SPC BENCHMARK 1/ENERGY™
FULL DISCLOSURE REPORT

IBM CORPORATION
IBM FLASHSYSTEM™ 840

SPC-1/E V1.14

Submitted for Review: September 19, 2014
Submission Identifier: AE00007

First Edition – September 2014

Trademarks

Table of Contents

AUDIT CERTIFICATION

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

September 19, 2014

The SPC Benchmark 1/Energy™ Reported Data listed below for the IBM FlashSystem™ 840 was produced in compliance with the SPC Benchmark 1/Energy™ v1.14 Onsite Audit requirements.

SPC Benchmark 1/Energy™ v1.14 Reported Data	
Tested Storage Product (TSP) Name: IBM FlashSystem™ 840	
Metric	**Reported Result**
SPC-1 IOPS™	369,994.84
SPC-1 Price-Performance	$1.32/SPC-1 IOPS™
Total ASU Capacity	25,769.804 GB
Data Protection Level	Protected 1 *(RAID-5)*
Total Price (including three-year maintenance)	$486,660.36
Currency Used	U.S. Dollars
Target Country for availability, sales and support	USA

Power Environment

Average RMS Voltage: 201.70 **Average Power Factor:** 0.982

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	756.14	61661.77	81.55	2,580.04
Medium Daily Usage:	4	14	6	785.18	157237.73	200.26	2,679.12
High Daily Usage:	18	6	0	825.79	268229.69	324.82	2,817.66
			Composite Metrics:	789.04	162,376.40	205.79	

Annual Energy Use, kWh: 6,911.97
Energy Cost, $/kWh: $ 0.12 **Annual Energy Cost, $:** $ 829.44

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

AUDIT CERTIFICATION *(CONT.)*

The following SPC Benchmark 1/Energy™ Onsite 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 physical 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).
- Physical verification of the components to match the above diagram.
- Listings and commands to configure the Benchmark Configuration/Tested Storage Configuration, including customer tunable parameters that were changed from default values.
- SPC-1 Workload Generator commands and parameters used for the audited SPC Test Runs.
- The following Host System requirements were verified by physical inspection and information supplied by 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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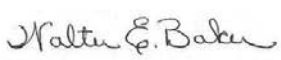
AUDIT CERTIFICATION *(CONT.)*

- 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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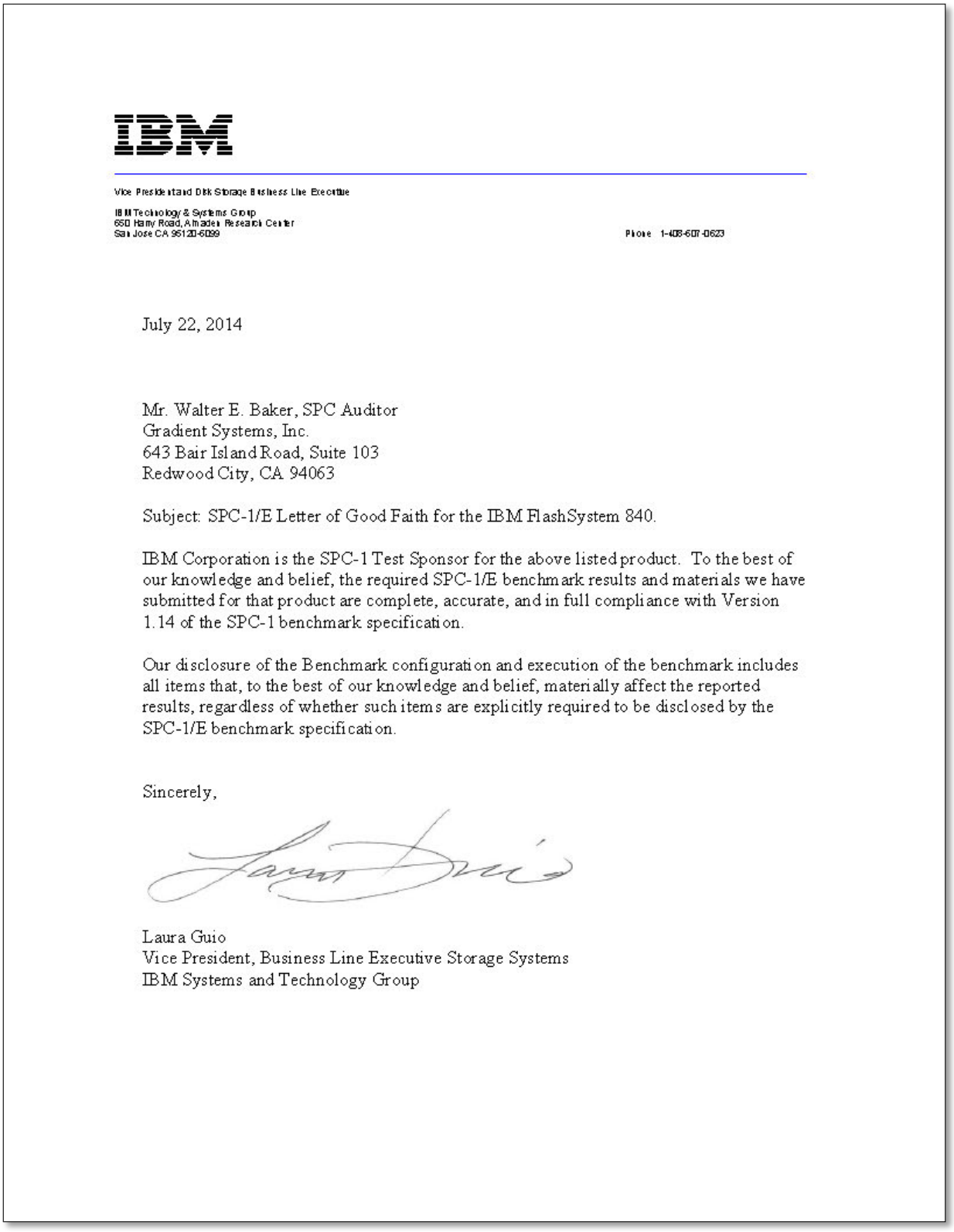
LETTER OF GOOD FAITH



IBM

Vice President and Disk Storage Business Line Executive

IBM Technology & Systems Group
650 Harry Road, Almaden Research Center
San Jose CA 95120-6099

Phone: 1-408-927-0623

July 22, 2014

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 840.

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,

Laura Guio
Vice President, Business Line Executive Storage Systems
IBM Systems and Technology Group

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	September 19, 2014
Date the FDR was submitted to the SPC	September 19, 2014
Date the Priced Storage Configuration is available for shipment to customers	currently available
Date the TSC completed audit certification	September 19, 2014

Tested Storage Product (TSP) Description

IBM FlashSystem 840 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 840 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 840 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™ 840	
Metric	**Reported Result**
SPC-1 IOPS™	369,994.84
SPC-1 Price-Performance™	$1.32/SPC-1 IOPS™
Total ASU Capacity	25,769.804 GB
Data Protection Level	Protected 1 *(RAID-5)*
Total Price	$486,660.36
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 24.

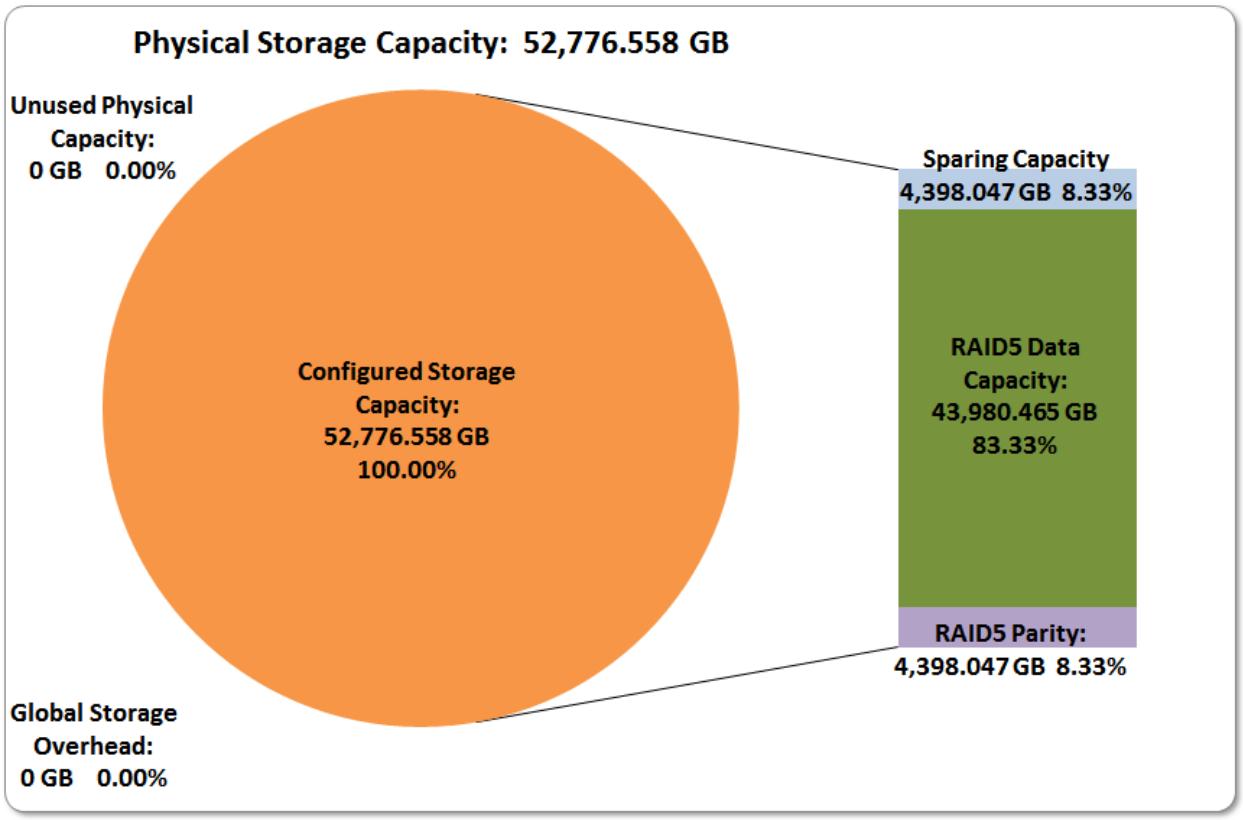
Currency Used is formal name for the currency used in calculating the **Total Price** and **SPC-1 Price-Performance™**. That currency may be the local currency of the **Target Country** or the currency of a difference country *(non-local currency)*.

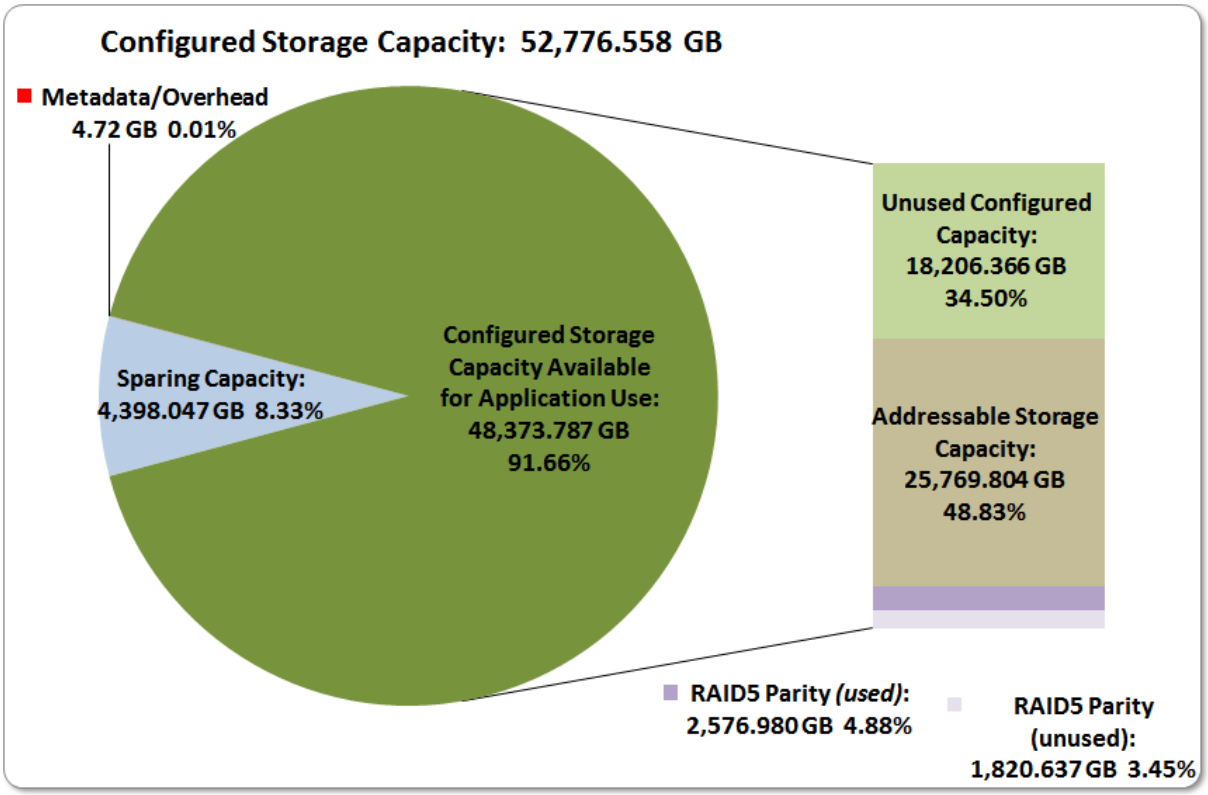
The **Target Country** is the country in which the Priced Storage Configuration is available for sale and in which the required hardware maintenance and software support is provided either directly from the Test Sponsor or indirectly via a third-party supplier.

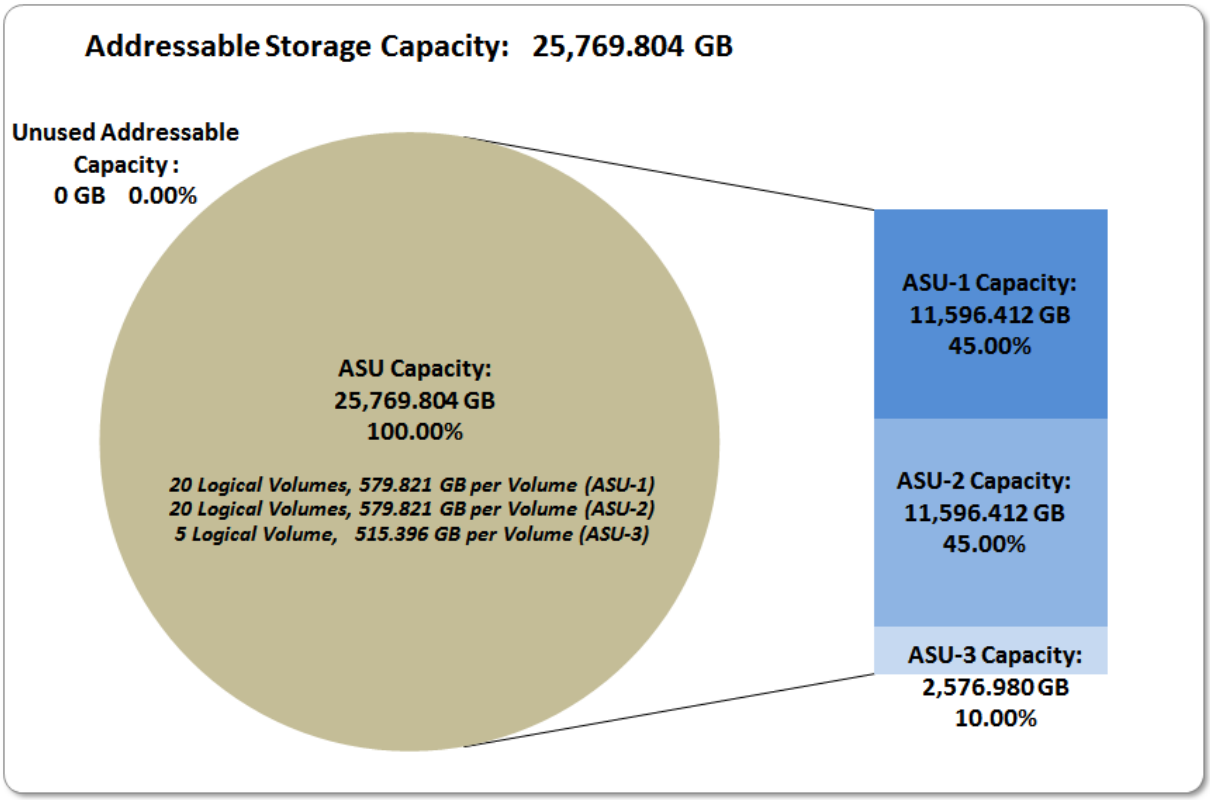
Storage Capacities, Relationships, and Utilization

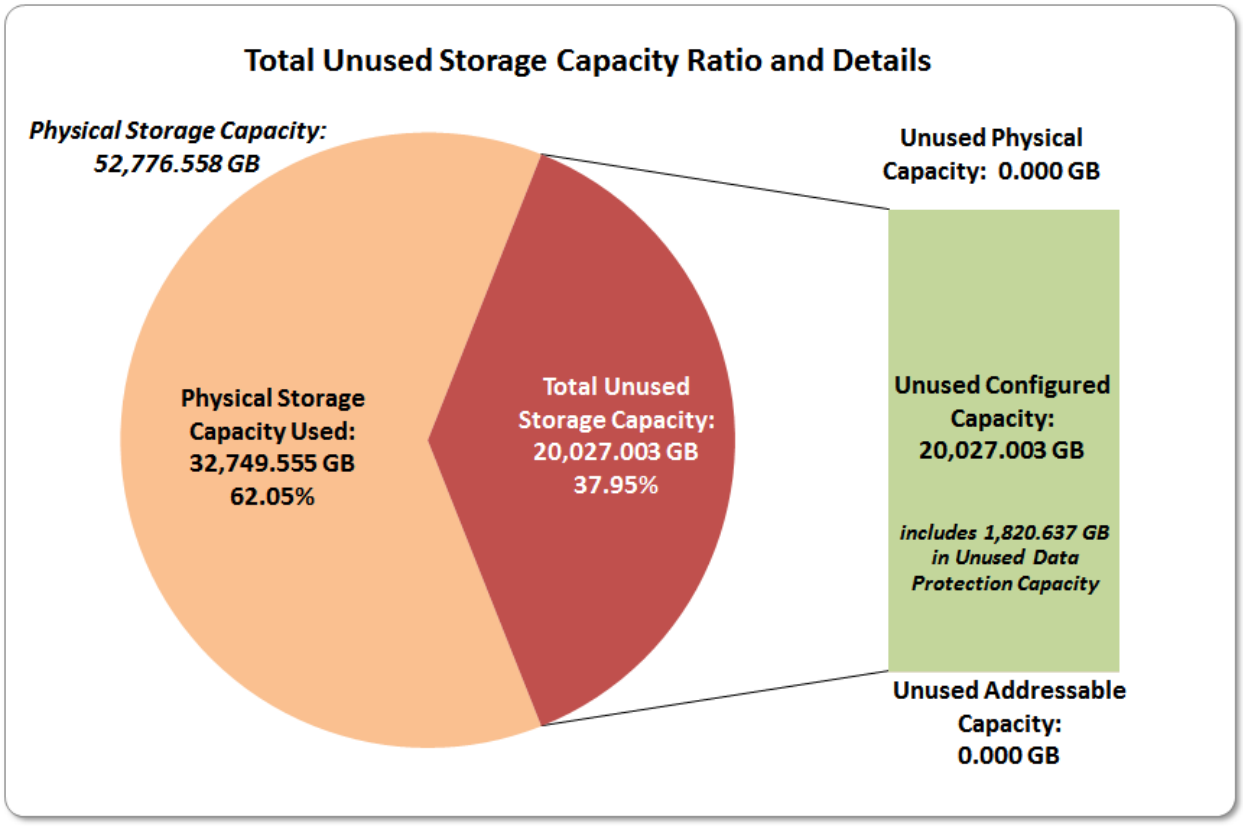
The following four charts and table document the various storage capacities, used in this benchmark, and their relationships, as well as the storage utilization values required to be reported.

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




Configured Storage Capacity: 52,776.558 GB
Metadata/Overhead
4.72 GB 0.01%
Sparing Capacity:
4,398.047 GB 8.33%
Configured Storage Capacity Available for Application Use:
48,373.787 GB
91.66%
Unused Configured Capacity:
18,206.366 GB
34.50%
Addressable Storage Capacity:
25,769.804 GB
48.83%
RAID5 Parity (used):
2,576.980 GB 4.88%
RAID5 Parity (unused):
1,820.637 GB 3.45%


Addressable Storage Capacity: 25,769.804 GB
Unused Addressable Capacity:
0 GB 0.00%
ASU Capacity:
25,769.804 GB
100.00%
20 Logical Volumes, 579.821 GB per Volume (ASU-1)
20 Logical Volumes, 579.821 GB per Volume (ASU-2)
5 Logical Volume, 515.396 GB per Volume (ASU-3)
ASU-1 Capacity:
11,596.412 GB
45.00%
ASU-2 Capacity:
11,596.412 GB
45.00%
ASU-3 Capacity:
2,576.980 GB
10.00%



SPC-1 Storage Capacity Utilization	
Application Utilization	48.83%
Protected Application Utilization	53.71%
Unused Storage Ratio	37.95%

Application Utilization: Total ASU Capacity *(25,769.804 GB)* divided by Physical Storage Capacity *(52,776.558 GB)*

Protected Application Utilization: Total ASU Capacity *(25,769.804 GB)* plus total Data Protection Capacity *(4,398.047 GB)* minus unused Data Protection Capacity *(1,820.637 GB)* divided by Physical Storage Capacity *(25,769.804 GB)*

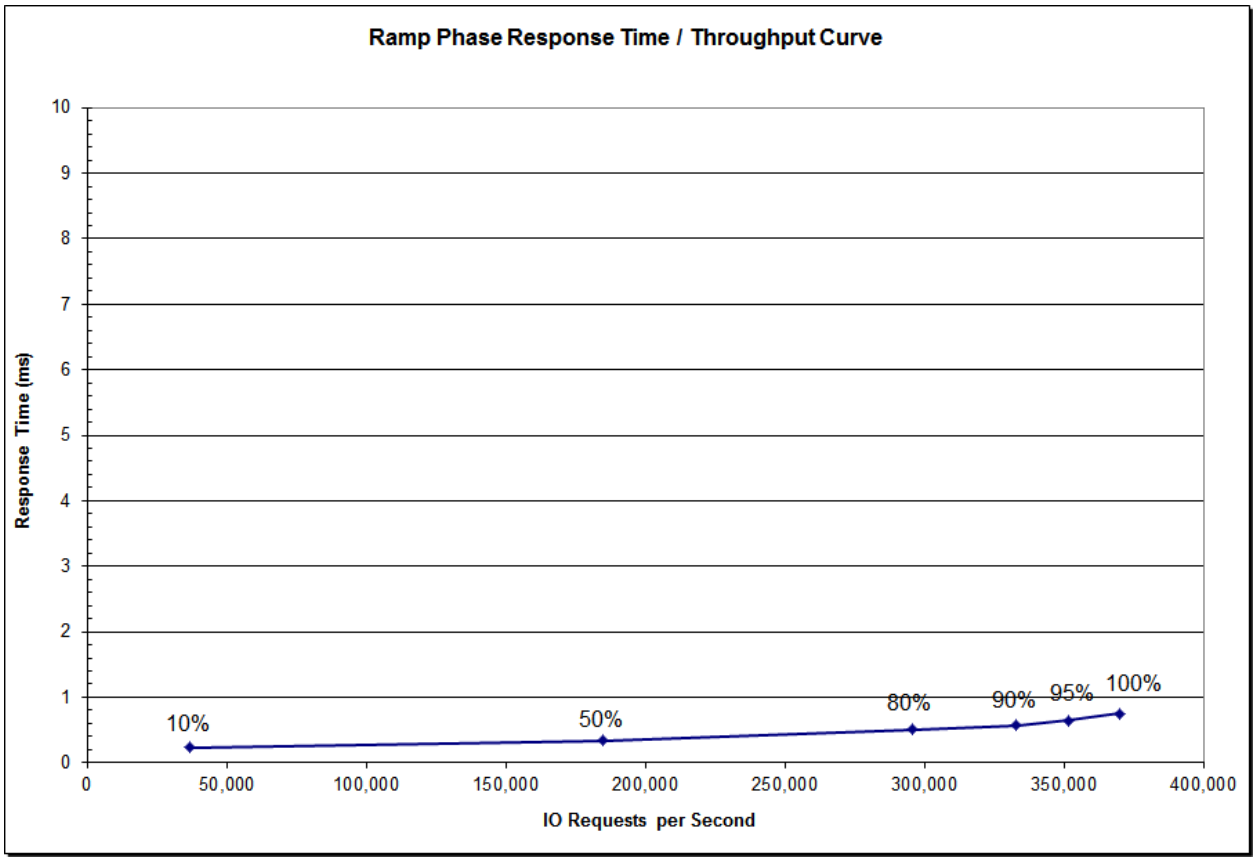
Unused Storage Ratio: Total Unused Capacity *(20,027.003 GB)* divided by Physical Storage Capacity *(25,769.804 GB)* and may not exceed 45%.

Detailed information for the various storage capacities and utilizations is available on pages 30-31.

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	37,011.27	184,985.30	295,977.82	332,996.17	351,497.45	369,994.84
Average Response Time (ms):						
All ASUs	0.23	0.34	0.50	0.57	0.65	0.75
ASU-1	0.24	0.37	0.56	0.63	0.72	0.82
ASU-2	0.24	0.38	0.56	0.64	0.71	0.81
ASU-3	0.21	0.26	0.37	0.41	0.47	0.55
Reads	0.28	0.50	0.78	0.88	1.00	1.13
Writes	0.20	0.23	0.33	0.37	0.42	0.50

SPC-1/E Reported Data

The initial SPC-1/E energy extension temperature, recorded during the first one minute of the Idle Test was 72F. The final SPC-1/E energy extension temperature, recorded during the last one minute of the Primary Metrics Test was 71F.

Power Environment

Average RMS Voltage:	**201.70**	**Average Power Factor:**	**0.982**

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	**756.14**	**61661.77**	**81.55**	**2,580.04**
Medium Daily Usage:	4	14	6	**785.18**	**157237.73**	**200.26**	**2,679.12**
High Daily Usage:	18	6	0	**825.79**	**268229.69**	**324.82**	**2,817.66**
			Composite Metrics:	**789.04**	**162,376.40**	**205.79**	

Annual Energy Use, kWh:	**6,911.97**		
Energy Cost, $/kWh:	$ 0.12	**Annual Energy Cost, $:**	**$ 829.44**

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: 837.78W at 80% of maximum reported performance *(295,977.82 SPC-1 IOPS)*.

MODERATE SPC-1 Workload: 789.82W at 50% of maximum reported performance *(184,985.30 SPC-1 IOPS)*.

IDLE SPC-1 Workload: 739.31W 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

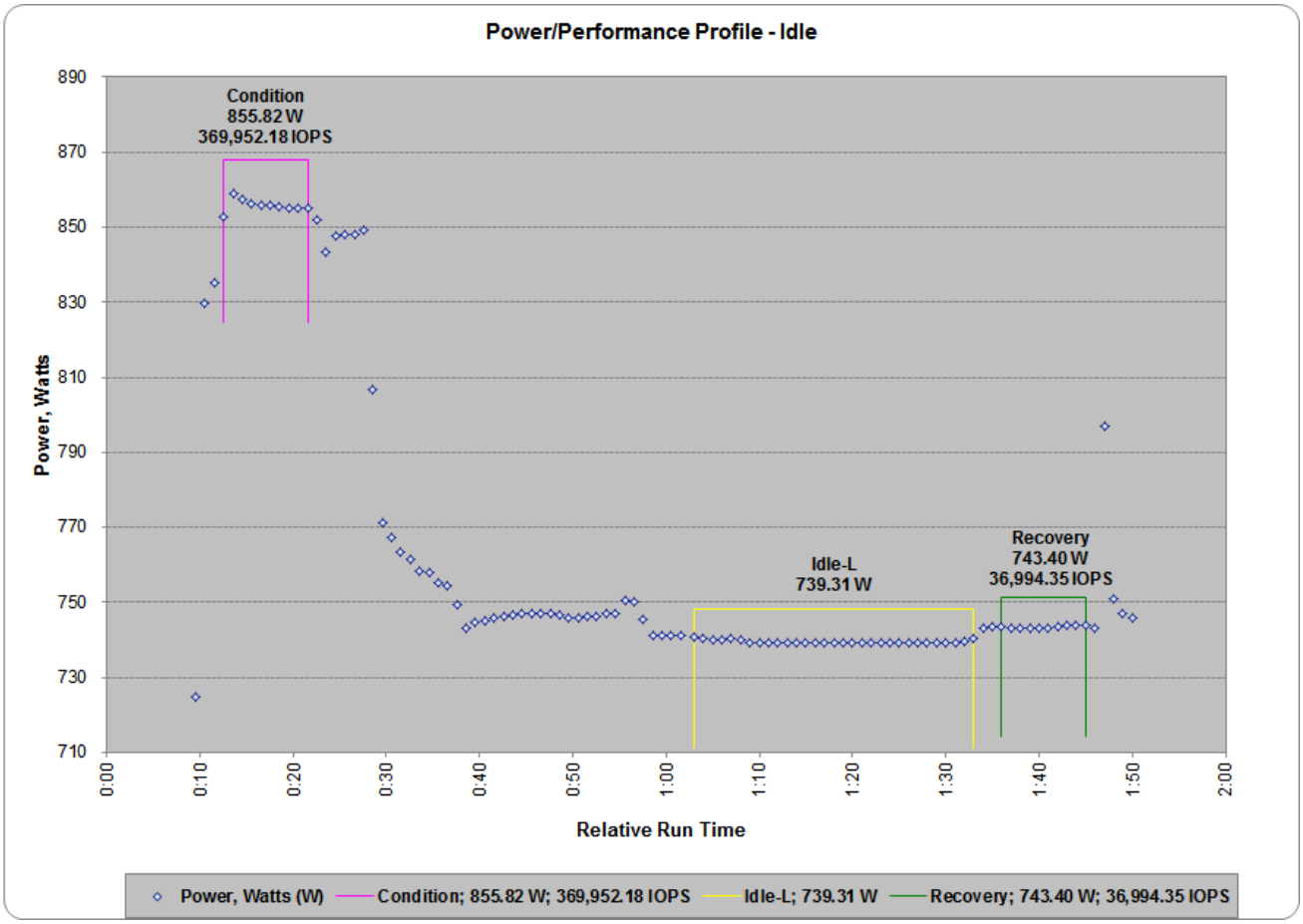
The following four SPC-1/E Power/Performance Profile charts provide a complete "at a glance" illustration and report for each SPC-1/E execution component. The power consumption at each step is reported and, where appropriate the measured SPC-1 performance *(SPC-1 IOPS™)* is also reported.

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.

SPC-1/E Power/Performance Profile Data

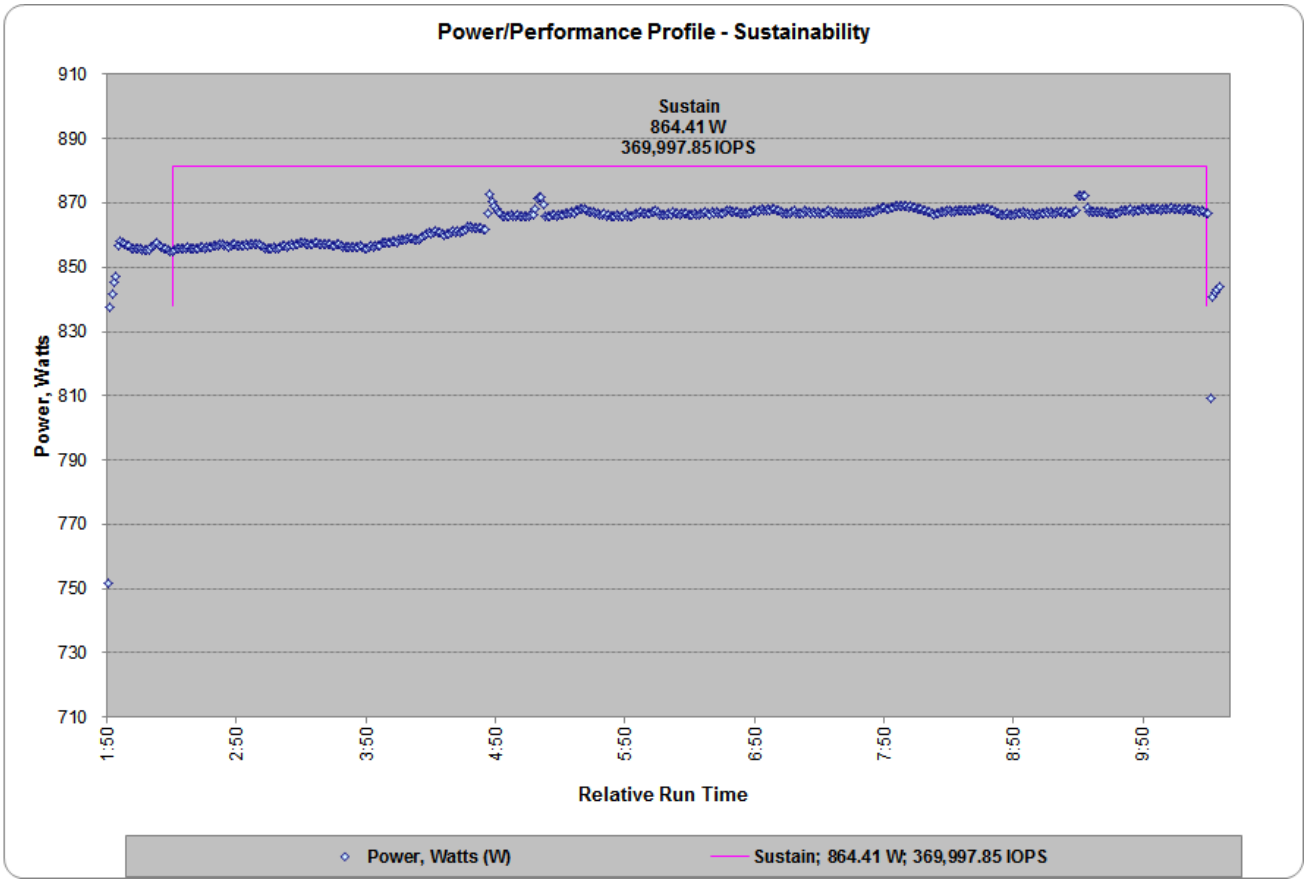
Execution Component	Load Level	SPC-1 IOPS™	Power (W)
Idle – Conditioning *(**Condition**)*	100%	369,952.18	855.82
Idle *(**Idle-L**)*	0%	-	739.31
Idle - Recovery *(**Recovery**)*	10%	36,994.35	743.40
Sustainability *(**Sustain**)*	100%	369,997.85	864.41
IOPS *(**100%**)*	100%	369,994.84	862.83
Ramp95 *(**95%**)*	95%	351,497.45	856.04
Ramp90 *(**90%**)*	90%	332,996.17	849.64
Ramp80 *(**80%**)*	80%	295,977.82	837.78
Ramp50 *(**50%**)*	50%	184,985.30	789.82
Ramp10 *(**10%**)*	10%	37,011.27	742.89
Repeat1 LRT *(**10%**)*	10%	36,993.22	742.21
Repeat1 IOPS *(**100%**)*	100%	370,018.82	860.77
Repeat2 LRT *(**10%**)*	10%	37,002.47	741.74
Repeat2 IOPS *(**100%**)*	100%	370,033.30	859.28

Power/Performance Profile – Idle Test



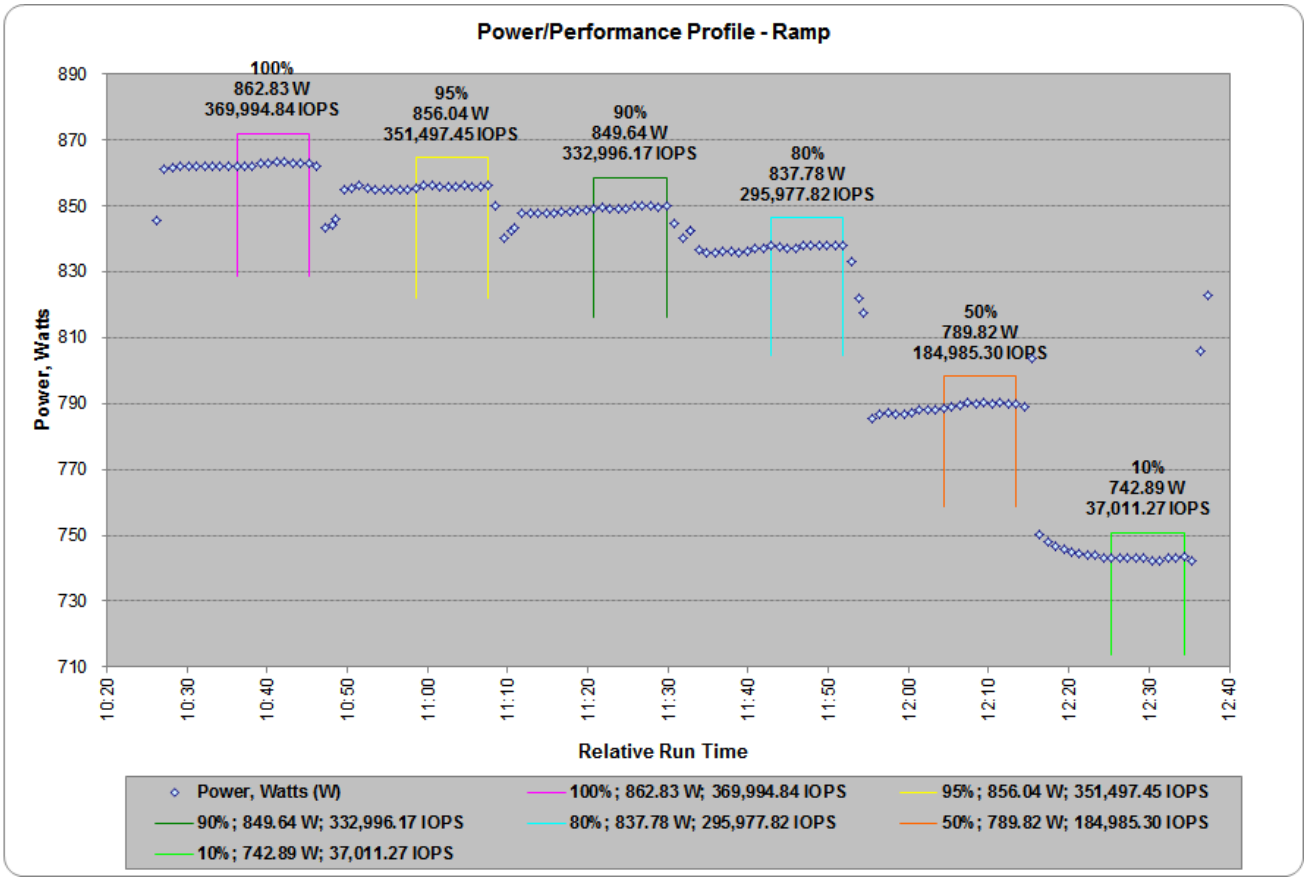
Execution Component	Load Level	SPC-1 IOPS™	Power (W)
Idle – Conditioning ***(Condition)***	100%	369,952.18	855.82
Idle ***(Idle-L)***	0%	-	739.31
Idle - Recovery ***(Recovery)***	10%	36,994.35	743.40

Power/Performance Profile – Sustainability Test Run



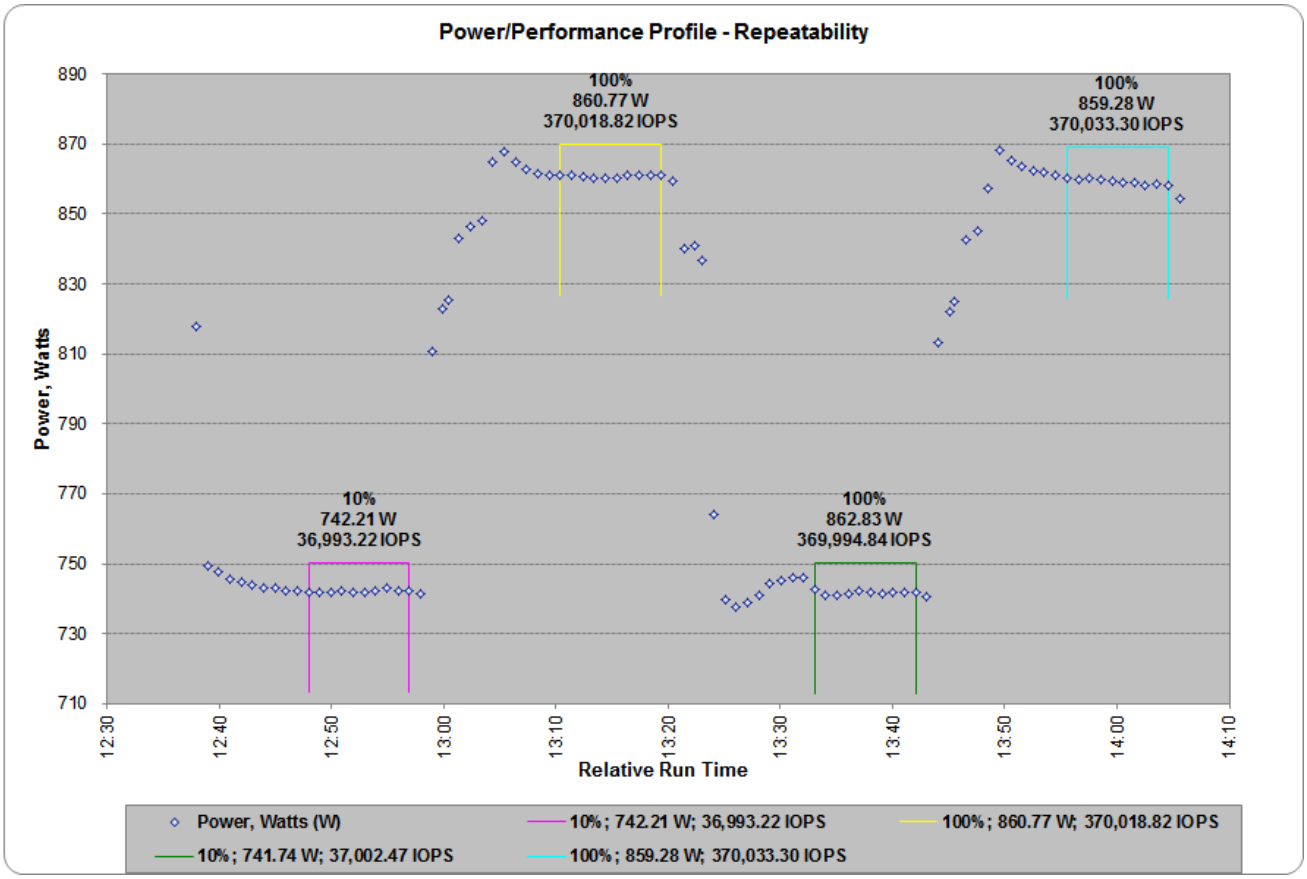
Execution Component	Load Level	SPC-1 IOPS™	Power (W)
Sustainability ***(Sustain)***	100%	369,997.85	864.41

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



Execution Component	Load Level	SPC-1 IOPS™	Power (W)
IOPS *(**100%**)*	100%	369,994.84	862.83
Ramp95 *(**95%**)*	95%	351,497.45	856.04
Ramp90 *(**90%**)*	90%	332,996.17	849.64
Ramp80 *(**80%**)*	80%	295,977.82	837.78
Ramp50 *(**50%**)*	50%	184,985.30	789.82
Ramp10 *(**10%**)*	10%	37,011.27	742.89

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



Execution Component	Load Level	SPC-1 IOPS™	Power (W)
Repeat1 LRT *(10%)*	10%	36,993.22	742.21
Repeat1 IOPS *(100%)*	100%	370,018.82	860.77
Repeat2 LRT *(10%)*	10%	37,002.47	741.74
Repeat2 IOPS *(100%)*	100%	370,033.30	859.28

Priced Storage Configuration Pricing

Component	Quantity	Unit Price	Unit Maint	List w/ Maint	% discount	Total Price
FlashSystem 840 (9840-AE1) w/12 SFPs, 1 year warranty included	1	42,000.00	6,240.00	48,240.00	39	29,426.40
eMLC (-AF11) 4 TB flash card	12	52,500.00	7,248.00	716,976.00	39	437,355.36
5m fibre channel cable (-3701)	12	75.00	0.00	900.00	30	630.00
8 Gbps dual port FC adapter (9179-5735)	6	4,583.00	0.00	27,498.00	30	19,248.60
Total Price						**486,660.36**

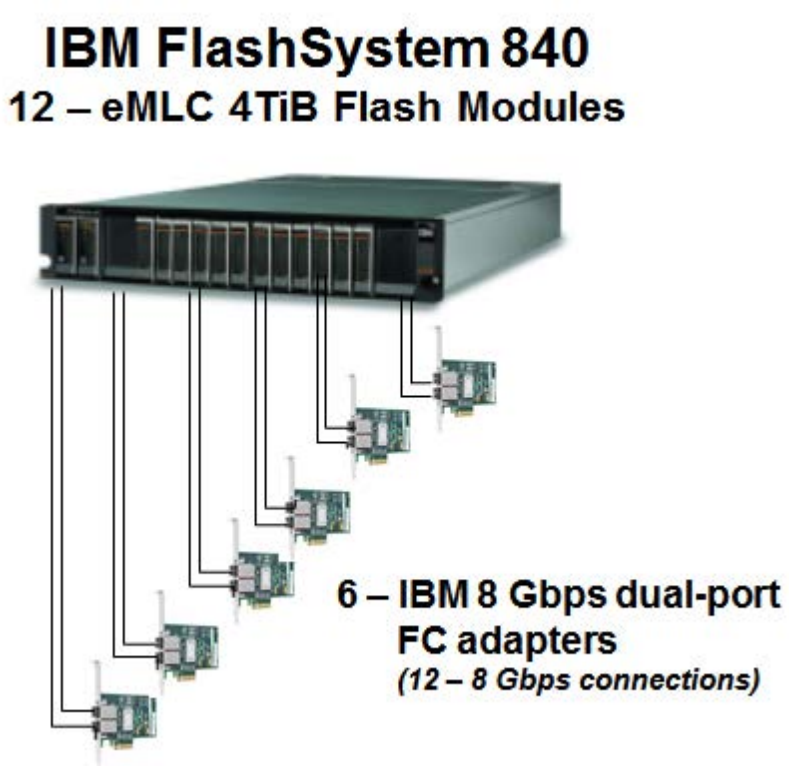
The above pricing includes hardware maintenance and software support for three years, 7 days per week, 24 hours per day. The hardware maintenance and software support provides the following:

- Acknowledgement of new and existing problems with four (4) hours.
- Onsite 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 Priced Storage Configuration.

Priced Storage Configuration Diagram



Priced Storage Configuration Components

Priced Storage Configuration
6 – IBM 8 Gbps dual-port FC adapters
IBM FlashSystem™ 840 Dual controllers 12 – 8 Gbps FC front-end connections *(w/12 SFPs)* *(12 connections used)* 40 – SAMNet backend lanes available and used *(proprietary interconnect similar to PCIe)*
12 – eMLC 4 TB Flash 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 27 (*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 Tested Storage Configuration was configured with local, directly connected storage and did not utilize a storage network.

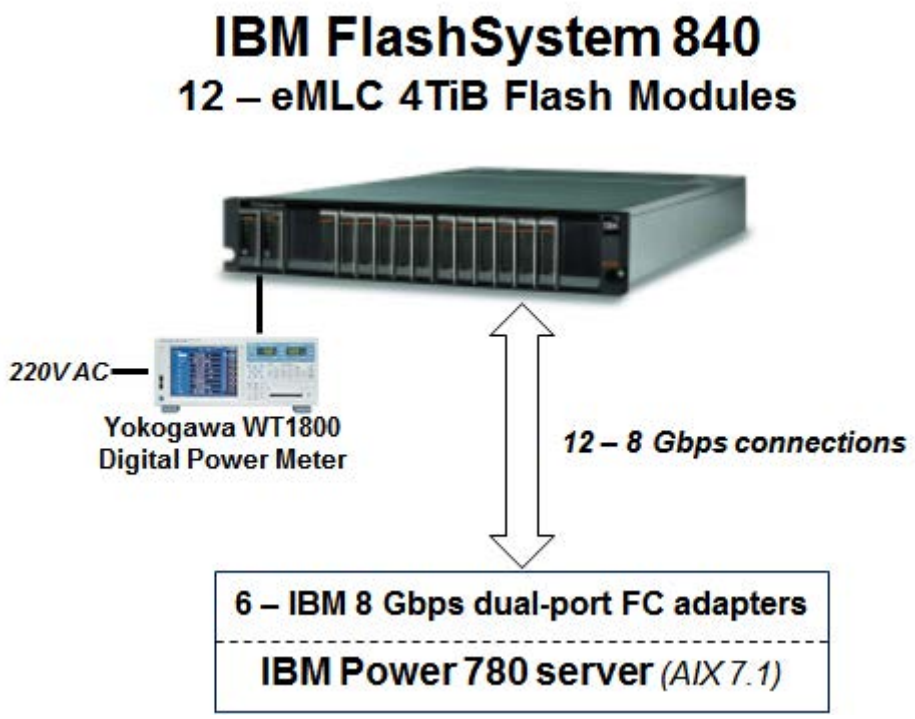
Host System and Tested Storage Configuration (TSC) Table of Components

Clause 9.4.3.4.3

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

The Host System and TSC table of components may be found on page 27 (*Host Systems and Tested Storage Configuration Components*).

Benchmark Configuration/Tested Storage Configuration Diagram



Host Systems and Tested Storage Configuration Components

Host System
IBM Power 780 server 16 – 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
6 – IBM 8 Gbps dual-port FC adapters
IBM FlashSystem™ 840 Dual controllers 12 – 8 Gbps FC front-end connections *(w/12 SFPs)* *(12 connections used)* 40 – SAMNet backend lanes available and used *(proprietary interconnect similar to PCIe)*
12 – eMLC 4 TB Flash 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 71 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 72 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 74.

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 74.

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 67 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 52,776.558 GB distributed over 12 solid state storage devices, each with a formatted capacity of 4,398.047 GB. There was 0.000 GB (0.00%) of Unused Storage within the Physical Storage Capacity. Global Storage Overhead consisted of 0.000 GB (0.00%) of the Physical Storage Capacity. There was 18,206.366 GB (34.50%) of Unused Storage within the Configured Storage Capacity. The Total ASU Capacity utilized 100% of the Addressable Storage Capacity resulting in 0.000 GB (0.00%) of Unused Storage within the Addressable Storage Capacity. The Data Protection *(RAID-5)* capacity was 4,398.047 GB of which 2,577.41 GB was utilized. The total Unused Storage capacity was 20,027.003 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.

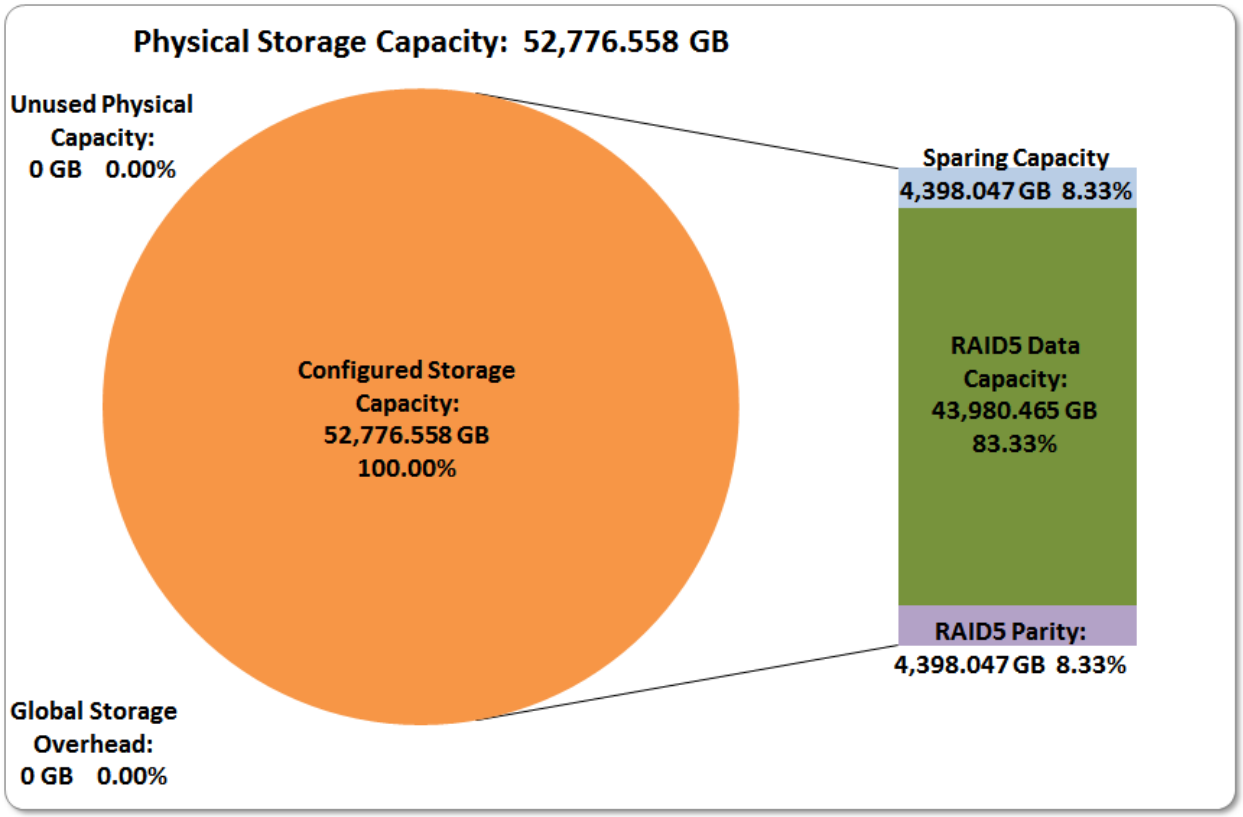
SPC-1 Storage Capacities

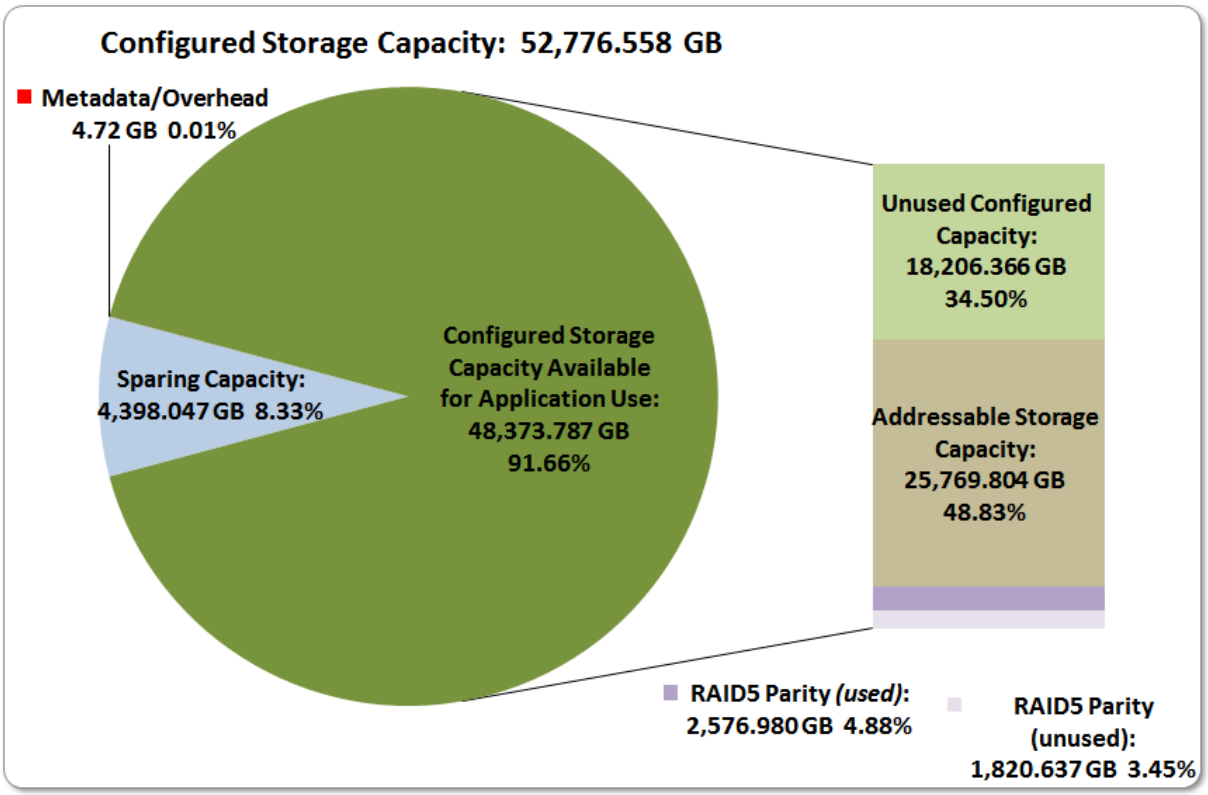
Storage Hierarchy Component	Units	Capacity
Total ASU Capacity	Gigabytes (GB)	25,769.804
Addressable Storage Capacity	Gigabytes (GB)	25,769.804
Configured Storage Capacity	Gigabytes (GB)	52,776.558
Physical Storage Capacity	Gigabytes (GB)	52,776.558
Data Protection *(RAID-5)*	Gigabytes (GB)	4,398.047
Required Storage *(metadata/sparing)*	Gigabytes (GB)	4,552.341
Global Storage Overhead	Gigabytes (GB)	0.000
Total Unused Storage	Gigabytes (GB)	20,027.003

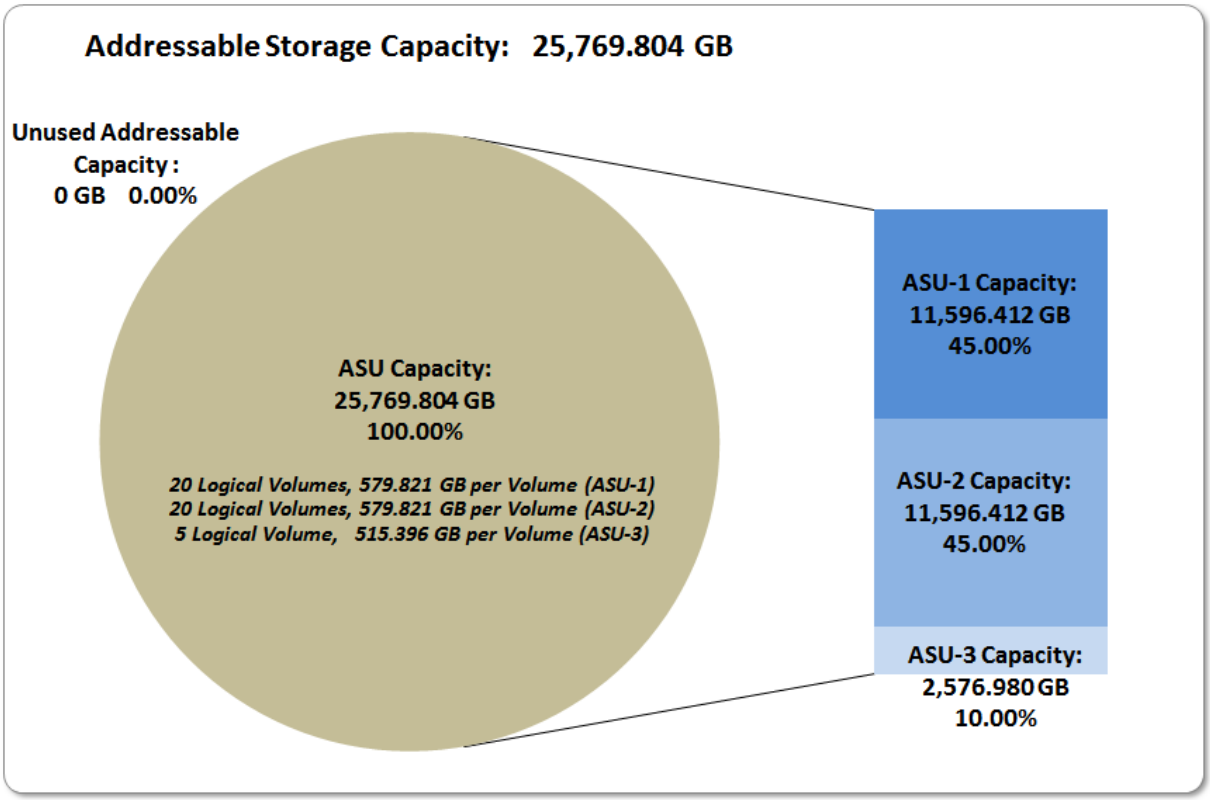
SPC-1 Storage Hierarchy Ratios

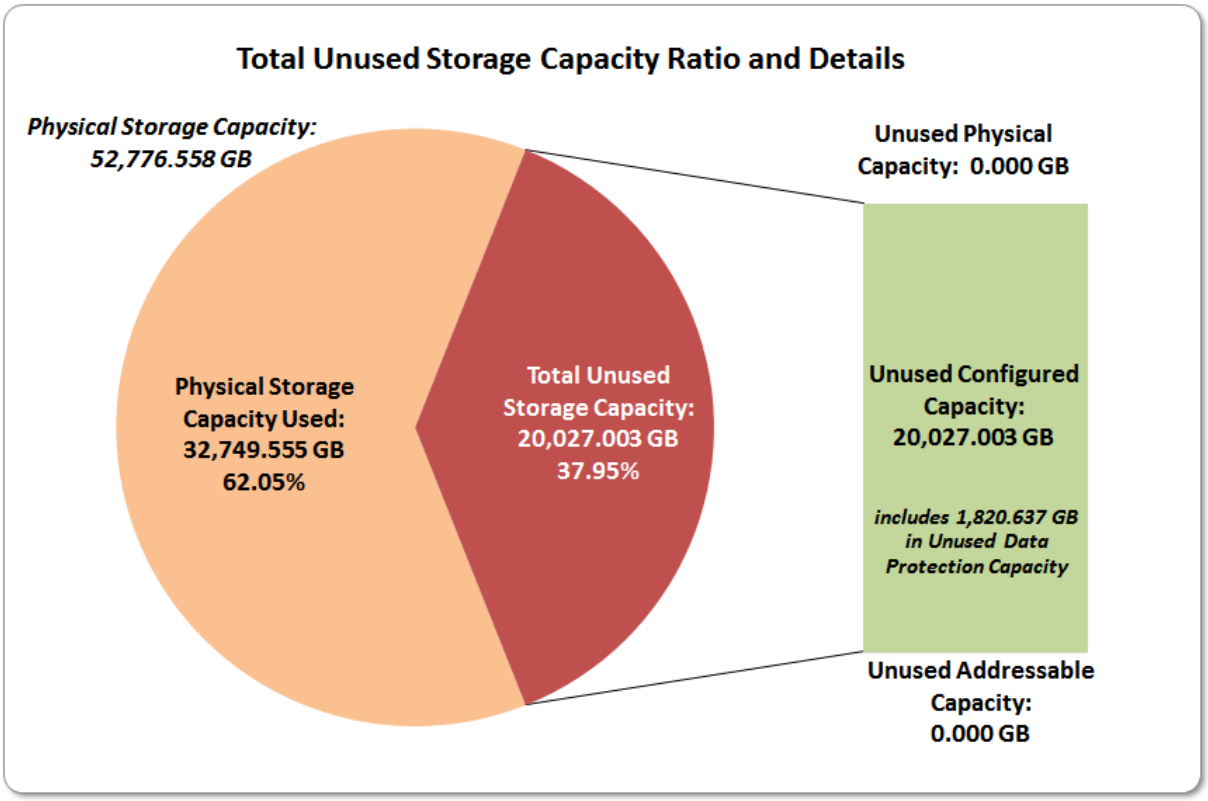
	Addressable Storage Capacity	Configured Storage Capacity	Physical Storage Capacity
Total ASU Capacity	100.00%	48.83%	48.83%
Required for Data Protection *(RAID-5)*		8.33%	8.33%
Addressable Storage Capacity		48.83%	48.83%
Required Storage *(metadata/spare)*		8.63%	8.63%
Configured Storage Capacity			100.00%
Global Storage Overhead			0.00%
Unused Storage:			
Addressable	0.00%		
Configured		34.50%	
Physical			0.00%

SPC-1 Storage Capacity Charts




Configured Storage Capacity: 52,776.558 GB
Metadata/Overhead
4.72 GB 0.01%
Sparing Capacity:
4,398.047 GB 8.33%
Configured Storage Capacity Available for Application Use:
48,373.787 GB
91.66%
Unused Configured Capacity:
18,206.366 GB
34.50%
Addressable Storage Capacity:
25,769.804 GB
48.83%
RAID5 Parity (used):
2,576.980 GB 4.88%
RAID5 Parity (unused):
1,820.637 GB 3.45%


Addressable Storage Capacity: 25,769.804 GB
Unused Addressable Capacity:
0 GB 0.00%
ASU Capacity:
25,769.804 GB
100.00%
20 Logical Volumes, 579.821 GB per Volume (ASU-1)
20 Logical Volumes, 579.821 GB per Volume (ASU-2)
5 Logical Volume, 515.396 GB per Volume (ASU-3)
ASU-1 Capacity:
11,596.412 GB
45.00%
ASU-2 Capacity:
11,596.412 GB
45.00%
ASU-3 Capacity:
2,576.980 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	48.83%
Protected Application Utilization	53.71%
Unused Storage Ratio	37.95%

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 (11,596.412 GB)	**ASU-2 (11,596.412 GB)**	**ASU-3 (2,576.980 GB)**
20 Logical Volumes 579.821 GB per Logical Volume (579.821 GB used per Logical Volume)	20 Logical Volumes 579.821 GB per Logical Volume (579.821 GB used per Logical Volume)	5 Logical Volumes 515.396 GB per Logical Volume (515.396 GB used per Logical Volume)

The Data Protection Level used for all Logical Volumes was **Protected 1** using ***RAID-5*** as described on page 12. See "ASU Configuration" in the **IOPS Test Results File** for more detailed configuration information.

SPC-1 BENCHMARK EXECUTION RESULTS

This portion of the Full Disclosure Report documents the results of the various SPC-1 Tests, Test Phases, and Test Runs. "SPC-1 Test Execution Definitions" on page 68 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 included in the benchmark execution.

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 79.

Sustainability Test Results File

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

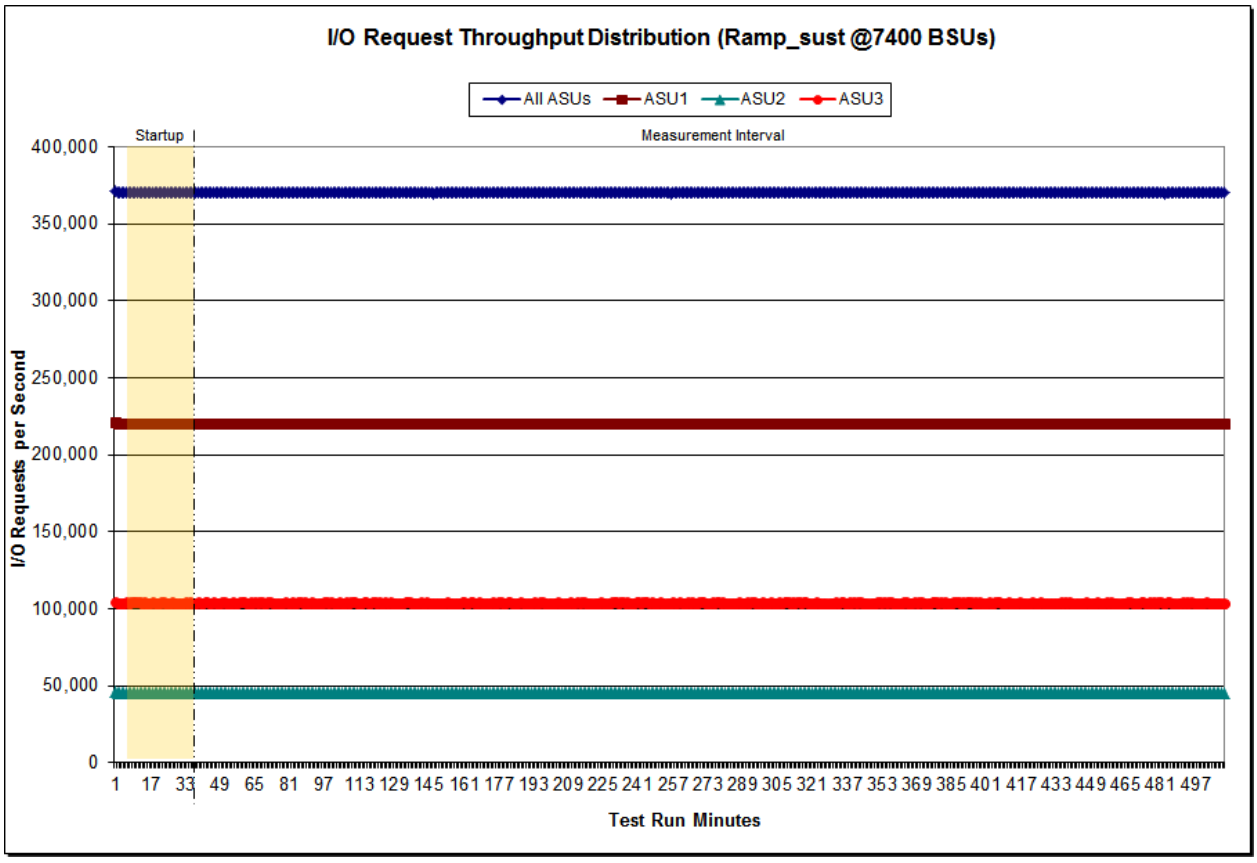
Sustainability Test Results File

Sustainability – 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

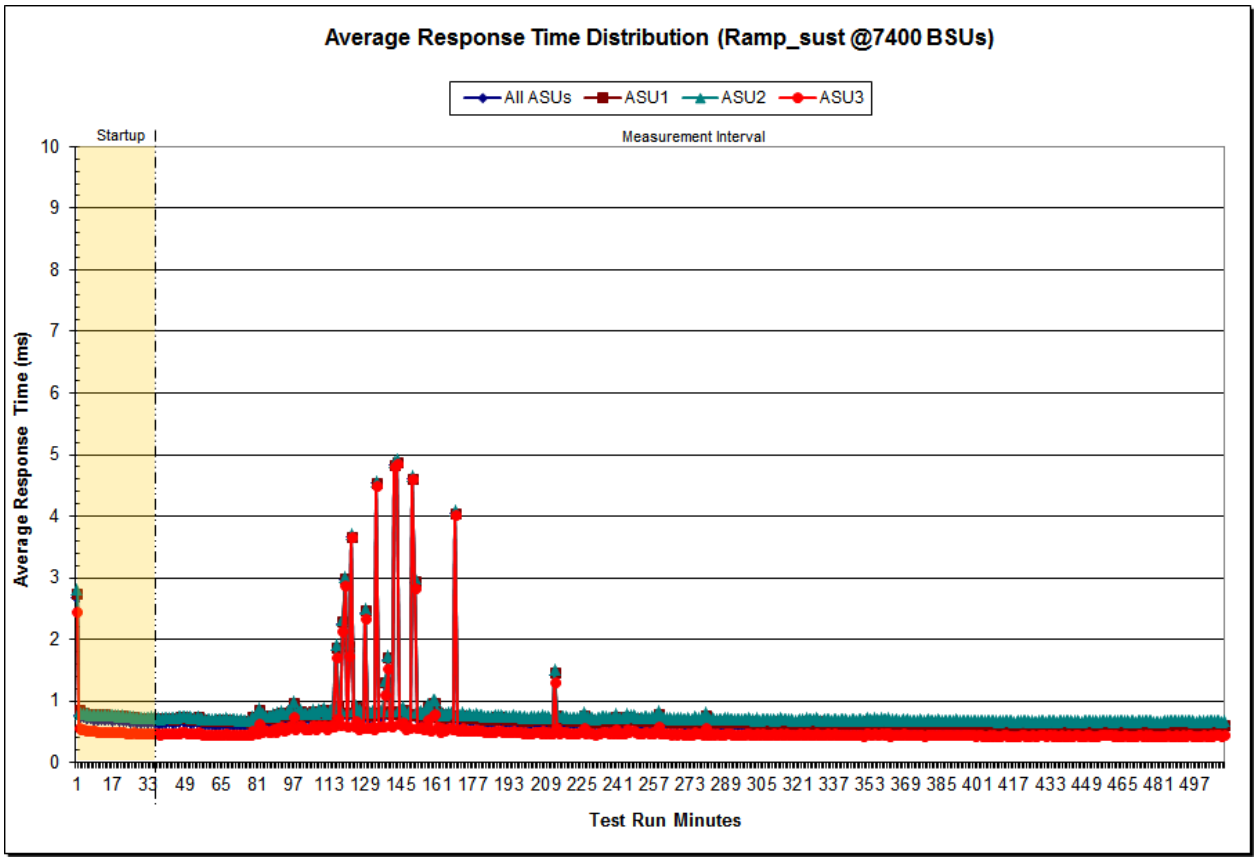


Sustainability – Average Response Time (ms) Distribution Data

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

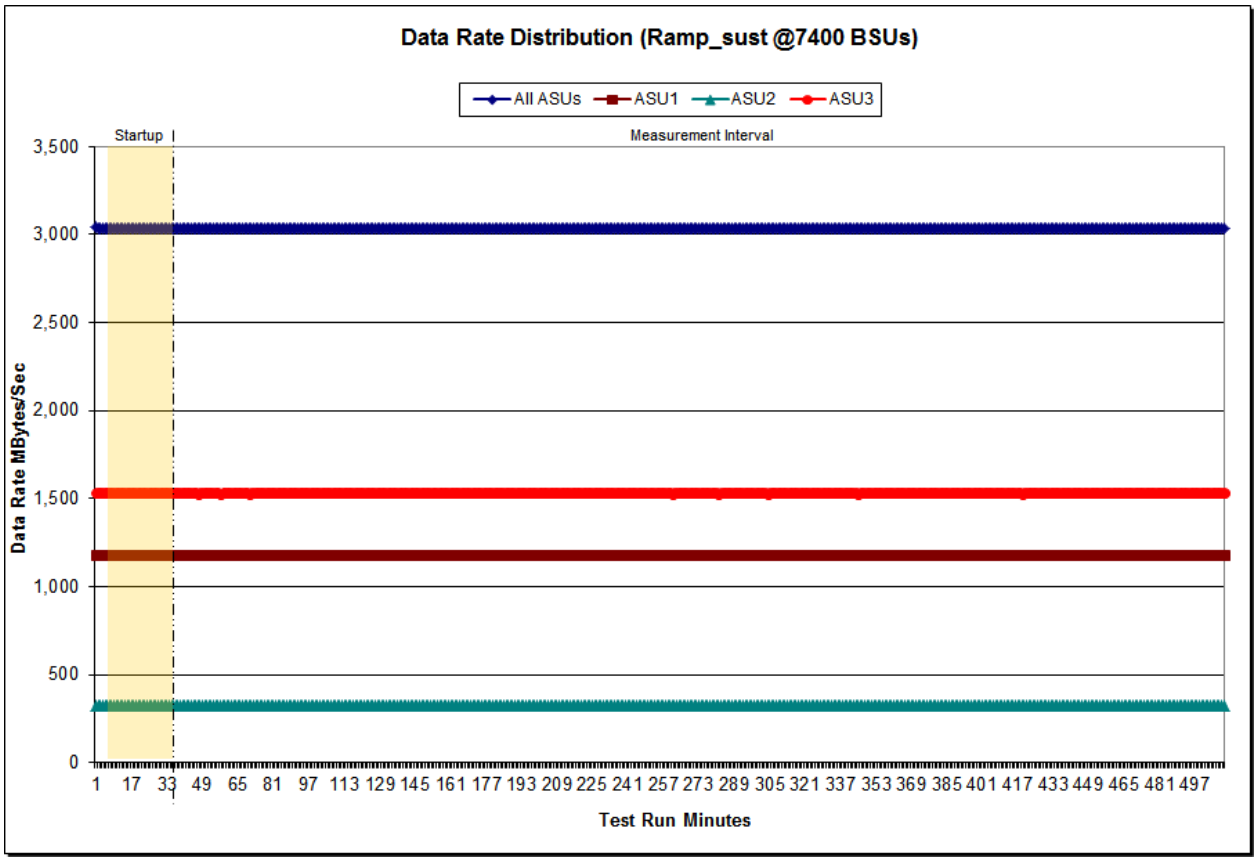


Sustainability – Data Rate Distribution Data (MB/second)

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



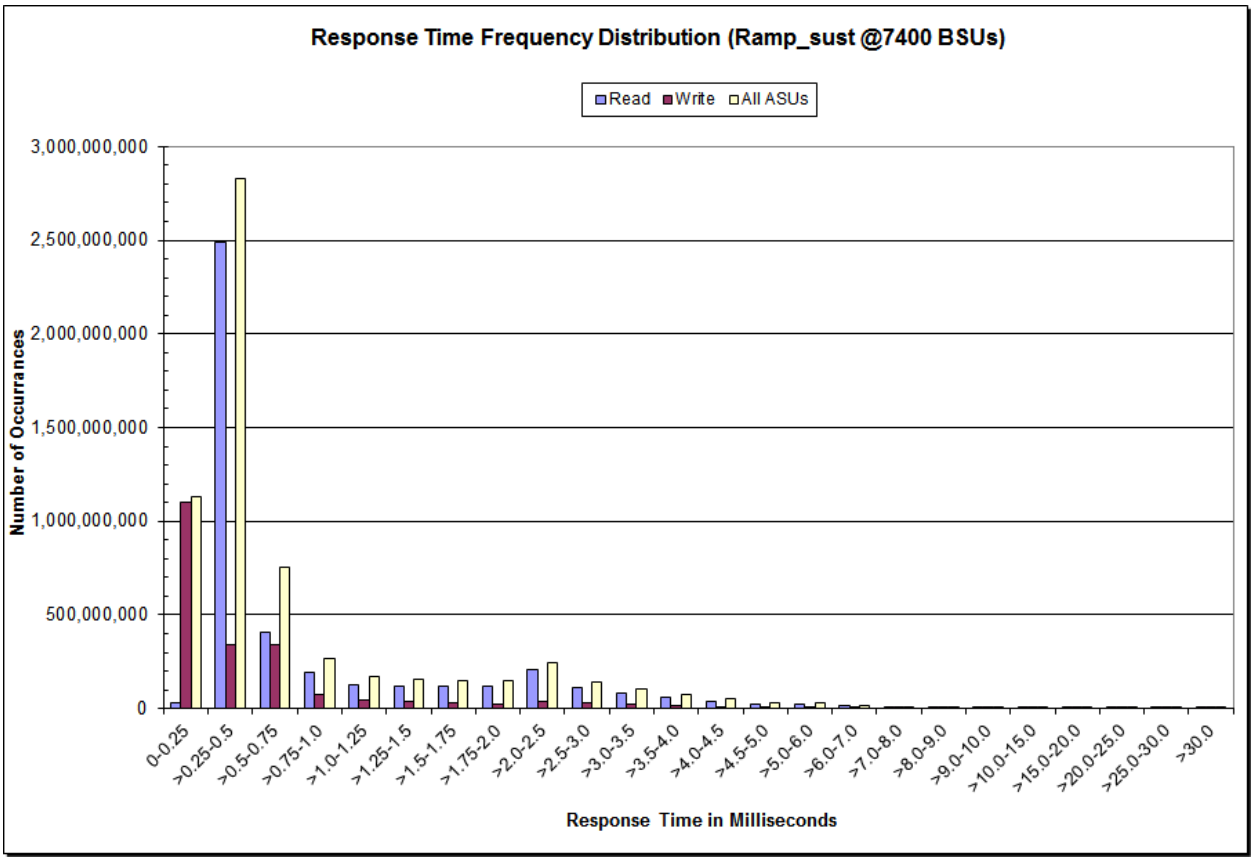
Sustainability – Response Time Frequency Distribution Data

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	30,709,547	2,486,657,695	410,109,960	195,350,974	126,939,442	121,290,263	121,401,164	121,365,967
Write	1,102,675,897	343,692,376	341,732,541	72,447,917	45,461,709	36,600,123	31,154,157	27,073,912
All ASUs	1,133,385,444	2,830,350,071	751,842,501	267,798,891	172,401,151	157,890,386	152,555,321	148,439,879
ASU1	595,052,731	4,149,289,669	460,426,055	185,969,153	118,805,810	110,133,719	107,383,523	105,353,222
ASU2	136,666,723	821,827,731	91,463,254	38,486,732	25,296,892	23,914,857	23,965,138	24,111,767
ASU3	401,665,990	(2,140,767,329)	199,953,192	43,343,006	28,298,449	23,841,810	21,206,660	18,974,890

Response Time (ms)	>2.0-2.5	>2.5-3.0	>3.0-3.5	>3.5-4.0	>4.0-4.5	>4.5-5.0	>5.0-6.0	>6.0-7.0
Read	204,799,452	114,839,950	85,365,486	59,115,003	39,897,211	22,109,985	25,223,953	12,839,012
Write	41,677,355	27,865,912	20,177,925	14,117,792	9,670,664	6,578,315	8,583,211	5,026,239
All ASUs	246,476,807	142,705,862	105,543,411	73,232,795	49,567,875	28,688,300	33,807,164	17,865,251
ASU1	174,986,061	99,233,399	73,163,930	50,946,655	34,665,912	19,877,867	23,299,320	12,193,691
ASU2	42,036,621	24,163,590	18,423,934	12,687,497	8,510,913	4,666,333	5,271,426	2,699,340
ASU3	29,454,125	19,308,873	13,955,547	9,598,643	6,391,050	4,144,100	5,236,418	2,972,220

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	6,785,161	3,920,170	2,325,000	3,939,199	1,416,402	1,290,174	1,204,976	4,602,941
Write	3,144,620	2,056,313	1,397,289	3,252,426	1,929,715	1,950,948	1,869,637	7,334,659
All ASUs	9,929,781	5,976,483	3,722,289	7,191,625	3,346,117	3,241,122	3,074,613	11,937,600
ASU1	6,662,316	3,952,646	2,418,715	4,507,272	2,024,307	1,947,578	1,827,489	6,956,007
ASU2	1,456,242	858,768	524,492	962,603	419,910	403,931	380,997	1,447,205
ASU3	1,811,223	1,165,069	779,082	1,721,750	901,900	889,613	866,127	3,534,388

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	0.001	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 79.

IOPS Test Results File

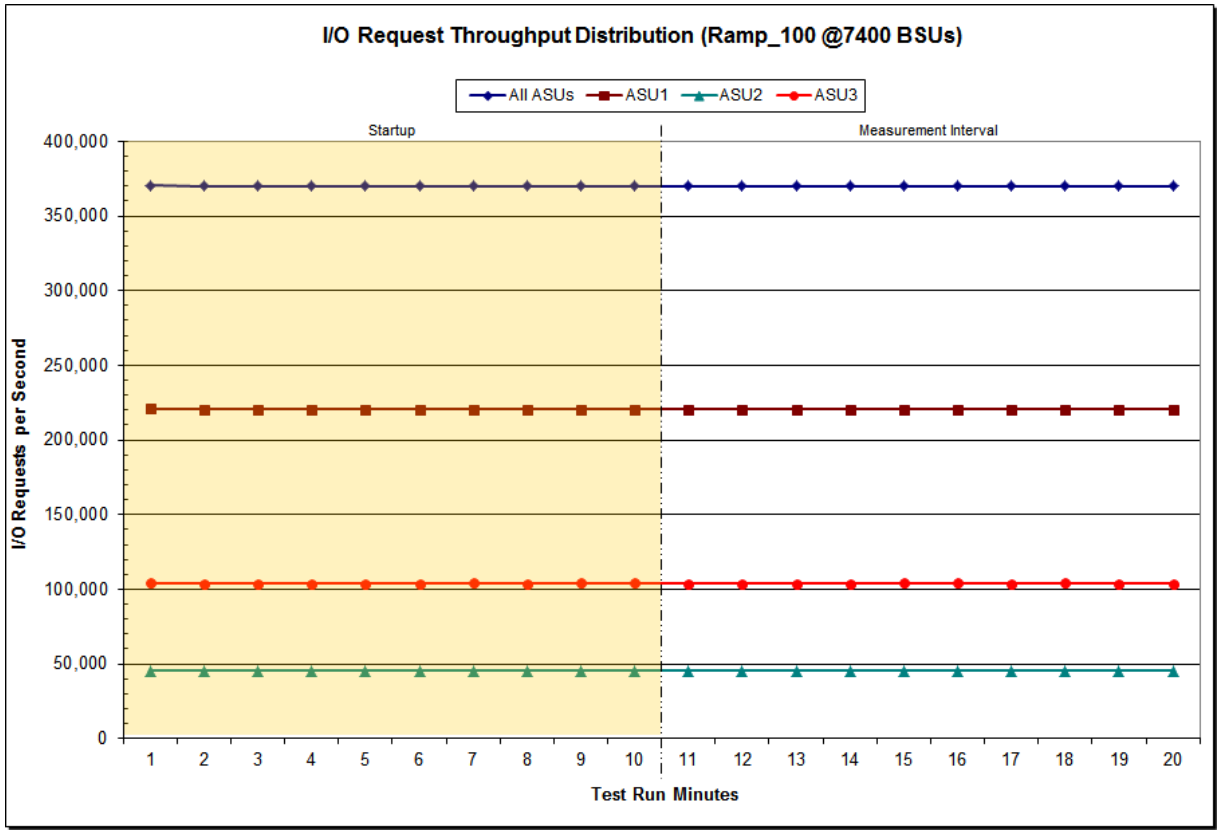
A link to the test results file generated from the IOPS Test Run is listed below.

IOPS Test Results File

IOPS Test Run – I/O Request Throughput Distribution Data

7,400 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	4:36:09	4:46:10	0-9	0:10:01
Measurement Interval	4:46:10	4:56:11	9-19	0:10:01
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	370,262.85	220,728.95	45,526.20	104,007.70
1	370,099.25	220,652.48	45,513.85	103,932.92
2	369,850.55	220,403.55	45,516.30	103,930.70
3	369,867.47	220,509.18	45,479.65	103,878.63
4	369,886.03	220,420.23	45,530.58	103,935.22
5	370,020.32	220,558.25	45,490.62	103,971.45
6	370,071.20	220,605.37	45,472.92	103,992.92
7	369,856.80	220,438.52	45,510.57	103,907.72
8	370,078.00	220,580.82	45,503.70	103,993.48
9	370,076.97	220,571.92	45,507.20	103,997.85
10	369,858.20	220,423.72	45,488.08	103,946.40
11	370,010.82	220,565.53	45,547.10	103,898.18
12	369,877.42	220,511.58	45,497.00	103,868.83
13	369,981.20	220,504.68	45,531.60	103,944.92
14	370,114.97	220,629.98	45,475.35	104,009.63
15	370,163.67	220,600.00	45,549.97	104,013.70
16	369,966.95	220,533.83	45,523.50	103,909.62
17	370,109.78	220,583.92	45,492.17	104,033.70
18	369,936.52	220,489.77	45,498.20	103,948.55
19	369,928.88	220,437.35	45,520.18	103,971.35
Average	***369,994.84***	***220,528.04***	***45,512.32***	***103,954.49***

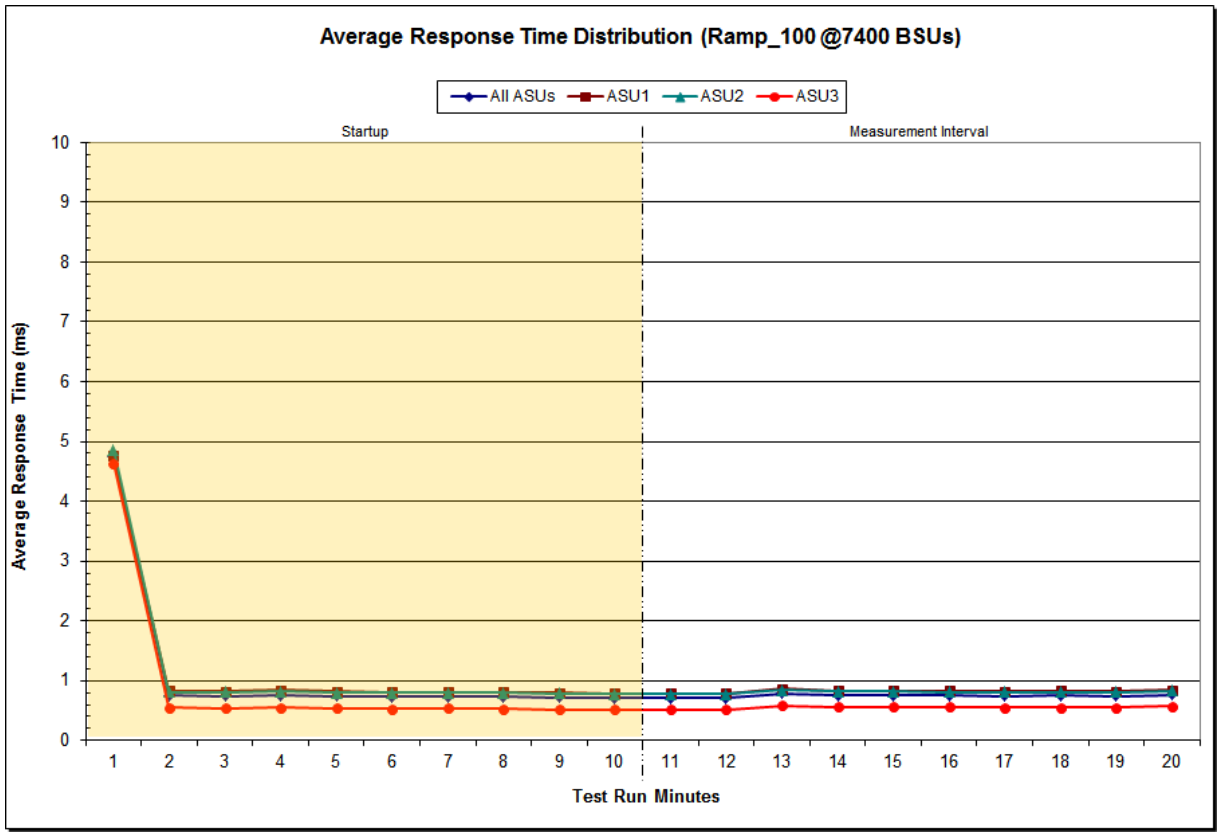
IOPS Test Run – I/O Request Throughput Distribution Graph



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

7,400 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	4:36:09	4:46:10	0-9	0:10:01
Measurement Interval	4:46:10	4:56:11	9-19	0:10:01
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	4.74	4.76	4.86	4.64
1	0.75	0.84	0.81	0.55
2	0.74	0.82	0.80	0.54
3	0.76	0.84	0.82	0.55
4	0.74	0.82	0.80	0.54
5	0.73	0.81	0.80	0.53
6	0.73	0.81	0.80	0.53
7	0.73	0.81	0.80	0.53
8	0.72	0.80	0.78	0.52
9	0.71	0.78	0.77	0.51
10	0.71	0.79	0.78	0.52
11	0.71	0.79	0.78	0.52
12	0.78	0.86	0.84	0.59
13	0.76	0.84	0.82	0.56
14	0.75	0.83	0.82	0.56
15	0.75	0.83	0.81	0.56
16	0.74	0.82	0.81	0.55
17	0.75	0.83	0.81	0.56
18	0.74	0.82	0.81	0.55
19	0.77	0.84	0.83	0.58
Average	***0.75***	***0.82***	***0.81***	***0.55***

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



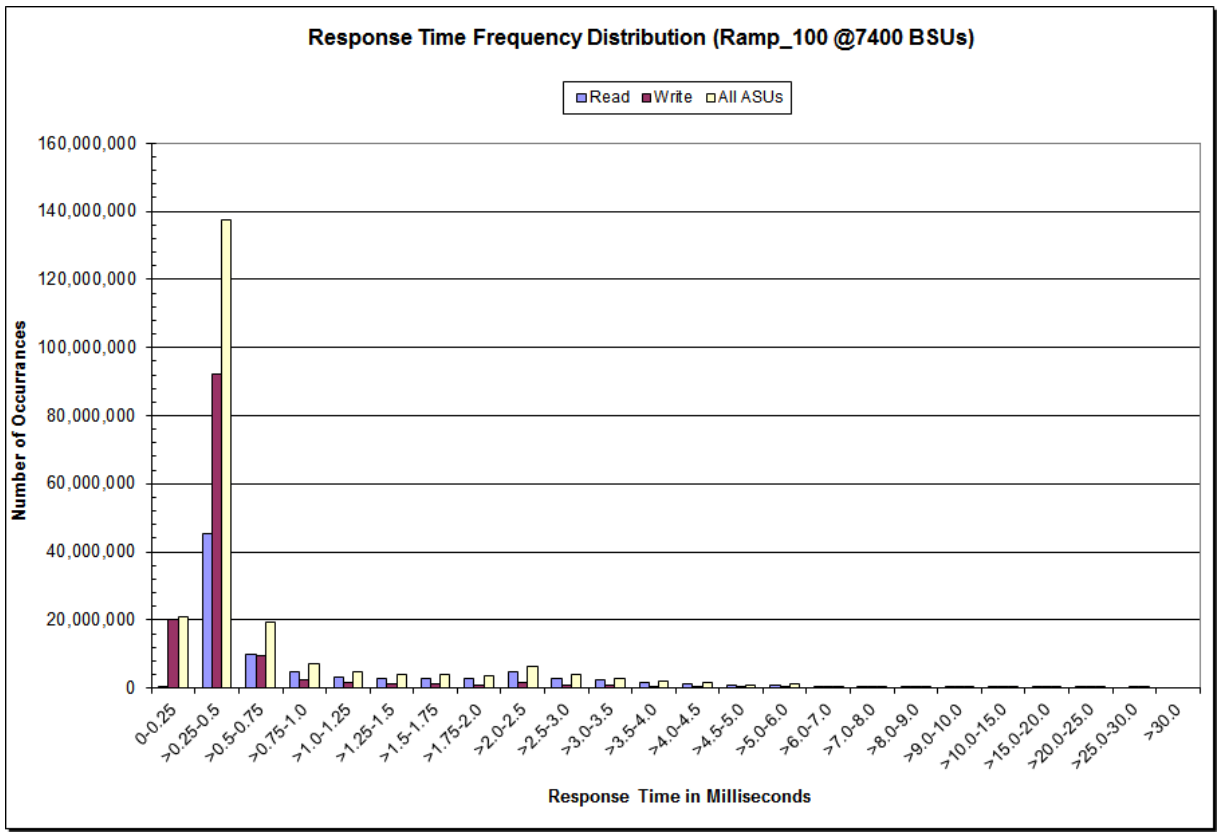
IOPS Test Run – Response Time Frequency Distribution Data

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	521,522	45,191,313	9,788,498	4,614,498	3,070,492	2,862,846	2,819,901	2,840,565
Write	20,339,349	92,277,993	9,637,206	2,478,968	1,632,414	1,323,129	1,112,141	945,370
All ASUs	20,860,871	137,469,306	19,425,704	7,093,466	4,702,906	4,185,975	3,932,042	3,785,935
ASU1	10,856,351	78,755,916	11,822,169	4,803,321	3,171,976	2,858,612	2,717,076	2,659,249
ASU2	2,512,347	16,153,917	2,314,350	946,514	634,875	581,700	566,194	560,006
ASU3	7,492,173	42,559,473	5,289,185	1,343,631	896,055	745,663	648,772	566,680

Response Time (ms)	>2.0-2.5	>2.5-3.0	>3.0-3.5	>3.5-4.0	>4.0-4.5	>4.5-5.0	>5.0-6.0	>6.0-7.0
Read	4,929,723	3,011,178	2,291,185	1,691,420	1,205,800	756,936	939,742	493,850
Write	1,449,793	979,729	686,614	473,089	318,742	213,327	256,663	127,713
All ASUs	6,379,516	3,990,907	2,977,799	2,164,509	1,524,542	970,263	1,196,405	621,563
ASU1	4,521,193	2,806,617	2,104,083	1,552,885	1,108,121	709,982	884,379	463,405
ASU2	978,636	593,393	454,772	323,224	223,295	133,411	159,033	80,923
ASU3	879,687	590,897	418,944	288,400	193,126	126,870	152,993	77,235

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	256,062	135,364	71,982	80,172	3,579	182	1	-
Write	69,495	40,778	23,250	30,674	2,887	364	41	15
All ASUs	325,557	176,142	95,232	110,846	6,466	546	42	15
ASU1	241,187	128,989	69,026	77,951	3,851	240	9	4
ASU2	42,019	22,355	11,931	13,729	669	49	3	3
ASU3	42,351	24,798	14,275	19,166	1,946	257	30	8

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
221,996,555	221,996,540	15

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	0.001	0.001	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 16.

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

Clause 9.4.3.7.4

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

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

SPC-1 Workload Generator Input Parameters

The SPC-1 Workload Generator input parameters for the Sustainability, IOPS, Response Time Ramp, Repeatability, and Persistence Test Runs are documented in *Appendix E: SPC-1 Workload Generator Input Parameters* on Page 79.

Response Time Ramp Test Results File

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

95% Load Level

90% Load Level

80% Load Level

50% Load Level

10% Load Level

Response Time Ramp Distribution (IOPS) Data

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

100% Load Level - 7,400 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	4:36:09	4:46:10	0-9	0:10:01
Measurement Interval	4:46:10	4:56:11	10-19	0:10:01

(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3
0	370,262.85	220,728.95	45,526.20	104,007.70
1	370,099.25	220,652.48	45,513.85	103,932.92
2	369,850.55	220,403.55	45,516.30	103,930.70
3	369,867.47	220,509.18	45,479.65	103,878.63
4	369,886.03	220,420.23	45,530.58	103,935.22
5	370,020.32	220,558.25	45,490.62	103,971.45
6	370,071.20	220,605.37	45,472.92	103,992.92
7	369,856.80	220,438.52	45,510.57	103,907.72
8	370,078.00	220,580.82	45,503.70	103,993.48
9	370,076.97	220,571.92	45,507.20	103,997.85
10	369,858.20	220,423.72	45,488.08	103,946.40
11	370,010.82	220,565.53	45,547.10	103,898.18
12	369,877.42	220,511.58	45,497.00	103,868.83
13	369,981.20	220,504.68	45,531.60	103,944.92
14	370,114.97	220,629.98	45,475.35	104,009.63
15	370,163.67	220,600.00	45,549.97	104,013.70
16	369,966.95	220,533.83	45,523.50	103,909.62
17	370,109.78	220,583.92	45,492.17	104,033.70
18	369,936.52	220,489.77	45,498.20	103,948.55
19	369,928.88	220,437.35	45,520.18	103,971.35
Average	***369,994.84***	***220,528.04***	***45,512.32***	***103,954.49***

95% Load Level - 7,030 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	4:58:31	5:08:32	0-9	0:10:01
Measurement Interval	5:08:32	5:18:33	10-19	0:10:01

(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3
0	351,705.53	209,634.88	43,279.53	98,791.12
1	351,336.73	209,436.37	43,216.18	98,684.18
2	351,469.87	209,458.03	43,172.93	98,838.90
3	351,527.18	209,488.23	43,230.23	98,808.72
4	351,479.42	209,445.85	43,233.80	98,799.77
5	351,391.22	209,421.32	43,245.58	98,724.32
6	351,554.05	209,484.02	43,238.30	98,831.73
7	351,520.00	209,507.00	43,216.50	98,796.50
8	351,568.32	209,618.07	43,232.52	98,717.73
9	351,490.63	209,459.60	43,206.18	98,824.85
10	351,552.20	209,528.83	43,214.18	98,809.18
11	351,490.27	209,507.05	43,219.85	98,763.37
12	351,533.10	209,476.58	43,277.65	98,778.87
13	351,357.32	209,489.98	43,190.70	98,676.63
14	351,403.87	209,442.22	43,213.07	98,748.58
15	351,533.73	209,573.20	43,179.27	98,781.27
16	351,530.20	209,463.28	43,242.87	98,824.05
17	351,538.77	209,553.10	43,278.75	98,706.92
18	351,456.93	209,430.10	43,205.50	98,821.33
19	351,578.12	209,492.22	43,233.45	98,852.45
Average	***351,497.45***	***209,495.66***	***43,225.53***	***98,776.27***

90% Load Level - 6,660 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	5:20:46	5:30:47	0-9	0:10:01
Measurement Interval	5:30:47	5:40:48	10-19	0:10:01

(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3
0	333,204.25	198,573.27	40,939.42	93,691.57
1	333,049.13	198,458.38	40,977.83	93,612.92
2	332,938.95	198,499.85	40,907.83	93,531.27
3	332,993.25	198,482.15	40,956.63	93,554.47
4	333,078.55	198,502.70	40,984.22	93,591.63
5	332,984.32	198,405.63	41,014.00	93,564.68
6	333,127.80	198,567.85	40,950.10	93,609.85
7	332,919.77	198,455.75	40,962.35	93,501.67
8	332,852.15	198,413.32	40,916.20	93,522.63
9	332,944.57	198,470.10	40,930.77	93,543.70
10	332,965.33	198,459.72	40,908.27	93,597.35
11	332,938.77	198,465.22	40,950.68	93,522.87
12	333,058.02	198,470.13	40,985.50	93,602.38
13	332,953.38	198,409.88	40,949.28	93,594.22
14	332,984.53	198,466.28	40,933.35	93,584.90
15	333,090.92	198,562.93	40,929.18	93,598.80
16	332,966.32	198,447.80	40,956.40	93,562.12
17	332,970.00	198,474.18	40,971.75	93,524.07
18	333,011.40	198,511.12	40,951.25	93,549.03
19	333,023.03	198,451.52	40,971.90	93,599.62
Average	***332,996.17***	***198,471.88***	***40,950.76***	***93,573.54***

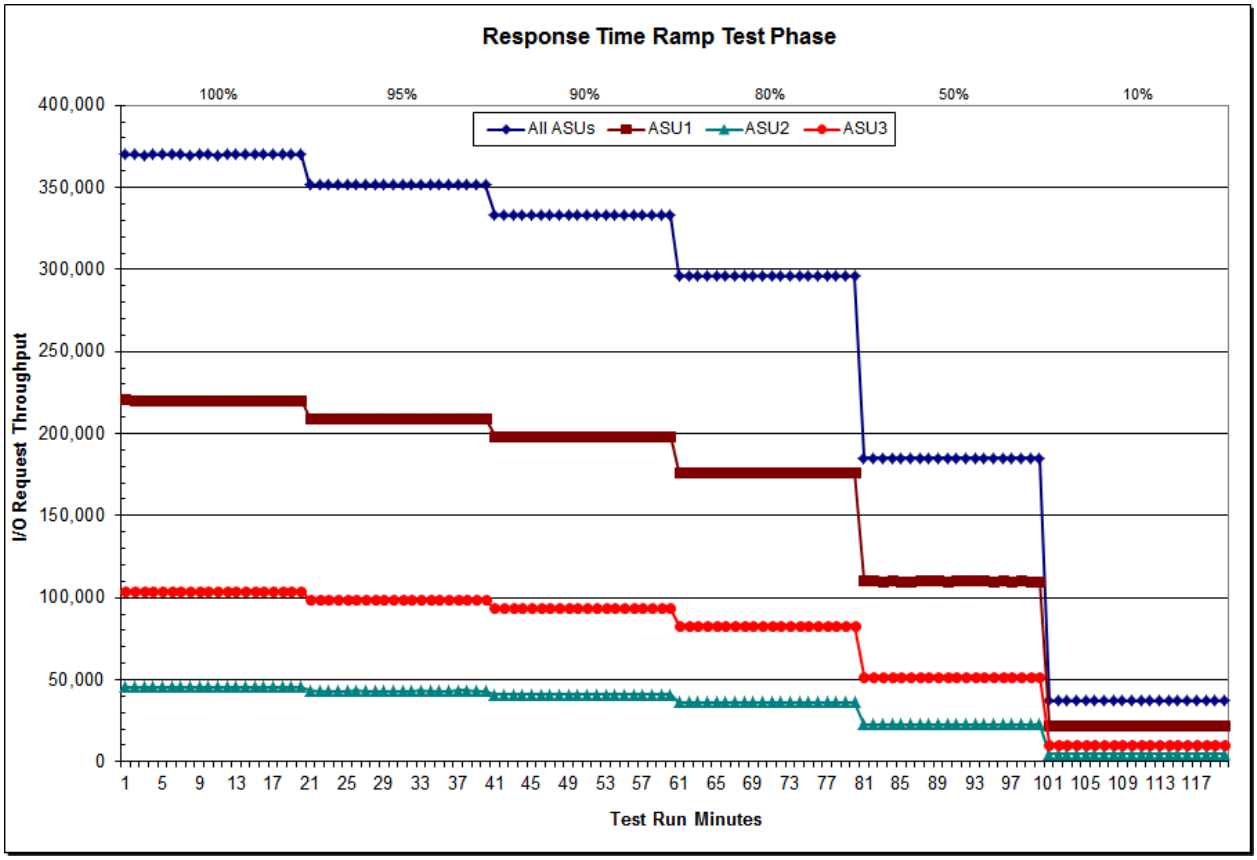
80% Load Level - 5,920 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	5:42:51	5:52:52	0-9	0:10:01
Measurement Interval	5:52:52	6:02:53	10-19	0:10:01

(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3
0	296,174.23	176,509.70	36,459.73	83,204.80
1	295,859.63	176,340.32	36,415.43	83,103.88
2	295,887.07	176,273.73	36,432.42	83,180.92
3	295,925.15	176,396.63	36,396.50	83,132.02
4	295,953.55	176,404.42	36,444.27	83,104.87
5	296,026.75	176,394.88	36,388.00	83,243.87
6	295,984.42	176,353.57	36,398.55	83,232.30
7	296,093.48	176,514.53	36,412.75	83,166.20
8	296,015.80	176,407.00	36,396.40	83,212.40
9	296,231.85	176,617.35	36,391.25	83,223.25
10	295,962.70	176,397.82	36,391.78	83,173.10
11	295,984.07	176,380.42	36,394.93	83,208.72
12	296,016.28	176,409.35	36,398.47	83,208.47
13	295,944.58	176,380.98	36,377.67	83,185.93
14	295,871.23	176,374.55	36,336.15	83,160.53
15	295,917.88	176,341.53	36,399.35	83,177.00
16	296,009.90	176,404.05	36,415.53	83,190.32
17	296,023.28	176,466.82	36,406.35	83,150.12
18	295,991.07	176,465.95	36,347.52	83,177.60
19	296,057.22	176,444.62	36,435.37	83,177.23
Average	***295,977.82***	***176,406.61***	***36,390.31***	***83,180.90***

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

50% Load Level - 3,700 BSUs	Start	Stop	Interval	Duration	10% Load Level - 740 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	6:04:24	6:14:25	0-9	0:10:01	Start-Up/Ramp-Up	6:25:20	6:35:21	0-9	0:10:01
Measurement Interval	6:14:25	6:24:25	10-19	0:10:00	Measurement Interval	6:35:21	6:45:21	10-19	0:10:00
(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3	*(60 second intervals)*	All ASUs	ASU-1	ASU-2	ASU-3
0	185,014.45	110,253.55	22,762.17	51,998.73	0	37,021.63	22,064.70	4,545.40	10,411.53
1	184,986.42	110,284.77	22,781.63	51,920.02	1	36,963.47	22,030.15	4,545.82	10,387.50
2	184,927.80	110,204.42	22,766.28	51,957.10	2	36,988.45	22,039.37	4,558.23	10,390.85
3	185,005.78	110,309.53	22,742.43	51,953.82	3	37,074.97	22,076.12	4,563.77	10,435.08
4	184,947.20	110,229.80	22,738.95	51,978.45	4	36,952.87	22,028.67	4,553.48	10,370.72
5	184,957.92	110,176.20	22,787.18	51,994.53	5	36,963.18	22,014.70	4,550.75	10,397.73
6	185,089.42	110,281.68	22,785.62	52,022.12	6	36,954.68	22,061.80	4,531.20	10,361.68
7	185,073.90	110,328.10	22,775.73	51,970.07	7	37,011.15	22,072.80	4,539.03	10,399.32
8	185,018.05	110,299.87	22,748.48	51,969.70	8	36,969.38	22,026.60	4,544.88	10,397.90
9	184,956.08	110,249.38	22,770.30	51,936.40	9	37,010.30	22,067.72	4,549.15	10,393.43
10	184,933.55	110,273.25	22,748.90	51,911.40	10	36,986.18	22,026.43	4,552.83	10,406.92
11	185,016.78	110,269.57	22,761.37	51,985.85	11	36,962.20	22,046.38	4,542.42	10,373.40
12	185,094.70	110,318.17	22,755.85	52,020.68	12	37,016.72	22,059.10	4,551.47	10,406.15
13	185,064.53	110,320.92	22,755.95	51,987.67	13	37,027.40	22,084.07	4,551.65	10,391.68
14	184,921.72	110,210.47	22,722.52	51,988.73	14	37,049.32	22,078.33	4,547.42	10,423.57
15	185,058.30	110,300.65	22,764.82	51,992.83	15	37,050.70	22,076.17	4,554.23	10,420.30
16	184,910.45	110,187.83	22,739.78	51,982.83	16	36,983.25	22,042.78	4,539.48	10,400.98
17	184,956.65	110,252.28	22,746.15	51,958.22	17	37,035.55	22,066.92	4,554.98	10,413.65
18	184,901.57	110,208.63	22,724.32	51,968.62	18	36,993.83	22,033.63	4,556.13	10,404.07
19	184,994.77	110,220.78	22,742.92	52,031.07	19	37,007.58	22,040.42	4,560.10	10,407.07
Average	***184,985.30***	***110,256.26***	***22,746.26***	***51,982.79***	*Average*	***37,011.27***	***22,055.42***	***4,551.07***	***10,404.78***

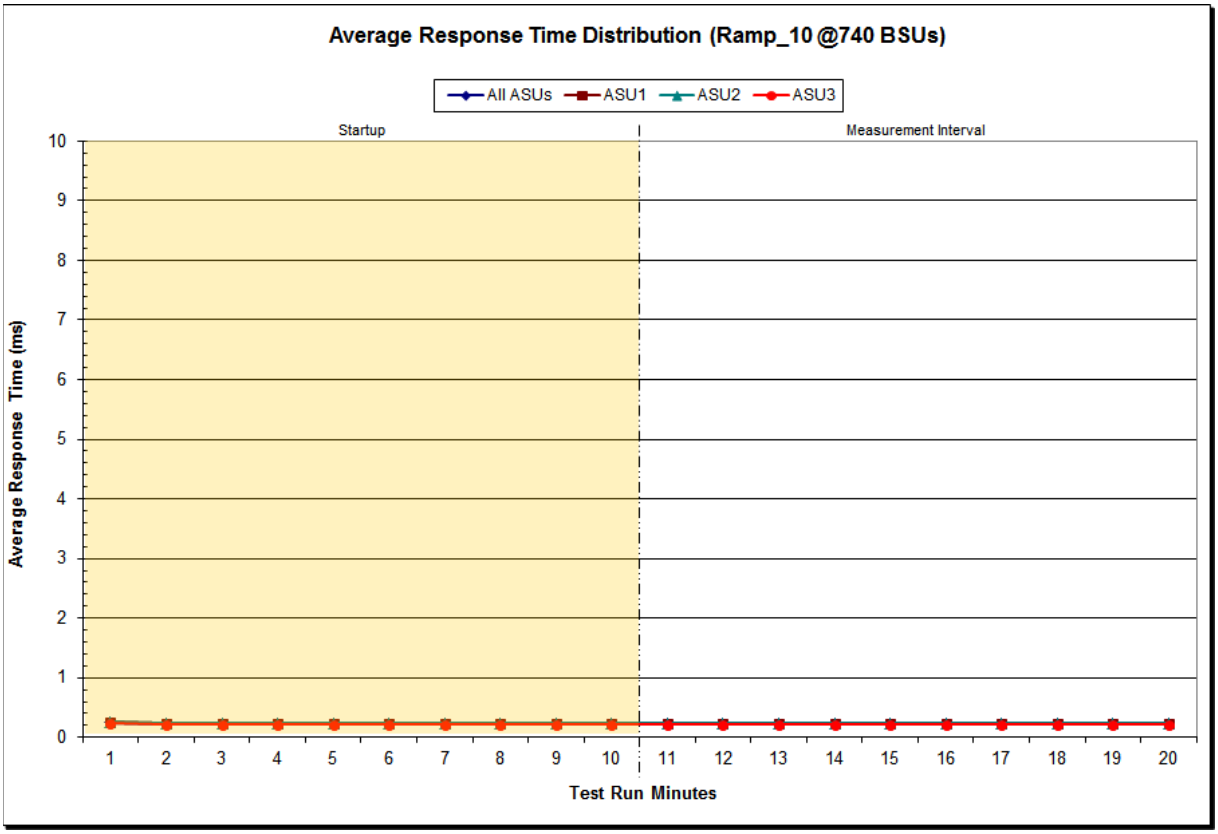
Response Time Ramp Distribution (IOPS) Graph



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

740 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	6:25:20	6:35:21	0-9	0:10:01
Measurement Interval	6:35:21	6:45:21	10-19	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	0.25	0.26	0.26	0.24
1	0.23	0.24	0.24	0.21
2	0.23	0.24	0.24	0.21
3	0.23	0.24	0.24	0.21
4	0.23	0.24	0.24	0.21
5	0.23	0.24	0.24	0.21
6	0.23	0.24	0.24	0.21
7	0.23	0.24	0.24	0.21
8	0.23	0.24	0.24	0.21
9	0.23	0.24	0.24	0.21
10	0.23	0.24	0.24	0.21
11	0.23	0.24	0.24	0.21
12	0.23	0.24	0.24	0.21
13	0.23	0.24	0.24	0.21
14	0.23	0.24	0.24	0.21
15	0.23	0.24	0.24	0.21
16	0.23	0.24	0.24	0.21
17	0.23	0.24	0.24	0.21
18	0.23	0.24	0.24	0.21
19	0.23	0.24	0.24	0.21
Average	***0.23***	***0.24***	***0.24***	***0.21***

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	0.2811	0.0700	0.2099	0.0180	0.0700	0.0350	0.2811
COV	0.003	0.001	0.002	0.001	0.004	0.001	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 79.

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	***369,994.84***
Repeatability Test Phase 1	370,018.82
Repeatability Test Phase 2	370,033.30

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.

Average Response Time	
Primary Metrics (SPC-1 LRT™	***0.23 ms***
Repeatability Test Phase 1	0.23 ms
Repeatability Test Phase 2	0.23 ms

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

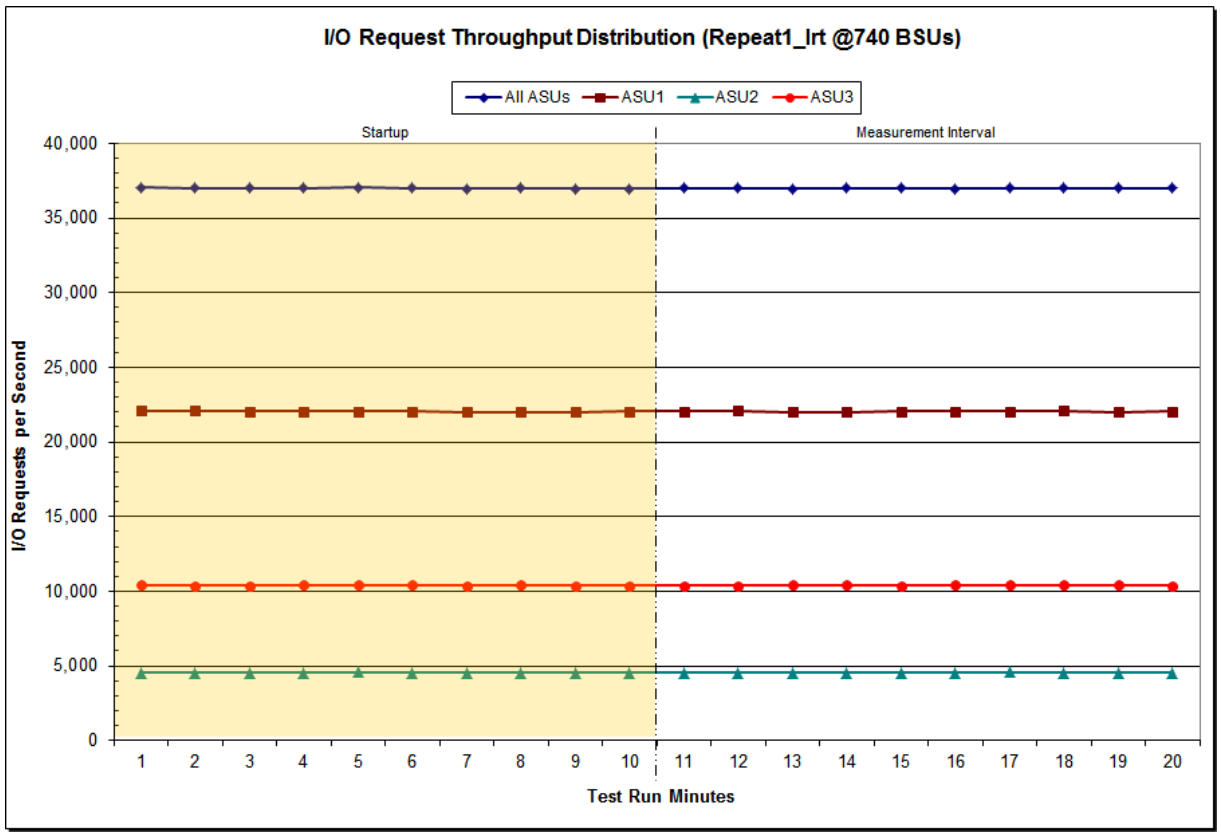
A link to the test result file generated from each Repeatability Test Run is listed below.

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

Repeatability 1 LRT – I/O Request Throughput Distribution Data

740 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	6:47:57	6:57:57	0-9	0:10:00
Measurement Interval	6:57:57	7:07:57	9-19	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	37,039.87	22,072.05	4,561.48	10,406.33
1	37,014.83	22,075.67	4,541.95	10,397.22
2	36,996.97	22,051.47	4,552.22	10,393.28
3	37,002.72	22,056.33	4,546.72	10,399.67
4	37,036.53	22,062.67	4,566.60	10,407.27
5	37,008.30	22,047.62	4,555.18	10,405.50
6	36,940.67	22,012.67	4,557.42	10,370.58
7	36,999.92	22,024.58	4,553.80	10,421.53
8	36,962.62	22,017.85	4,548.17	10,396.60
9	36,963.95	22,030.23	4,540.85	10,392.87
10	36,994.83	22,043.57	4,553.92	10,397.35
11	37,015.75	22,087.82	4,540.30	10,387.63
12	36,970.88	22,022.23	4,549.55	10,399.10
13	36,990.87	22,021.80	4,553.47	10,415.60
14	36,996.82	22,065.75	4,548.20	10,382.87
15	36,966.77	22,032.38	4,534.77	10,399.62
16	37,014.17	22,029.93	4,567.57	10,416.67
17	37,015.32	22,072.20	4,539.68	10,403.43
18	36,981.00	22,021.40	4,549.35	10,410.25
19	36,985.77	22,050.80	4,549.08	10,385.88
Average	***36,993.22***	***22,044.79***	***4,548.59***	***10,399.84***

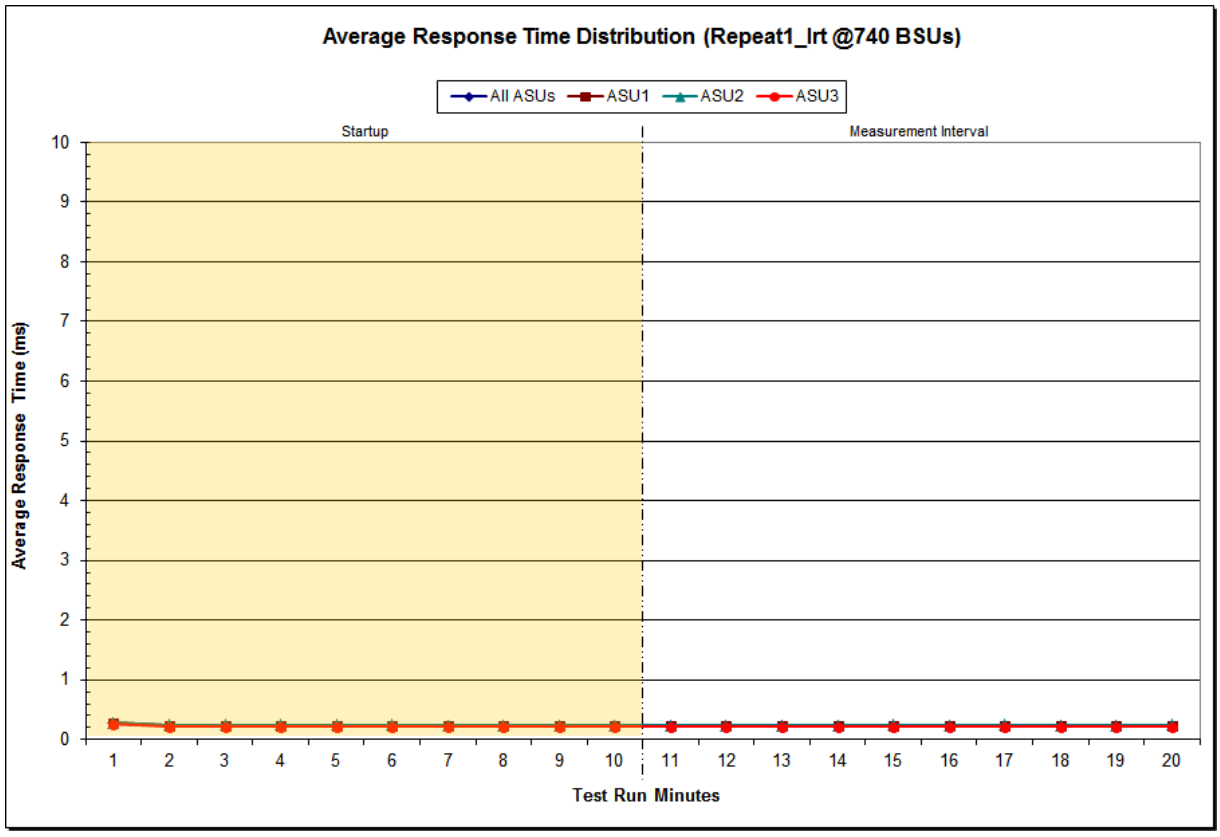
Repeatability 1 LRT – I/O Request Throughput Distribution Graph



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

740 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	6:47:57	6:57:57	0-9	0:10:00
Measurement Interval	6:57:57	7:07:57	9-19	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	0.27	0.28	0.29	0.26
1	0.23	0.24	0.24	0.21
2	0.23	0.24	0.24	0.21
3	0.23	0.24	0.24	0.21
4	0.23	0.24	0.24	0.21
5	0.23	0.24	0.24	0.21
6	0.23	0.24	0.24	0.21
7	0.23	0.24	0.24	0.21
8	0.23	0.24	0.24	0.21
9	0.23	0.24	0.24	0.21
10	0.23	0.24	0.24	0.21
11	0.23	0.24	0.24	0.21
12	0.23	0.24	0.24	0.21
13	0.23	0.24	0.24	0.21
14	0.23	0.24	0.24	0.21
15	0.23	0.24	0.24	0.21
16	0.23	0.24	0.24	0.21
17	0.23	0.24	0.24	0.21
18	0.23	0.24	0.24	0.21
19	0.23	0.24	0.24	0.21
Average	***0.23***	***0.24***	***0.24***	***0.21***

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

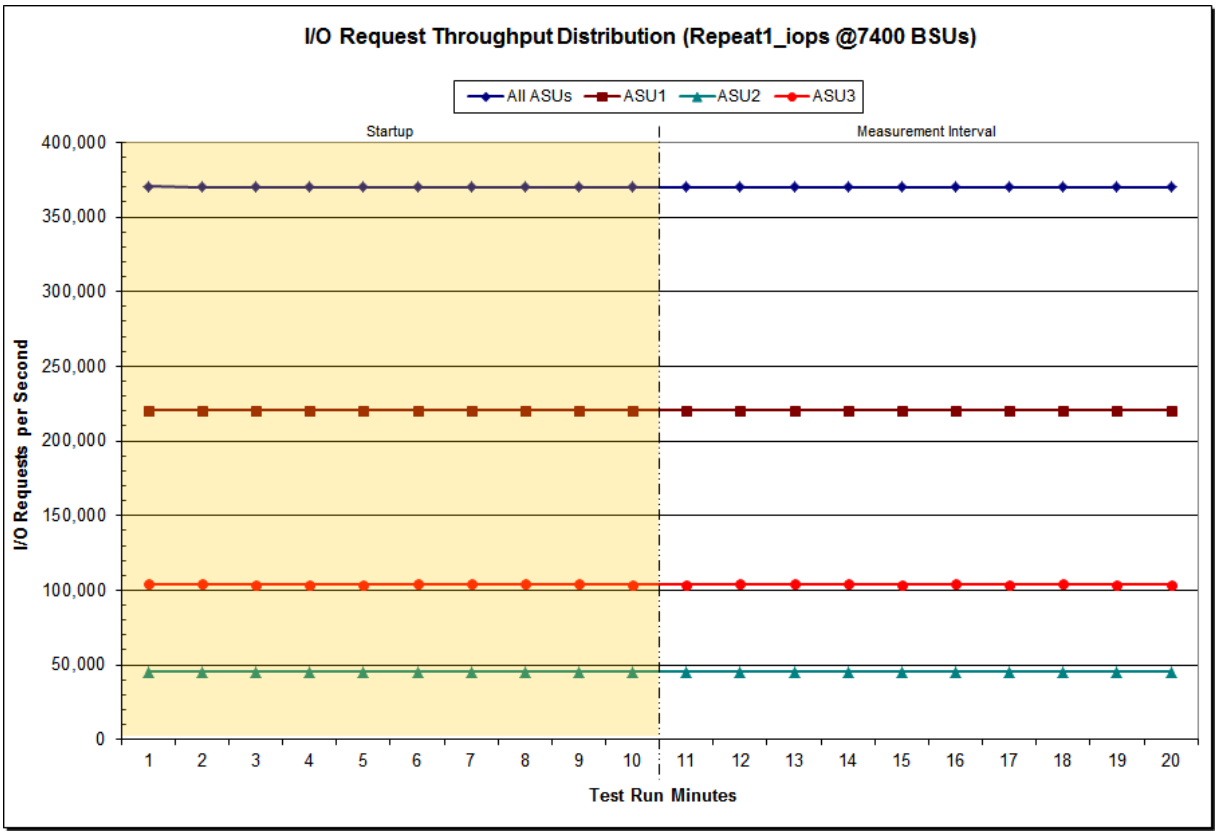


Repeatability 1 IOPS – I/O Request Throughput Distribution Data

7,400 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	7:10:24	7:20:25	0-9	0:10:01
Measurement Interval	7:20:25	7:30:26	9-19	0:10:01

60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	370,290.45	220,674.53	45,566.38	104,049.53
1	369,980.78	220,474.23	45,516.12	103,990.43
2	370,038.00	220,548.32	45,527.12	103,962.57
3	369,953.83	220,481.65	45,530.52	103,941.67
4	369,938.02	220,480.20	45,495.00	103,962.82
5	370,081.10	220,541.73	45,548.97	103,990.40
6	370,021.92	220,493.33	45,471.53	104,057.05
7	369,994.47	220,489.13	45,494.73	104,010.60
8	370,020.80	220,542.52	45,481.55	103,996.73
9	369,932.90	220,517.30	45,486.52	103,929.08
10	369,969.55	220,535.47	45,503.53	103,930.55
11	370,044.78	220,489.92	45,529.30	104,025.57
12	370,017.57	220,496.33	45,520.72	104,000.52
13	370,106.75	220,515.25	45,551.15	104,040.35
14	369,986.03	220,514.75	45,491.43	103,979.85
15	370,046.27	220,538.13	45,500.93	104,007.20
16	370,071.65	220,543.92	45,574.87	103,952.87
17	370,012.65	220,531.13	45,494.23	103,987.28
18	369,916.17	220,492.50	45,493.60	103,930.07
19	370,016.75	220,522.35	45,522.48	103,971.92
Average	***370,018.82***	***220,517.98***	***45,518.23***	***103,982.62***

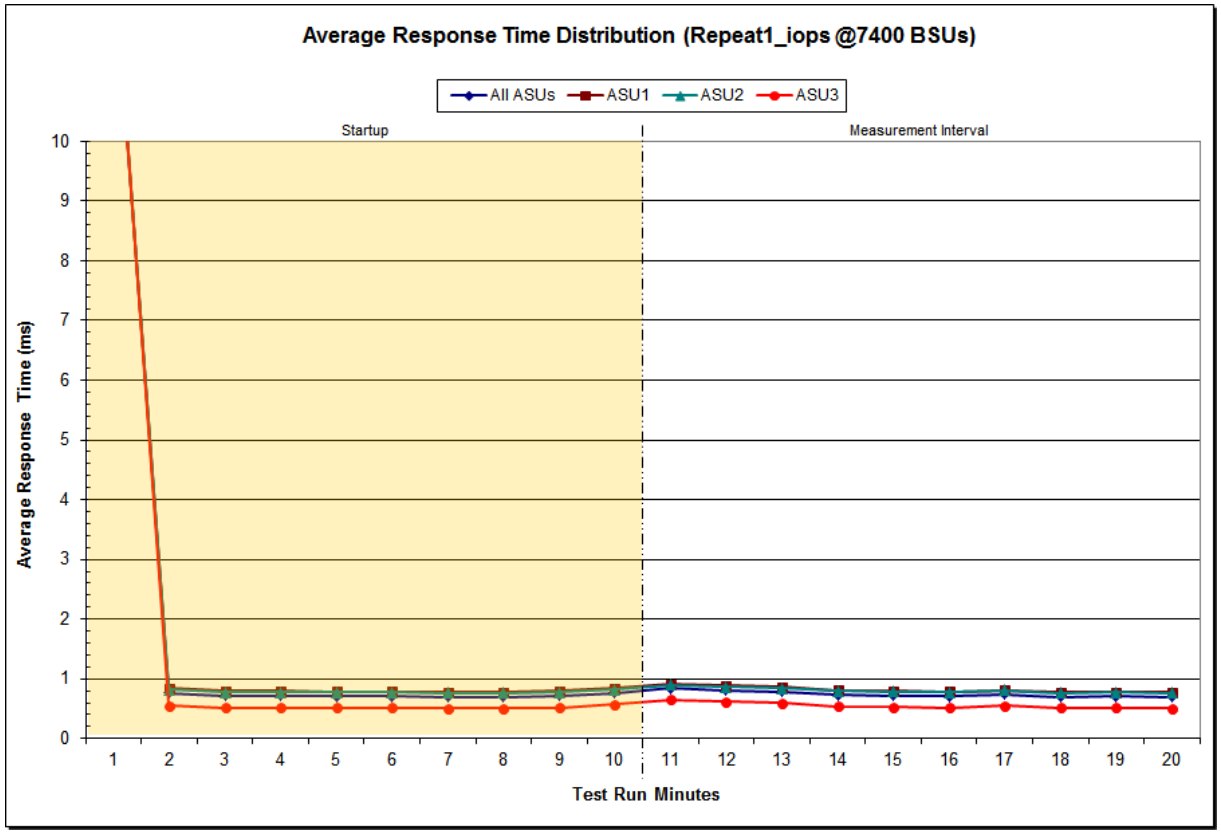
Repeatability 1 IOPS – I/O Request Throughput Distribution Graph



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

7,400 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	7:10:24	7:20:25	0-9	0:10:01
Measurement Interval	7:20:25	7:30:26	9-19	0:10:01
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	13.10	13.04	13.12	13.20
1	0.76	0.84	0.82	0.55
2	0.72	0.80	0.78	0.52
3	0.72	0.80	0.78	0.52
4	0.71	0.79	0.77	0.51
5	0.71	0.79	0.78	0.52
6	0.70	0.78	0.77	0.51
7	0.70	0.78	0.76	0.50
8	0.72	0.79	0.78	0.52
9	0.77	0.85	0.83	0.57
10	0.84	0.91	0.89	0.65
11	0.81	0.89	0.87	0.62
12	0.79	0.87	0.85	0.59
13	0.74	0.81	0.80	0.55
14	0.72	0.80	0.79	0.53
15	0.71	0.78	0.77	0.52
16	0.74	0.81	0.80	0.55
17	0.70	0.78	0.77	0.52
18	0.71	0.78	0.77	0.52
19	0.70	0.77	0.76	0.51
Average	***0.74***	***0.82***	***0.81***	***0.56***

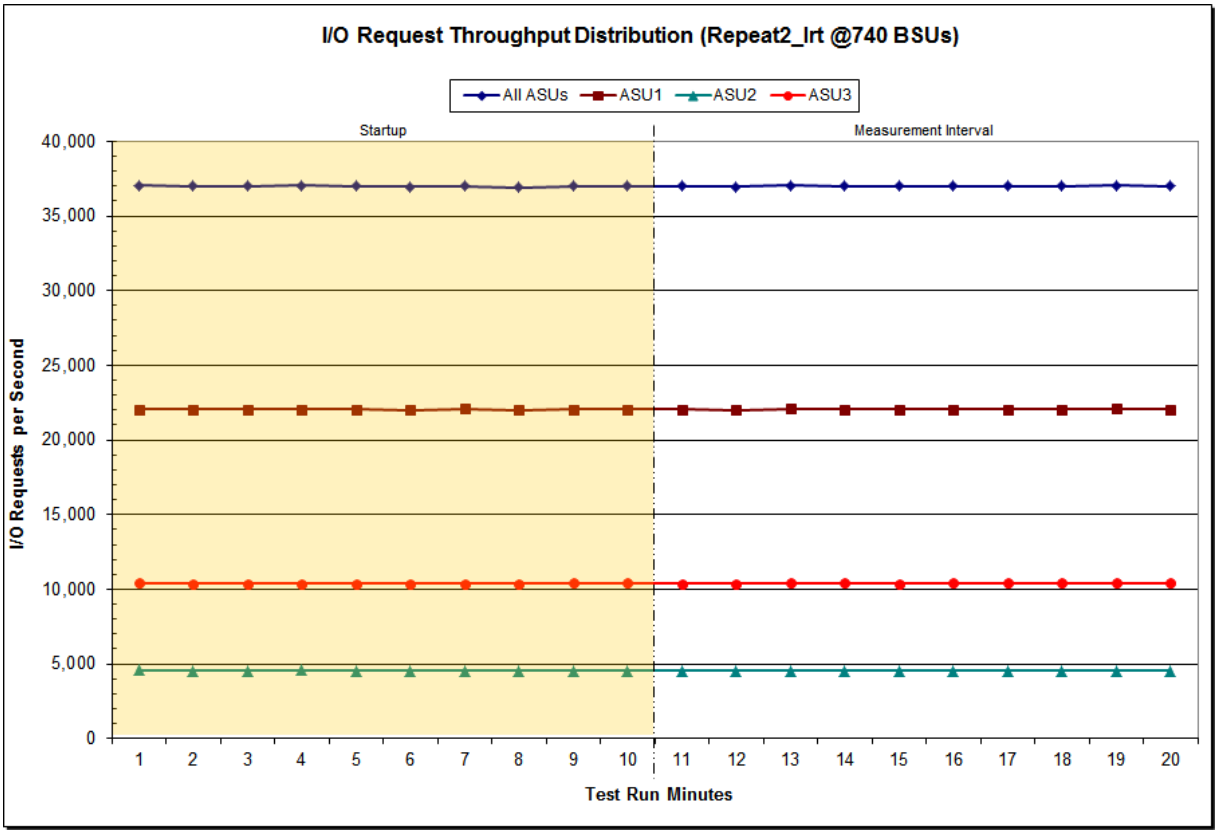
Repeatability 1 IOPS –Average Response Time (ms) Distribution Graph



Repeatability 2 LRT – I/O Request Throughput Distribution Data

740 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	7:33:04	7:43:04	0-9	0:10:00
Measurement Interval	7:43:04	7:53:04	9-19	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	37,038.07	22,069.62	4,564.50	10,403.95
1	36,985.50	22,038.17	4,559.42	10,387.92
2	36,988.68	22,060.43	4,555.37	10,372.88
3	37,023.38	22,054.88	4,570.28	10,398.22
4	36,980.37	22,045.82	4,546.08	10,388.47
5	36,960.43	22,009.92	4,559.22	10,391.30
6	36,997.32	22,075.68	4,552.20	10,369.43
7	36,919.83	22,020.45	4,541.52	10,357.87
8	36,977.90	22,033.12	4,545.90	10,398.88
9	36,989.33	22,033.52	4,542.65	10,413.17
10	37,009.52	22,060.97	4,555.23	10,393.32
11	36,943.85	22,026.20	4,540.17	10,377.48
12	37,031.62	22,075.48	4,540.78	10,415.35
13	37,014.37	22,048.50	4,547.18	10,418.68
14	36,996.25	22,070.13	4,545.98	10,380.13
15	37,002.88	22,040.90	4,558.82	10,403.17
16	36,991.53	22,030.98	4,561.43	10,399.12
17	37,009.18	22,056.92	4,546.13	10,406.13
18	37,025.18	22,072.03	4,539.83	10,413.32
19	37,000.30	22,060.83	4,537.03	10,402.43
Average	***37,002.47***	***22,054.30***	***4,547.26***	***10,400.91***

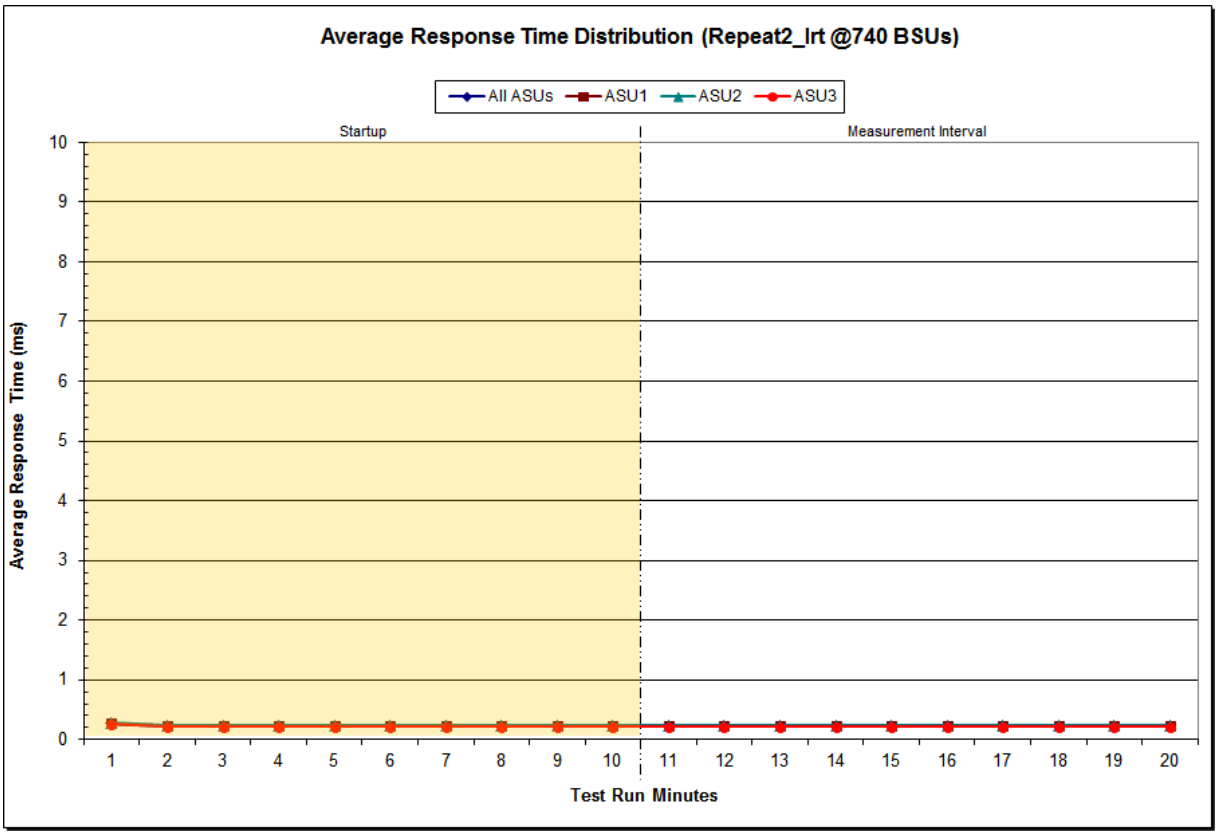
Repeatability 2 LRT – I/O Request Throughput Distribution Graph



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

740 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	7:33:04	7:43:04	0-9	0:10:00
Measurement Interval	7:43:04	7:53:04	9-19	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	0.27	0.28	0.28	0.26
1	0.23	0.24	0.24	0.21
2	0.23	0.24	0.24	0.21
3	0.23	0.24	0.24	0.21
4	0.23	0.24	0.24	0.21
5	0.23	0.24	0.24	0.21
6	0.23	0.24	0.24	0.21
7	0.23	0.24	0.24	0.21
8	0.23	0.24	0.24	0.21
9	0.23	0.24	0.24	0.21
10	0.23	0.24	0.24	0.21
11	0.23	0.24	0.24	0.21
12	0.23	0.24	0.24	0.21
13	0.23	0.24	0.24	0.21
14	0.23	0.24	0.24	0.21
15	0.23	0.24	0.24	0.21
16	0.23	0.24	0.24	0.21
17	0.23	0.24	0.24	0.21
18	0.23	0.24	0.24	0.21
19	0.23	0.24	0.24	0.21
Average	***0.23***	***0.24***	***0.24***	***0.21***

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

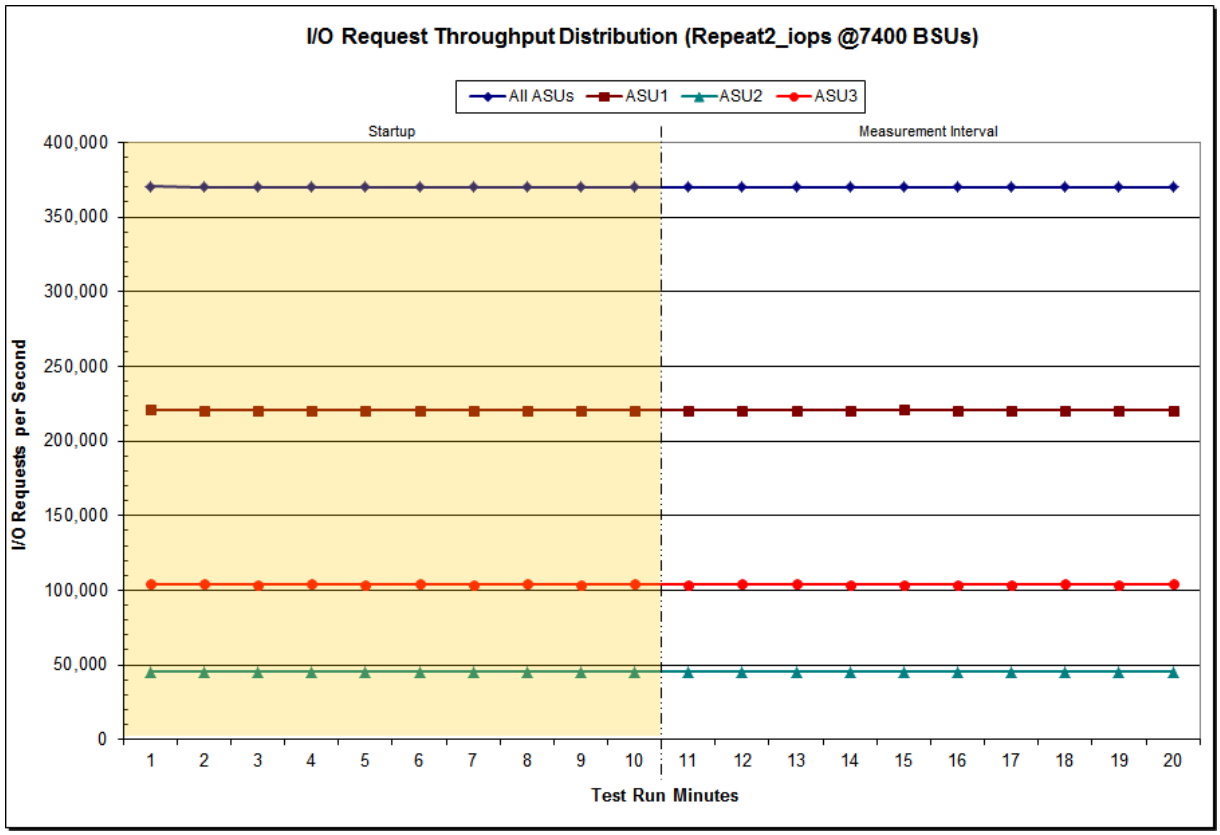


Repeatability 2 IOPS – I/O Request Throughput Distribution Data

7,400 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	7:55:32	8:05:33	0-9	0:10:01
Measurement Interval	8:05:33	8:15:34	9-19	0:10:01

60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	370,319.52	220,765.67	45,560.73	103,993.12
1	370,019.78	220,448.28	45,562.10	104,009.40
2	369,992.55	220,598.30	45,496.35	103,897.90
3	370,033.93	220,530.55	45,511.82	103,991.57
4	369,845.75	220,444.73	45,456.05	103,944.97
5	369,985.98	220,497.83	45,485.12	104,003.03
6	369,869.17	220,460.43	45,465.33	103,943.40
7	369,967.87	220,431.83	45,496.83	104,039.20
8	370,027.83	220,507.93	45,573.08	103,946.82
9	370,125.10	220,621.48	45,490.52	104,013.10
10	370,078.95	220,619.52	45,531.83	103,927.60
11	370,175.05	220,605.38	45,535.08	104,034.58
12	369,974.22	220,452.52	45,512.73	104,008.97
13	369,896.88	220,464.70	45,516.32	103,915.87
14	370,088.73	220,717.40	45,505.67	103,865.67
15	370,028.12	220,598.45	45,521.22	103,908.45
16	370,039.00	220,554.58	45,502.32	103,982.10
17	370,070.25	220,507.38	45,530.77	104,032.10
18	370,002.82	220,521.27	45,505.52	103,976.03
19	369,978.93	220,440.03	45,537.08	104,001.82
Average	***370,033.30***	***220,548.12***	***45,519.85***	***103,965.32***

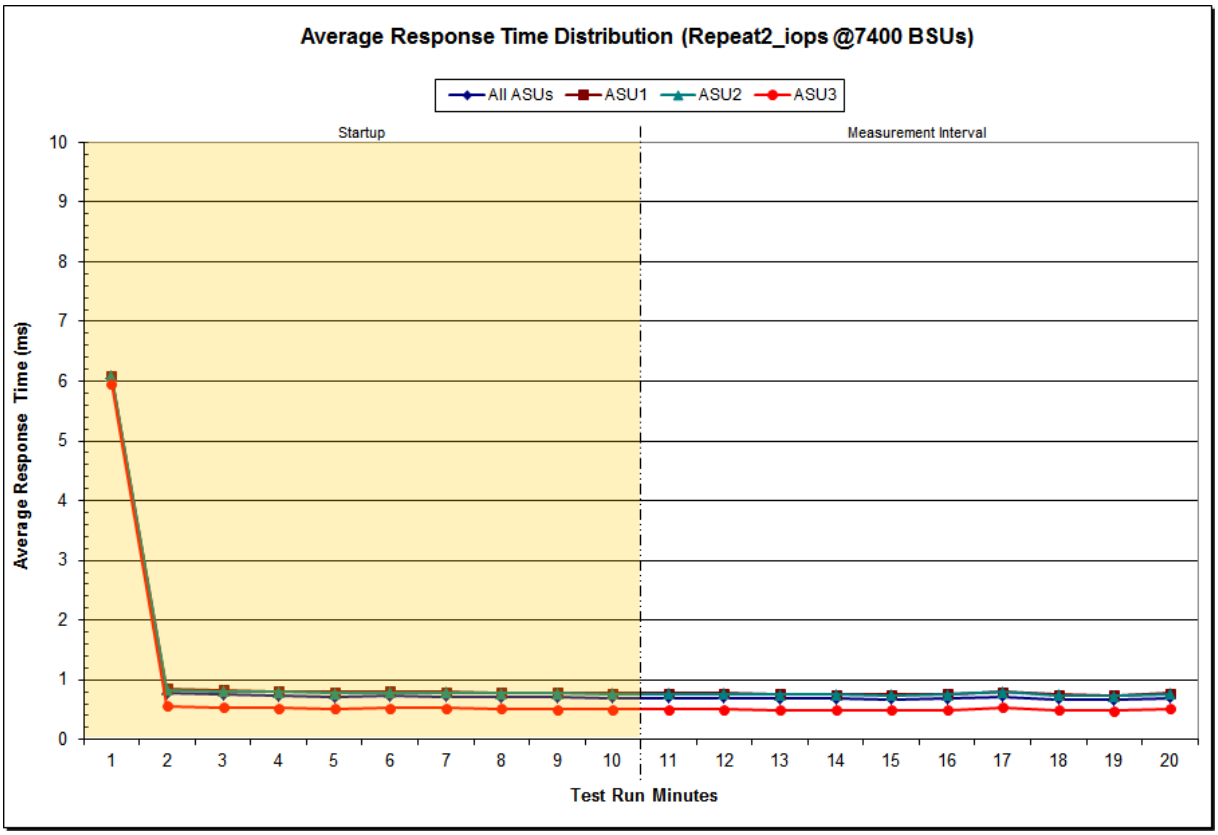
Repeatability 2 IOPS – I/O Request Throughput Distribution Graph



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

7,400 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	7:55:32	8:05:33	0-9	0:10:01
Measurement Interval	8:05:33	8:15:34	9-19	0:10:01
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	6.05	6.09	6.08	5.96
1	0.77	0.86	0.83	0.56
2	0.75	0.83	0.81	0.54
3	0.73	0.81	0.80	0.53
4	0.71	0.79	0.78	0.51
5	0.73	0.81	0.79	0.53
6	0.72	0.80	0.78	0.52
7	0.71	0.79	0.77	0.51
8	0.70	0.78	0.77	0.51
9	0.69	0.77	0.76	0.50
10	0.70	0.78	0.77	0.51
11	0.70	0.78	0.77	0.51
12	0.69	0.76	0.75	0.50
13	0.68	0.76	0.75	0.49
14	0.68	0.75	0.74	0.49
15	0.69	0.76	0.76	0.50
16	0.72	0.80	0.79	0.54
17	0.68	0.75	0.74	0.49
18	0.67	0.74	0.74	0.48
19	0.70	0.78	0.77	0.51
Average	***0.69***	***0.77***	***0.76***	***0.50***

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



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

Clause 3.4.3

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

Clauses 5.1.10 and 5.3.15.2

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

Clause 5.3.15.3

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

	ASU1-1	ASU1-2	ASU1-3	ASU1-4	ASU2-1	ASU2-2	ASU2-3	ASU3-1
IM	***0.0350***	***0.2810***	***0.0700***	***0.2100***	***0.0180***	***0.0700***	***0.0350***	***0.2810***
MIM	0.0350	0.2811	0.0699	0.2100	0.0180	0.0700	0.0350	0.2811
COV	0.003	0.002	0.003	0.002	0.004	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	0.001	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	0.0701	0.2101	0.0179	0.0699	0.0350	0.2811
COV	0.002	0.001	0.003	0.002	0.005	0.003	0.005	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	0.000	0.001	0.001

Data Persistence Test

Clause 6

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

- *Is capable of maintain data integrity across a power cycle.*
- *Ensures the transfer of data between Logical Volumes and host systems occurs without corruption or loss.*

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

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

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

Clause 9.4.3.8

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

1. *A listing or screen image of all input parameters supplied to the Workload Generator.*
2. *For the successful Data Persistence Test Run, a table illustrating key results. The content, appearance, and format of this table are specified in Table 9-12. Information displayed in this table shall be obtained from the Test Run Results File referenced below in #3.*
3. *For the successful Data Persistence Test Run, the human readable Test Run Results file produced by the Workload Generator (may be contained in an appendix).*

SPC-1 Workload Generator Input Parameters

The SPC-1 Workload Generator input parameters for the Sustainability, IOPS, Response Time Ramp, Repeatability, and Persistence Test Runs are documented in *Appendix E: SPC-1 Workload Generator Input Parameters* on Page 79.

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	2,803,823
Total Number of Logical Blocks Verified	2,648,175
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	1,024
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™ 840 as documented in this Full Disclosure Report is currently available for customer purchase and shipment.

PRICING INFORMATION

Clause 9.4.3.3.6

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

Pricing information may be found in the Priced Storage Configuration Pricing section on page 17.

TESTED STORAGE CONFIGURATION (TSC) AND PRICED STORAGE CONFIGURATION DIFFERENCES

Clause 9.4.3.3.8

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

A list of all differences between the Tested Storage Configuration (TSC) and Priced Storage Configuration may be found in the Executive Summary portion of this document on page 17.

ANOMALIES OR IRREGULARITIES

Clause 9.4.3.10

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

There were no anomalies or irregularities encountered during the SPC-1 Onsite Audit of the IBM FlashSystem™ 840.

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-2 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-2 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.

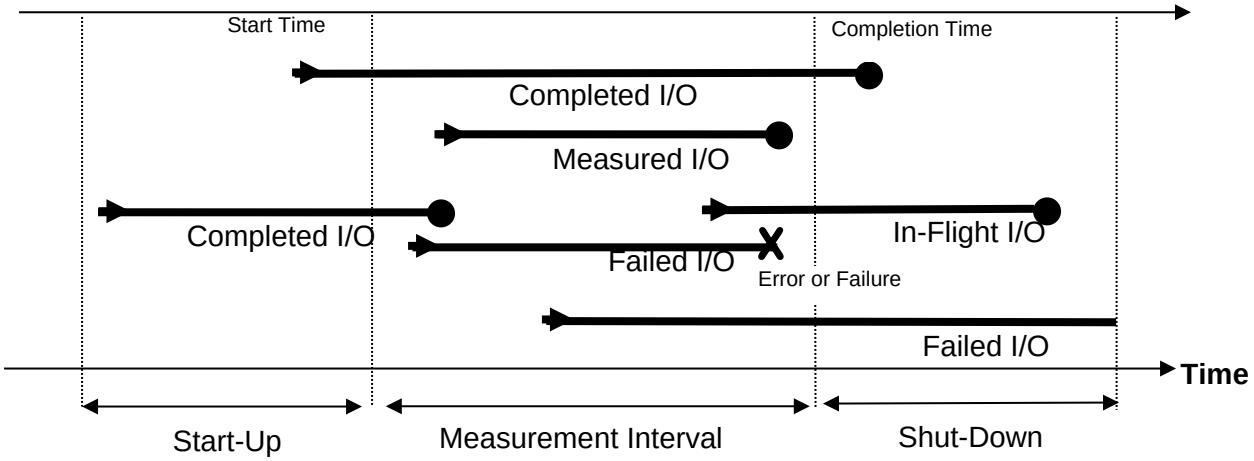
Steady State: The consistent and sustainable throughput of the TSC. During this period the load presented to the TSC by the Workload Generator is constant.

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

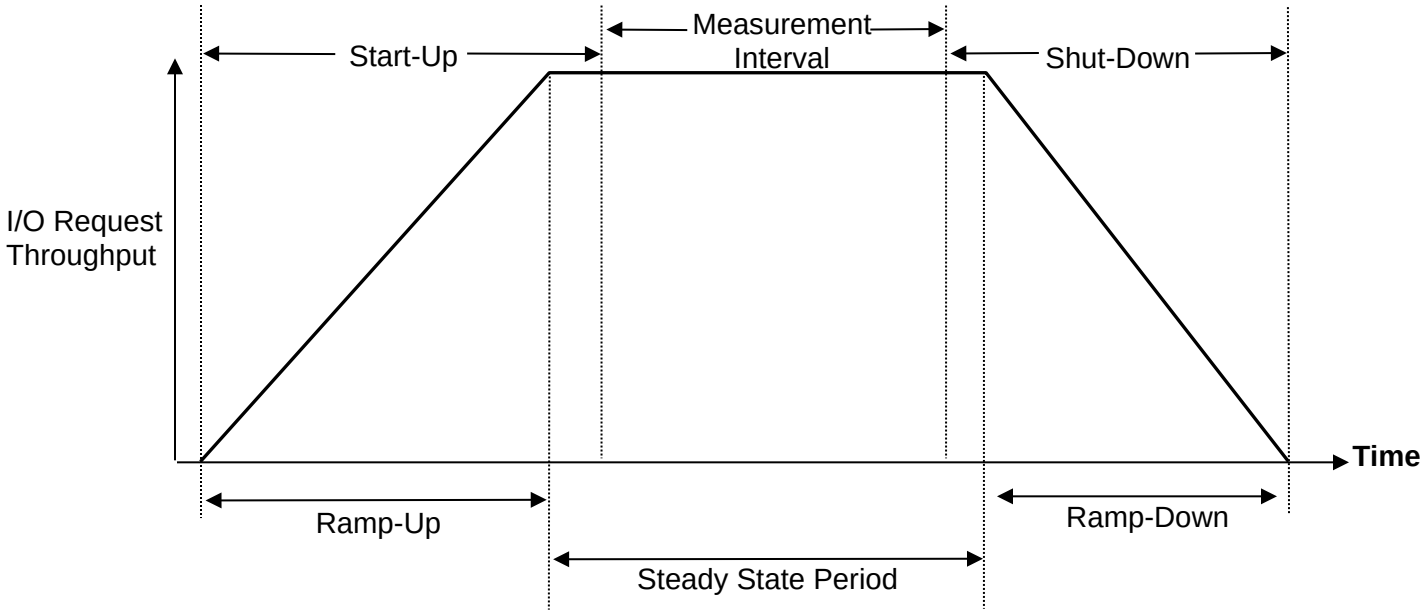
Test Run: The execution of SPC-1 for the purpose of producing or supporting an SPC-1 test result. SPC-1 Test Runs may have a finite and measured Ramp-Up period, Start-Up period, Shut-Down period, and Ramp-Down period as illustrated in the SPC-1 Test Run Components below. All SPC-1 Test Runs shall have 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 was set to 256 from a default value of 64. The maximum transfer size of LUN 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 **AIX Configuration** section on page 72.

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 **AIX Tuning Parameters** section on page 73.

APPENDIX C: TESTED STORAGE CONFIGURATION (TSC) CREATION

FlashSystem 840 Configuration

The FlashSystem 840 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 FS840.

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 780 GiB are created. The volumes were named **lun0, lun1**…**lun31**.

```
#create 32 X 780GiB
let i=0;while ((i<32));do
mkvdisk -iogrp io_grp0 -mdiskgrp 0 -name lun_$i -size 780 -unit gb
let i=i+1;done
```

The port topology was set to arbitrated-loop, corresponding to a direct host connection.

```
#set port topology to arbitrated loop
let i=0;while ((i<16));do
chportfc –topology al $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 **hdisk5**, **hdisk6**…**hdisk36** 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 780 GiB hdisks in an LVG with PP size 128 MiB, total 199648 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 4,320 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 4320
let i=i+1;done
```

Five additional logical volumes named **thin41**, **thin42** … **thin45** were created with a size of 3,840 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 3840
let i=i+1;done
```

AIX Tuning Parameters

Tuning steps were taken to permit large levels of IOPS when running on a single 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=579820584960,lun=/dev/rthin1
sd=sd2,size=579820584960,lun=/dev/rthin2
sd=sd3,size=579820584960,lun=/dev/rthin3
sd=sd4,size=579820584960,lun=/dev/rthin4
sd=sd5,size=579820584960,lun=/dev/rthin5
sd=sd6,size=579820584960,lun=/dev/rthin6
sd=sd7,size=579820584960,lun=/dev/rthin7
sd=sd8,size=579820584960,lun=/dev/rthin8
sd=sd9,size=579820584960,lun=/dev/rthin9
sd=sd10,size=579820584960,lun=/dev/rthin10
sd=sd11,size=579820584960,lun=/dev/rthin11
sd=sd12,size=579820584960,lun=/dev/rthin12
sd=sd13,size=579820584960,lun=/dev/rthin13
sd=sd14,size=579820584960,lun=/dev/rthin14
sd=sd15,size=579820584960,lun=/dev/rthin15
sd=sd16,size=579820584960,lun=/dev/rthin16
sd=sd17,size=579820584960,lun=/dev/rthin17
sd=sd18,size=579820584960,lun=/dev/rthin18
sd=sd19,size=579820584960,lun=/dev/rthin19
sd=sd20,size=579820584960,lun=/dev/rthin20
sd=sd21,size=579820584960,lun=/dev/rthin21
sd=sd22,size=579820584960,lun=/dev/rthin22
sd=sd23,size=579820584960,lun=/dev/rthin23
sd=sd24,size=579820584960,lun=/dev/rthin24
sd=sd25,size=579820584960,lun=/dev/rthin25
sd=sd26,size=579820584960,lun=/dev/rthin26
sd=sd27,size=579820584960,lun=/dev/rthin27
sd=sd28,size=579820584960,lun=/dev/rthin28
sd=sd29,size=579820584960,lun=/dev/rthin29
sd=sd30,size=579820584960,lun=/dev/rthin30
sd=sd31,size=579820584960,lun=/dev/rthin31
sd=sd32,size=579820584960,lun=/dev/rthin32
sd=sd33,size=579820584960,lun=/dev/rthin33
sd=sd34,size=579820584960,lun=/dev/rthin34
sd=sd35,size=579820584960,lun=/dev/rthin35
sd=sd36,size=579820584960,lun=/dev/rthin36
sd=sd37,size=579820584960,lun=/dev/rthin37
sd=sd38,size=579820584960,lun=/dev/rthin38
sd=sd39,size=579820584960,lun=/dev/rthin39
sd=sd40,size=579820584960,lun=/dev/rthin40
sd=sd41,size=515396075520,lun=/dev/rthin41
sd=sd42,size=515396075520,lun=/dev/rthin42
sd=sd43,size=515396075520,lun=/dev/rthin43
sd=sd44,size=515396075520,lun=/dev/rthin44
sd=sd45,size=515396075520,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
*==================================
*
*20 hours for Violin 30TB prefill
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
```

Primary Metrics, Repeatability and Persistence Tests

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

```
javaparms="-Xms1280m -Xmx1280m -Xss256k -Xgcpolicy:optavgpause"
sd=default
sd=asu1_1,size=579820584960,lun=/dev/rthin1
sd=asu1_2,size=579820584960,lun=/dev/rthin2
sd=asu1_3,size=579820584960,lun=/dev/rthin3
sd=asu1_4,size=579820584960,lun=/dev/rthin4
sd=asu1_5,size=579820584960,lun=/dev/rthin5
sd=asu1_6,size=579820584960,lun=/dev/rthin6
sd=asu1_7,size=579820584960,lun=/dev/rthin7
sd=asu1_8,size=579820584960,lun=/dev/rthin8
sd=asu1_9,size=579820584960,lun=/dev/rthin9
sd=asu1_10,size=579820584960,lun=/dev/rthin10
sd=asu1_11,size=579820584960,lun=/dev/rthin11
sd=asu1_12,size=579820584960,lun=/dev/rthin12
sd=asu1_13,size=579820584960,lun=/dev/rthin13
sd=asu1_14,size=579820584960,lun=/dev/rthin14
sd=asu1_15,size=579820584960,lun=/dev/rthin15
sd=asu1_16,size=579820584960,lun=/dev/rthin16
sd=asu1_17,size=579820584960,lun=/dev/rthin17
sd=asu1_18,size=579820584960,lun=/dev/rthin18
sd=asu1_19,size=579820584960,lun=/dev/rthin19
sd=asu1_20,size=579820584960,lun=/dev/rthin20
sd=asu2_1,size=579820584960,lun=/dev/rthin21
sd=asu2_2,size=579820584960,lun=/dev/rthin22
sd=asu2_3,size=579820584960,lun=/dev/rthin23
sd=asu2_4,size=579820584960,lun=/dev/rthin24
sd=asu2_5,size=579820584960,lun=/dev/rthin25
sd=asu2_6,size=579820584960,lun=/dev/rthin26
sd=asu2_7,size=579820584960,lun=/dev/rthin27
sd=asu2_8,size=579820584960,lun=/dev/rthin28
sd=asu2_9,size=579820584960,lun=/dev/rthin29
sd=asu2_10,size=579820584960,lun=/dev/rthin30
sd=asu2_11,size=579820584960,lun=/dev/rthin31
sd=asu2_12,size=579820584960,lun=/dev/rthin32
sd=asu2_13,size=579820584960,lun=/dev/rthin33
sd=asu2_14,size=579820584960,lun=/dev/rthin34
sd=asu2_15,size=579820584960,lun=/dev/rthin35
sd=asu2_16,size=579820584960,lun=/dev/rthin36
sd=asu2_17,size=579820584960,lun=/dev/rthin37
sd=asu2_18,size=579820584960,lun=/dev/rthin38
sd=asu2_19,size=579820584960,lun=/dev/rthin39
sd=asu2_20,size=579820584960,lun=/dev/rthin40
sd=asu3_1,size=515396075520,lun=/dev/rthin41
sd=asu3_2,size=515396075520,lun=/dev/rthin42
sd=asu3_3,size=515396075520,lun=/dev/rthin43
sd=asu3_4,size=515396075520,lun=/dev/rthin44
sd=asu3_5,size=515396075520,lun=/dev/rthin45
```

SPC-2 Persistence Test

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=579820584960,lun=/dev/rthin1
sd=sd2,size=579820584960,lun=/dev/rthin2
sd=sd3,size=579820584960,lun=/dev/rthin3
sd=sd4,size=579820584960,lun=/dev/rthin4
sd=sd5,size=579820584960,lun=/dev/rthin5
sd=sd6,size=579820584960,lun=/dev/rthin6
sd=sd7,size=579820584960,lun=/dev/rthin7
sd=sd8,size=579820584960,lun=/dev/rthin8
sd=sd9,size=579820584960,lun=/dev/rthin9
sd=sd10,size=579820584960,lun=/dev/rthin10
sd=sd11,size=579820584960,lun=/dev/rthin11
sd=sd12,size=579820584960,lun=/dev/rthin12
sd=sd13,size=579820584960,lun=/dev/rthin13
sd=sd14,size=579820584960,lun=/dev/rthin14
sd=sd15,size=579820584960,lun=/dev/rthin15
sd=sd16,size=579820584960,lun=/dev/rthin16
sd=sd17,size=579820584960,lun=/dev/rthin17
sd=sd18,size=579820584960,lun=/dev/rthin18
sd=sd19,size=579820584960,lun=/dev/rthin19
sd=sd20,size=579820584960,lun=/dev/rthin20
sd=sd21,size=579820584960,lun=/dev/rthin21
sd=sd22,size=579820584960,lun=/dev/rthin22
sd=sd23,size=579820584960,lun=/dev/rthin23
sd=sd24,size=579820584960,lun=/dev/rthin24
sd=sd25,size=579820584960,lun=/dev/rthin25
sd=sd26,size=579820584960,lun=/dev/rthin26
sd=sd27,size=579820584960,lun=/dev/rthin27
sd=sd28,size=579820584960,lun=/dev/rthin28
sd=sd29,size=579820584960,lun=/dev/rthin29
sd=sd30,size=579820584960,lun=/dev/rthin30
sd=sd31,size=579820584960,lun=/dev/rthin31
sd=sd32,size=579820584960,lun=/dev/rthin32
sd=sd33,size=579820584960,lun=/dev/rthin33
sd=sd34,size=579820584960,lun=/dev/rthin34
sd=sd35,size=579820584960,lun=/dev/rthin35
sd=sd36,size=579820584960,lun=/dev/rthin36
sd=sd37,size=579820584960,lun=/dev/rthin37
sd=sd38,size=579820584960,lun=/dev/rthin38
sd=sd39,size=579820584960,lun=/dev/rthin39
sd=sd40,size=579820584960,lun=/dev/rthin40
sd=sd41,size=515396075520,lun=/dev/rthin41
sd=sd42,size=515396075520,lun=/dev/rthin42
sd=sd43,size=515396075520,lun=/dev/rthin43
sd=sd44,size=515396075520,lun=/dev/rthin44
sd=sd45,size=515396075520,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 command lines

```
rd=default,rampup=180,periods=90,measurement=300,runout=0,rampdown=0,buffers=1

rd=default,rdpct=0,xfersize=1024k
rd=TR1-5s_SPC-2-persist-w,streams=256
```

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

```
* Persistence Test Run 2
```

common command lines

```
maxpersistenceerrors=10
*corruptstreams=3

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

APPENDIX E: SPC-1 WORKLOAD GENERATOR INPUT PARAMETERS

ASU Pre-Fill, SPC-1/E Idle Test, Primary Metrics Test, Repeatability Test and SPC-1 Persistence Test Run 1

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.

```
rm -fr SPCOut
#Collect FS840 configuration details pre-run
getlvmdata.sh prerun
datestamp=$(date +%s)
echo "---- START PRELOG ----" $(date) | tee -a FS840.$datestamp.config.txt
echo "---- lsarray ---" >> FS840.$datestamp.config.txt
ssh -p 26 root@9.11.210.136 lsarray -bytes >> FS840.$datestamp.config.txt
echo "---- lsdrive ---" >> FS840.$datestamp.config.txt
ssh -p 26 root@9.11.210.136 lsdrive -bytes >> FS840.$datestamp.config.txt
echo "---- lsenclosure ---" >> FS840.$datestamp.config.txt
ssh -p 26 root@9.11.210.136 lsenclosure >> FS840.$datestamp.config.txt
echo "---- lsenclosurebattery ---" >> FS840.$datestamp.config.txt
ssh -p 26 root@9.11.210.136 lsenclosurebattery >> FS840.$datestamp.config.txt
echo "---- lsmdisk ---" >> FS840.$datestamp.config.txt
ssh -p 26 root@9.11.210.136 lsmdisk -bytes >> FS840.$datestamp.config.txt
echo "---- lsportfc ---" >> FS840.$datestamp.config.txt
ssh -p 26 root@9.11.210.136 lsportfc >> FS840.$datestamp.config.txt
echo "---- lssystem ---" >> FS840.$datestamp.config.txt
ssh -p 26 root@9.11.210.136 lssystem >> FS840.$datestamp.config.txt
echo "---- lsvdisk ---" >> FS840.$datestamp.config.txt
ssh -p 26 root@9.11.210.136 lsvdisk -bytes >> FS840.$datestamp.config.txt
echo "---- END PRELOG ----" $(date) | tee -a FS840.$datestamp.config.txt

rundir=`pwd`
cd Prefill_45LVM_texan
./runfill.sh
cd $rundir
#export PATH=$PATH:/usr/java6/bin
export SPC1HOME=/perform/spc1_2_3_install
export CLASSPATH=$SPC1HOME
export LIBPATH=$SPC1HOME
export IBM_JAVADUMP_OUTOFMEMORY=false
export IBM_HEAPDUMP_OUTOFMEMORY=false

#Energy measurement pre-condition
java -Xoptionsfile=javaopts.cfg range -b 7400 -t 600
rm -fr energy_precondition_100pct
mv rangetest energy_precondition_100pct
sleep 4200
java -Xoptionsfile=javaopts.cfg range -b 740 -t 600
rm -fr energy_precondition_10pct
mv rangetest energy_precondition_10pct

java -Xoptionsfile=javaopts.cfg metrics -b 7400 -s 1800:600 -t 28800
java -Xoptionsfile=javaopts.cfg repeat1 -b 7400 -s 600
java -Xoptionsfile=javaopts.cfg repeat2 -b 7400 -s 600
java -Xoptionsfile=javaoptsp.cfg persist1 -b 740
```

```
#SPC2 persist test
cd Persist
./runpersist1.sh

cd $rundir

#Collect FS840 configuration details post-run
getlvmdata.sh postrun
datestamp=$(date +%s)
echo "---- START POSTLOG ----" $(date) | tee -a FS840.$datestamp.config.txt
echo "---- lsarray ---" >> FS840.$datestamp.config.txt
ssh -p 26 root@9.11.210.136 lsarray -bytes >> FS840.$datestamp.config.txt
echo "---- lsdrive ---" >> FS840.$datestamp.config.txt
ssh -p 26 root@9.11.210.136 lsdrive -bytes >> FS840.$datestamp.config.txt
echo "---- lsenclosure ---" >> FS840.$datestamp.config.txt
ssh -p 26 root@9.11.210.136 lsenclosure >> FS840.$datestamp.config.txt
echo "---- lsenclosurebattery ---" >> FS840.$datestamp.config.txt
ssh -p 26 root@9.11.210.136 lsenclosurebattery >> FS840.$datestamp.config.txt
echo "---- lsmdisk ---" >> FS840.$datestamp.config.txt
ssh -p 26 root@9.11.210.136 lsmdisk -bytes >> FS840.$datestamp.config.txt
echo "---- lsportfc ---" >> FS840.$datestamp.config.txt
ssh -p 26 root@9.11.210.136 lsportfc >> FS840.$datestamp.config.txt
echo "---- lssystem ---" >> FS840.$datestamp.config.txt
ssh -p 26 root@9.11.210.136 lssystem >> FS840.$datestamp.config.txt
echo "---- lsvdisk ---" >> FS840.$datestamp.config.txt
ssh -p 26 root@9.11.210.136 lsvdisk -bytes >> FS840.$datestamp.config.txt
echo "---- END POSTLOG ----" $(date) | tee -a FS840.$datestamp.config.txt
```

ASU Pre-Fill

The following script, invoked from the above 'master' script, was used to execute the required ASU pre-fill.

```
#!/usr/bin/ksh
export PATH=$PATH:/perform/vdbench503
export VDBHOME=/perform/vdbench503
export CLASSPATH=$VDBHOME
export LIBPATH=$VDBHOME/aix
export IBM_JAVADUMP_OUTOFMEMORY=false
export IBM_HEAPDUMP_OUTOFMEMORY=false
vdbench -f fill.cfg -o fill_output
```

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

The following script, invoked from the above 'master' script, was used to execute the SPC-2 Persistence Test Run 1 *(write phase)*.

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

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

The following script was used to execute SPC-2 Persistence Test Run 2 *(read phase)* after the required TSC power shutdown and restart.

```
#export PATH=$PATH:/usr/java6/bin
export SPC2HOME=/perform/spc2install
export CLASSPATH=$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
```