- lsvdisk ---" >> FS900.$datestamp.config.txt
ssh -p 26 root@9.11.210.136 lsvdisk -bytes >> FS900.$datestamp.config.txt
echo "---- END POSTLOG ----" $(date) | tee -a FS900.$datestamp.config.txt
```

runfill.sh

The script, invoked from **runall.sh**, executes the ASU pre-fill

```
#!/usr/bin/ksh
export PATH=$PATH:/usr/java6/jre/bin
export PATH=$PATH:/perform/vdbench50402
export VDBHOME=/perform/vdbench50402
export CLASSPATH=$VDBHOME
export LIBPATH=$VDBHOME/aix
export IBM_JAVADUMP_OUTOFMEMORY=false
export IBM_HEAPDUMP_OUTOFMEMORY=false
vdbench -f fill.cfg -o fill_output
```

allhost_jvmstart.sh

The script, invoked from **runall.sh**, starts the Slave JVMs on the four Host Systems.

```
#use SSH commands to start JVMs on all hosts
export HERE=`pwd`
ksh refreshslaves.sh 1 22 $HERE
echo "perfsh9a complete"
ssh perfsh9b "ksh $HERE/refreshslaves.sh 23 44 $HERE"
echo "perfsh9b complete"
ssh perfsh9e "ksh $HERE/refreshslaves.sh 45 66 $HERE"
echo "perfsh9e complete"
ssh perfsh9f "ksh $HERE/refreshslaves.sh 67 88  $HERE"
echo "perfsh9f complete"
```

refreshslaves.sh

The script, invoked from **allhost_jvmstart.sh**, actually starts each Slave JVM on a specific Host System.

```
if [ $# -lt 3 ]
then
   echo "usage: refreshslaves.sh first last directory"
   return
fi
#export PATH=/usr/java8_64/jre/bin:$PATH
export PATH=/usr/java6/jre/bin:$PATH
export SPC1HOME=/perform/spc1install
export CLASSPATH=$SPC1HOME
export LIBPATH=$SPC1HOME
export IBM_JAVADUMP_OUTOFMEMORY=false
export IBM_HEAPDUMP_OUTOFMEMORY=false
i=$1
run_dir=$3
while [[ $i -le $2 ]]
do
ps -ef | grep  slav$i | grep -v grep > /dev/null
if [ $? -ne 0 ]
then
   nohup /usr/java6/jre/bin/java -Xoptionsfile=$run_dir/javaopts.cfg spc1 -f
$run_dir/slav$i.txt > $run_dir/slav$i.out &
fi
let i="i+1"
done
```

allhost_jvmstop.sh

The script, invoked from **runall.sh**, terminates the Slave JVMs on the four Host Systems.

```
#use SSH commands to stop JVMs on all hosts
HERE=`pwd`
ksh rmslaves.sh
ssh perfsh9b "ksh $HERE/rmslaves.sh"
ssh perfsh9e "ksh $HERE/rmslaves.sh"
ssh perfsh9f "ksh $HERE/rmslaves.sh"
```

rmslaves.sh

The script, invoked from **allhost_jvmstop.sh**, actually terminates each Slave JVM on a specific Host System.

```
proc_num=$(ps -ef |grep slav|grep -v "grep"|grep -v "rmslaves"|awk '{print $2}')
if [[ -n $proc_num ]];then
kill -9 $proc_num
fi
```

persistence1.sh

The script, invoked from **runall.sh**, executes the reduced level SPC-1 Persistence Test Run 1 *(write phase)*.

```
export PATH=$PATH:/usr/java6/jre/bin
export SPC1HOME=/perform/spc1install
export CLASSPATH=$SPC1HOME
export LIBPATH=$SPC1HOME
export IBM_JAVADUMP_OUTOFMEMORY=false
export IBM_HEAPDUMP_OUTOFMEMORY=false

java -Xoptionsfile=javaoptsp.cfg persist1 -b 880
```

runpersist1.sh

The script, invoked from **runall.sh**, executes the SPC-2 Persistence Test Run 1 *(write phase)*.

runpersist2.sh

This script executes the SPC-2 Persistence Test Run 2 *(read phase)*.

```
export PATH=$PATH:/usr/java6/jre/bin
export SPC2HOME=/perform/spc2install
export CLASSPATH=$SPC2HOME
export LIBPATH=$SPC2HOME/aix
export IBM_JAVADUMP_OUTOFMEMORY=false
export IBM_HEAPDUMP_OUTOFMEMORY=false
rm -fr persistr
java -Xoptionsfile=javaopts.cfg vdbench -f persistr.cfg -o persist
```