



**SPC BENCHMARK 1C/ENERGY™  
FULL DISCLOSURE REPORT**

**IBM CORPORATION  
IBM SYSTEM STORAGE™ EXP 12S**

**SPC-1C/E™ V1.3**

**Submitted for Review: June 3, 2009  
Submission Identifier: CE00001**

**First Edition – June 2009**

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## AUDIT CERTIFICATION



Bruce McNutt  
IBM Corporation  
9000 South Rita Road  
Tucson, AZ 85744

June 2, 2009

The SPC Benchmark 1C/Energy™ Reported Data listed below for the IBM System Storage™ EXP 12S were produced in compliance with the SPC Benchmark 1C/Energy™ V1.3 Onsite Audit requirements.

SPC Benchmark 1C/Energy™ V1.3 Reported Data	
Tested Storage Configuration (TSC) Name: IBM System Storage™ EXP 12S	
Metric	Reported Result
SPC-1C IOPS™	45,000.20
Total ASU Capacity	547,608 GB
Data Protection Level	Unprotected
Total TSC Price (including three-year maintenance)	\$87,468.35

	Usage Profile			Nominal Power, W	Nominal Traffic, IOPS	Nominal IOPS/W
	Heavy	Moderate	Idle			
Low Daily Usage:	0	8	16	161.50	7498.96	46.43
Medium Daily Usage:	4	14	6	162.64	19118.11	117.55
High Daily Usage:	18	6	0	164.01	32601.39	198.77
Composite Metrics:				162.72	19,739.49	121.31
Annual Energy Use, kWh:	1,425.41					
Energy Cost, \$/kWh:	\$ 0.12			Annual Energy Cost, \$: \$ 171.05		

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## **AUDIT CERTIFICATION (CONT.)**

IBM System Storage™ EXP 12S  
SPC-1 Audit Certification

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The following SPC Benchmark 1C/Energy™ Onsite Audit requirements were reviewed and found compliant with V1.3 of the SPC Benchmark 1C/Energy™ Specification:

- A Letter of Good Faith, signed by a senior executive.
- The following Data Repository storage items were verified by information supplied by IBM Corporation:
  - ✓ Physical Storage Capacity and requirements.
  - ✓ Configured Storage Capacity and requirements.
  - ✓ Addressable Storage Capacity and requirements.
  - ✓ Capacity of each Logical Volume and requirements.
  - ✓ Capacity of each Application Storage Unit (ASU) and requirements.
- An appropriate diagram of the Benchmark Configuration/Tested Storage Configuration.
- Listings and commands to configure the Benchmark Configuration/Tested Storage Configuration, including customer tunable parameters that were changed from default values.
- SPC-1C/E™ Workload Generator commands and parameters used for the audited SPC Test Runs.
- The following Host System requirements were verified by 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-1C™ Workload Generator on the Host System.
  - ✓ A valid SPC-1C™ site license.
  - ✓ The TSC boundary within the Host System.
- The Test Results Files and resultant Summary Results Files received from IBM Corporation for each of following were authentic, accurate, and compliant with all of the requirements and constraints of Clauses 4, 6, and 12 of the SPC Benchmark 1C/Energy™ 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 WT210 Digital Power Meter, used to record power consumption, was verified as an SPC approved "Power Extension apparatus" with a current calibration certificate.
- All power supplies present in the Tested Storage Configuration were verified as active.

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**AUDIT CERTIFICATION (CONT.)**

IBM System Storage™ EXP 12S  
SPC-1 Audit Certification

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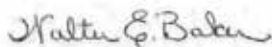
IBM Corporation provided documentation of the following:

- ✓ Voltage (220), amperage (30), and phase characteristics (*angle*) 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  $\pm 0.1^{\circ}\text{C}$ :
  - ✓ 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 9 of the SPC Benchmark 1C/Energy™ Specification.
- The Full Disclosure Report (*FDR*) met all of the requirements in Clauses 10 and 12 of the SPC Benchmark 1C/Energy™ 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



Vice President, Disk Systems  
IBM Technology & Systems Group  
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Phone: 914-765-3010

May 26, 2009

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

Subject: SPC-1C/E Letter of Good Faith for the IBM System Storage EXP 12S

IBM Corporation is the SPC-1C/E Test Sponsor for the above listed product. To the best of our knowledge and belief, the required SPC-1C/E benchmark results and materials we have submitted for that product are complete, accurate, and in full compliance with Version 1.3 of the SPC-1C/E 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-1C benchmark specification.

Sincerely,

A handwritten signature in black ink, appearing to read "Robert Cancilla".

Robert Cancilla

## **EXECUTIVE SUMMARY**

### **Test Sponsor and Contact Information**

<b>Test Sponsor and Contact Information</b>	
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### **Revision Information and Key Dates**

<b>Revision Information and Key Dates</b>	
<b>SPC-1C/E Specification revision number</b>	V1.3
<b>SPC-1C Workload Generator revision number</b>	V1.0
<b>Date Results were first used publicly</b>	June 3, 2009
<b>Date the FDR was submitted to the SPC</b>	June 3, 2009
<b>Date the TSC is available for shipment to customers</b>	May 22, 2009
<b>Date the TSC completed audit certification</b>	June 2, 2009

### **Tested Storage Product (TSP) Description**

The IBM System Storage EXP 12S is a high-density 2U, 19-inch rack-mountable disk drive enclosure which expands disk capacity on a POWER6 processor-based server. It offers:

- Modular SAS disk expansion drawer.
- Up to twelve hot-swappable 3.5 inch SAS disk drives.
- A variety of supported connection options.
- Redundant hot-plug power and cooling.
- Redundant and hot-swappable SAS expanders.

This SPC-1C/E Result demonstrates the new ability of the IBM System Storage™ EXP 12S, available as of May 22, 2009, to incorporate up to 8 solid state devices.

### Summary of Results

SPC-1C Results	
Tested Storage Product: IBM System Storage™ EXP 12S	
Metric	Reported Result
SPC-1C IOPS™	45,000.20
Total ASU Capacity	547.608 GB
Data Protection Level	Unprotected
Total Price – Priced Storage Configuration	\$87,468.35

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

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

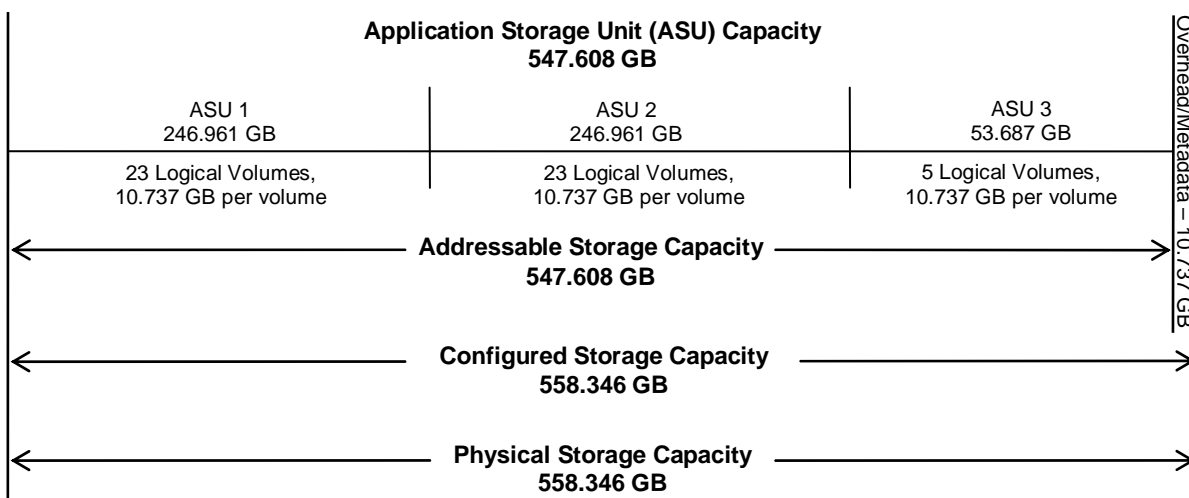
A **Data Protection Level** of **UNPROTECTED** makes no claim of data protection in the event of a single point of failure..

### Storage Capacities and Relationships

The Tested Storage Configuration (TSC) must be configured so that there is either no Unused Storage or that the sum of Total ASU Capacity and storage required for data protection equals 50% (+-1 GiB) of the Physical Storage Capacity. This configuration meets the 50% requirement as documented below:

$$\begin{aligned}
 &558.346 \text{ GB (Physical Storage Capacity)} \\
 &547.608 \text{ GB (Total ASU Capacity)} + 0.000 \text{ GB (data protection)} \\
 &+ 10.737 \text{ GB (metadata/overhead)} = 558.346 \text{ GB}
 \end{aligned}$$

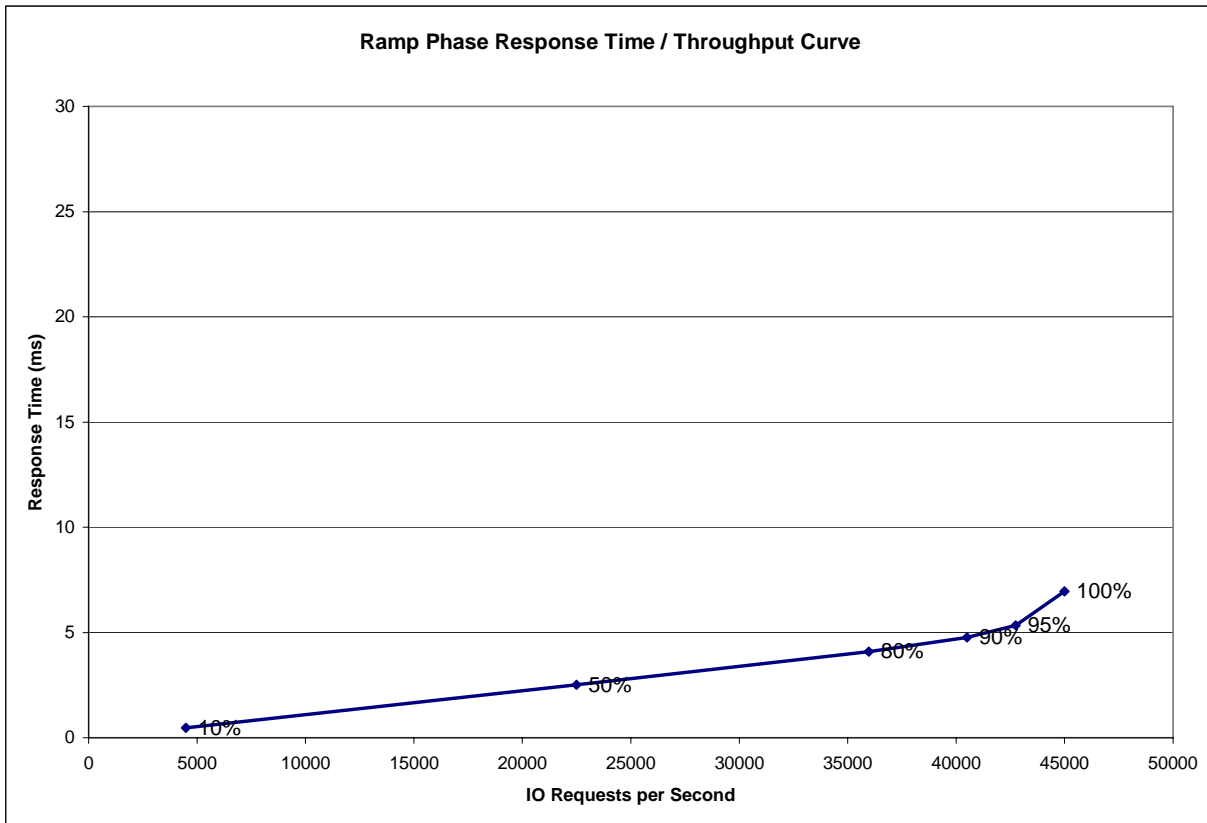
The following diagram documents the various storage capacities, used in this benchmark, and their relationships.



### Response Time – Throughput Curve

The Response Time-Throughput Curve illustrates the Average Response Time (milliseconds) and I/O Request Throughput at 100%, 95%, 90%, 80%, 50%, and 10% of the workload level used to generate the SPC-1C 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
<b>I/O Request Throughput</b>	4,497.09	22,496.89	35,969.55	40,491.46	42,745.04	45,000.20
<b>Average Response Time (ms):</b>						
All ASUs	0.46	2.51	4.10	4.76	5.33	6.95
ASU-1	0.52	2.69	4.37	5.07	5.65	7.23
ASU-2	0.54	2.81	4.49	5.17	5.74	7.34
ASU-3	0.31	1.99	3.33	3.92	4.47	6.16
Reads	0.75	3.41	5.43	6.26	6.89	8.53
Writes	0.28	1.93	3.22	3.79	4.31	5.91

**SPC-1C/E Reported Data**

	Usage Profile					
	Hours of Use per Day			Nominal Power, W	Nominal Traffic, IOPS	Nominal IOPS/W
	Heavy	Moderate	Idle			
Low Daily Usage:	0	8	16	161.50	7498.96	46.43
Medium Daily Usage:	4	14	6	162.64	19118.11	117.55
High Daily Usage:	18	6	0	164.01	32601.39	198.77
<b>Composite Metrics:</b>				162.72	19,739.49	121.31
Annual Energy Use, kWh:	1,425.41					
Energy Cost, \$/kWh:	\$ 0.12			Annual Energy Cost, \$:	\$ 171.05	

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-1C Workload:** 164.37W at 80% of maximum reported performance (*35,969.55 SPC-1C IOPS*).

**MODERATE SPC-1C Workload:** 162.94W at 50% of maximum reported performance (*22,496.89 SPC-1C IOPS*).

**IDLE SPC-1C Workload:** 160.78W at 0% of maximum reported performance (*0.00 SPC-1C IOPS*).

**LOW DAILY USAGE:** Zero (0) hours of **HEAVY SPC-1C Workload**, eight (8) hours of **MODERATE SPC-1C Workload**, and sixteen (16) hours of **IDLE SPC-1C Workload**.

**MEDIUM DAILY USAGE:** Four (4) hours of **HEAVY SPC-1C Workload**, fourteen (14) hours of **MODERATE SPC-1C Workload**, and six (6) hours of **IDLE SPC-1C Workload**.

**HIGH DAILY USAGE:** Eighteen (18) hours of **HEAVY SPC-1C Workload**, six (6) hours of **MODERATE SPC-1C Workload**, and zero (0) hours of **IDLE SPC-1C Workload**.

**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**.

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

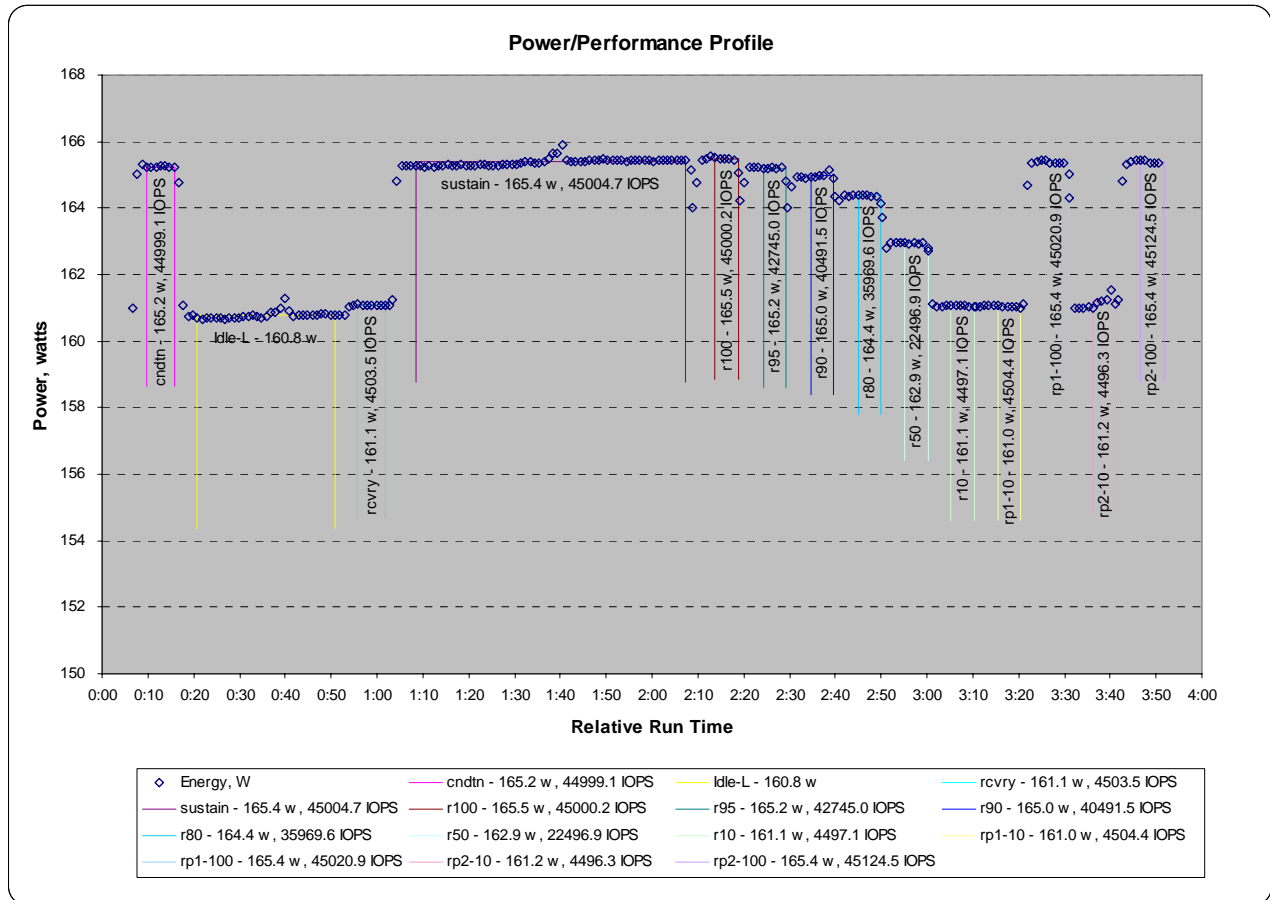
**ANNUAL ENERGY USE, kWh:** An estimate of the average energy use across the three environments over the course of a year and computed as (**NOMINAL POWER** \* 24 \* 0.365).

**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-1C/E Power/Performance Profile

The SPC-1C/E Power/Performance Profile chart provides a complete “at a glance” illustration and report for each SPC-1C/E execution component. The power consumption at each step is reported and, where appropriate the measured SPC-1C performance (*SPC-1C IOPS*) is also reported.



**Tested Storage Configuration Pricing (Priced Storage Configuration)**

Product	Description	quantity	Unit Price	Unit Maint per month	Extended Price	Extended Maint
9117-MMA	Power 570 host processor					
5886	EXP12S expansion drawer	1	4,500.00	200.00	4,500.00	\$4,800.00
3586	69 GB 3.5in SAS Solid State Drive	8	10,000.00	90.00	80,000.00	\$17,280.00
5904	PCI-X DDR 1.5 GB cache SAS RAID Adapter	1	8,500.00		8,500.00	\$0.00
6671	Power cord (drawer to IBM PDU), 250V/10A	1	28.00		28.00	\$0.00
3692	SAS Cable (YO), Adapter to SAS Enclosure	1	110.00		110.00	\$0.00
	Total Extended				93,138.00	\$22,080.00
	Discount				28.00%	7.57%
	<b>Total Price w/ maintainance</b>					<b>\$87,468.35</b>

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

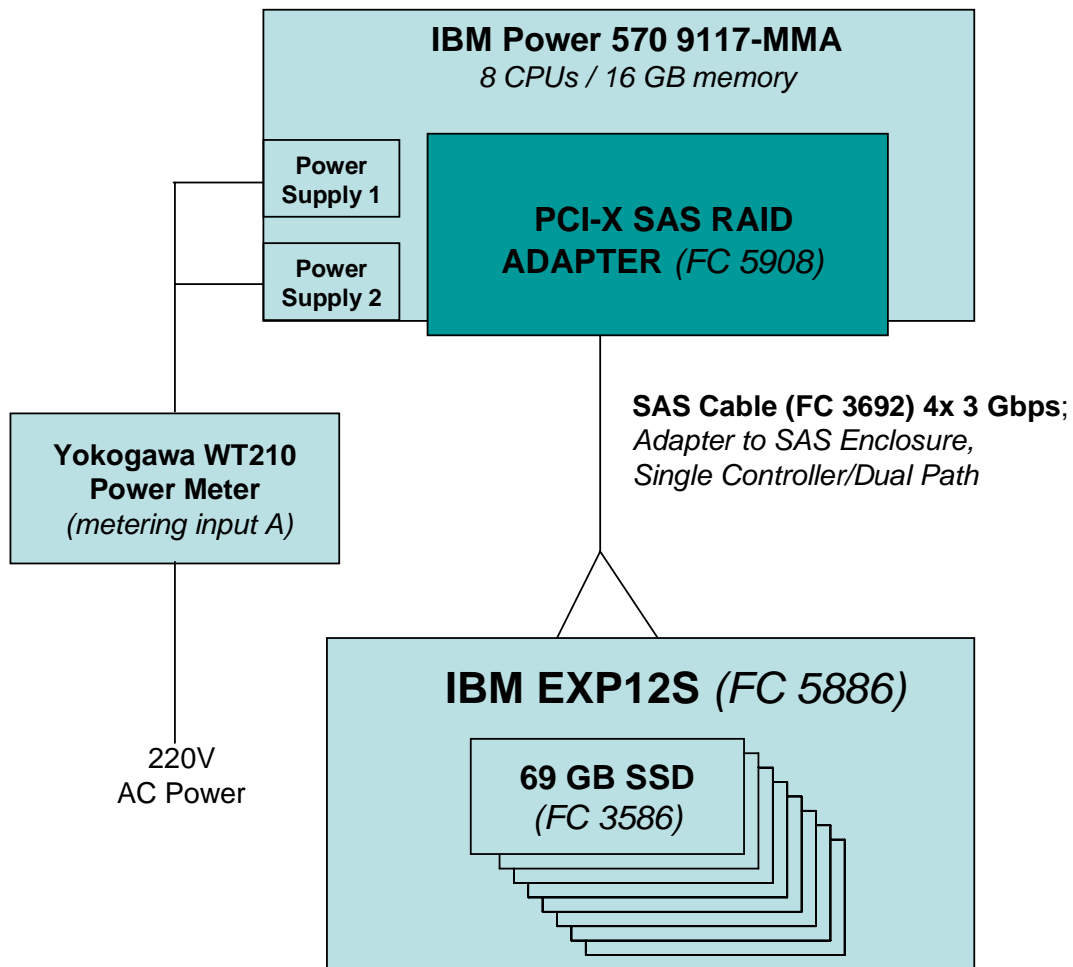
- Acknowledgement of new and existing problems with four (4) hours.
- Onsite present of a qualified maintenance engineer or provision of a customer replaceable part within four (4) hours of the above acknowledgement for any hardware failure that results in an inoperative Price Storage Configuration that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

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

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



**Benchmark Configuration/Tested Storage Configuration Diagram**



**Benchmark Configuration/Tested Storage Configuration Components**

Host System:	Tested Storage Configuration (TSC):
IBM Power 570 9117 MMA 8 – 4.2 GHz Power 6 CPUs 8 MB L2 cache per 2 CPUs 32 MB L3 cache per 2 CPUs	1 – PCI-X SAS RAID adapter with 1.5 GB cache
16 GB main memory	1 – SAS cable that provides one adapter connection and two drive enclosure connections
AIX 6.2 TL02	1 – EXP12S expansion drawer
PCI-X	8 – 69 GB 3.5" SAS Solid State Drive (SSD)
Other BC Components	
1 – Yokogawa WT210 Digital Power Meter	

In each of the following sections of this document, the appropriate Full Disclosure Report requirement, from the SPC-1C 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 10.4.5.10**

*The Executive Summary will contain a one page BC/TSC diagram that illustrates all major components of the BC/TSC.*

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

### **Host System and Tested Storage Configuration**

#### **Clause 10.4.5.11**

*The Executive Summary will contain a table that lists the major components of each Host System and the Tested Storage Configuration (TSC).*

The table listing the major components of each Host System and the Tested Storage Configuration may be found on page 17 (*Benchmark Configuration/Tested Storage Configuration Components*).

### **Customer Tunable Parameters and Options**

#### **Clause 10.4.6.1**

*All Benchmark Configuration (BC) components with customer tunable parameters and options that have been altered from their default values must be listed in the Full Disclosure Report (FDR). The FDR entry for each of those components must include both the name of the component and the altered value of the parameter or option. If the parameter name is not self-explanatory to a knowledgeable practitioner, a brief description of the parameter's use must also be included in the FDR entry.*

“Appendix B: Customer Tunable Parameters and Options” on page 61 contains the customer tunable parameters and options that have been altered from their default values for this benchmark.

### **Tested Storage Configuration (TSC) Description**

#### **Clause 10.4.6.2**

*The Full Disclosure Report must include sufficient information to recreate the logical representation of the Tested Storage Configuration (TSC). In addition to customer tunable parameters and options (Clause 10.4.6.1), 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 10.4.5.10.*

- *The logical representation of the TSC, configured from the above components that will be presented to the SPC-1C Workload Generator.*
- *Listings of scripts used to create the logical representation of the TSC.*
- *If scripts were not used, a description of the process used with sufficient detail to recreate the logical representation of the TSC.*

“Appendix C: Tested Storage Configuration (TSC) Creation” on page 62 contains the detailed information that describes how to create and configure the logical TSC.

## **SPC-1C Workload Generator Storage Configuration**

### Clause 10.4.6.3

*The Full Disclosure Report will include all SPC-1C Workload Generator storage configuration commands and parameters used in the SPC-1C benchmark measurements.*

The SPC-1C Workload Generator storage configuration commands and parameters for this measurement appear in “Appendix D: SPC-1C Workload Generator Storage Commands and Parameters” on page 64.

## SPC-1C DATA REPOSITORY

This portion of the Full Disclosure Report presents the detailed information that fully documents the various SPC-1C storage capacities and mappings used in the Tested Storage Configuration. “SPC-1C Data Repository Definitions” on page 57 contains definitions of terms specific to the SPC-1C Data Repository.

### Storage Capacities and Relationships

#### Clause 10.4.7.1

Two tables and an illustration documenting the storage capacities and relationships of the SPC-1C Storage Hierarchy (Clause 2.1) shall be included in the FDR.

#### SPC-1C Storage Capacities

SPC-1C Storage Capacities		
Storage Hierarchy Component	Units	Capacity
Total ASU Capacity	Gigabytes (GB)	547.608
Addressable Storage Capacity	Gigabytes (GB)	547.608
Configured Storage Capacity	Gigabytes (GB)	558.346
Physical Storage Capacity	Gigabytes (GB)	558.346
Data Protection ( <i>Unprotected</i> )	Gigabytes (GB)	0.000
Required Storage	Gigabytes (GB)	10.737
Global Storage Overhead	Gigabytes (GB)	0.000
Total Unused Storage	Gigabytes (GB)	0.000

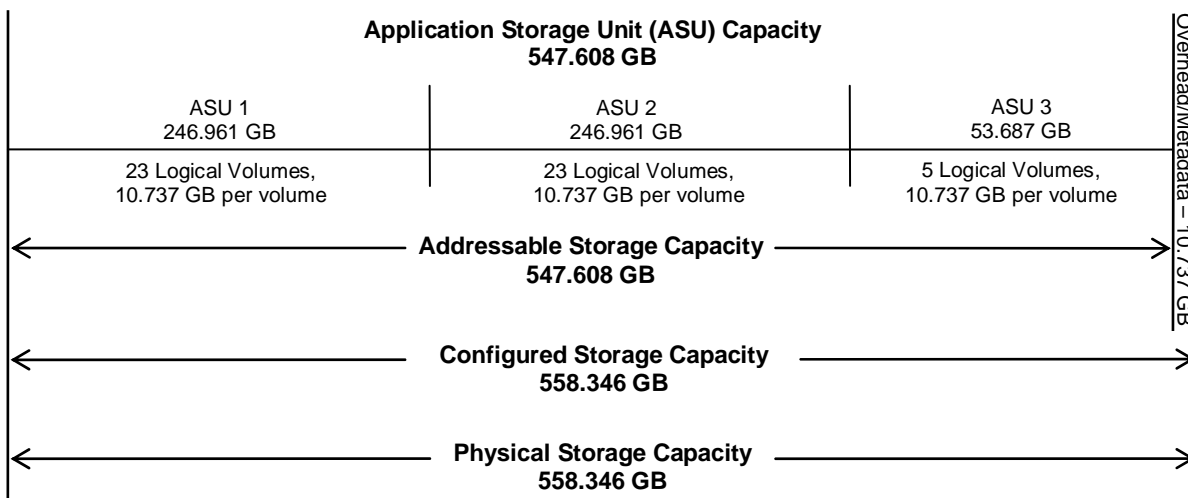
#### SPC-1C Storage Hierarchy Ratios

	Addressable Storage Capacity	Configured Storage Capacity	Physical Storage Capacity
<b>Total ASU Capacity</b>	100.00%	98.08%	98.08%
<b>Required for Data Protection (<i>Unprotected</i>)</b>		0.00%	0.00%
<b>Addressable Storage Capacity</b>		98.08%	98.08%
<b>Required Storage</b>		1.92%	1.92%
<b>Configured Storage Capacity</b>			100.00%
<b>Global Storage Overhead</b>			0.00%
<b>Unused Storage:</b>			
<b>Addressable</b>	0.00%		
<b>Configured</b>		0.00%	
<b>Physical</b>			0.00%

The Physical Storage Capacity consisted of 558.346 GB distributed over 8 solid state devices (SSDs) each with a formatted capacity of 69.793 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 Physical Storage Capacity. There was 0.000 GB (0.00%) of Unused Storage within the Configured Storage Capacity. The Total ASU Capacity utilized 100.00% of the Addressable Storage Capacity resulting in 0.000 GB (0.00%) of Unused Storage within the Addressable Storage Capacity.

### SPC-1C Storage Capacities and Relationships Illustration

The various storage capacities configured in the benchmark result are illustrated below (not to scale).



### Logical Volume Capacity and ASU Mapping

Clause 10.4.7.2

*A table illustrating the capacity of each ASU and the mapping of Logical Volumes to ASUs shall be provided in the FDR. ... Logical Volumes shall be sequenced in the table from top to bottom per its position in the contiguous address space of each ASU. The capacity of each Logical Volume shall be stated. ... In conjunction with this table, the Test Sponsor shall provide a complete description of the type of data protection (see Clause 2.7) used on each Logical Volume.*

Logical Volume Capacity and Mapping		
ASU-1 (246.961 GB)	ASU-2 (246.961 GB)	ASU-3 (53.687 GB)
23 Logical Volumes 10.737 GB per Logical Volume (10.737 GB used per Logical Volume)	23 Logical Volumes 10.737 GB per Logical Volume (10.737 GB used per Logical Volume)	5 Logical Volumes 10.737 GB per Logical Volume (10.737 GB used per Logical Volume)

The Data Protection Level used for all Logical Volumes was UNPROTECTED as described on page 12. See “ASU Configuration” in the [IOPS Test Results File](#) for more detailed configuration information.

## **SPC-1C BENCHMARK EXECUTION RESULTS**

This portion of the Full Disclosure Report documents the results of the various SPC-1C Tests, Test Phases, and Test Runs. “SPC-1C Test Execution Definitions” on page 58 contains definitions of terms specific to the SPC-1C Tests, Test Phases, and Test Runs.

### **Clause 6.4.2**

*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 selected Test sequence. If the selected Test sequence is interrupted, the SPC-1C measurement is invalid. This does not apply to the interruption caused by the Host System/TSC power cycle between Persistence Test Run 1 and Persistence Test Run 2.*

## **SPC-1C Tests, Test Phases, and Test Runs**

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

- **Primary Metrics Test**
  - Sustainability Test Phase and Test Run
  - IOPS Test Phase and Test Run
  - Response Time Ramp Test Phase
    - 95% of IOPS Test Run
    - 90% of IOPS Test Run
    - 80% of IOPS Test Run
    - 50% of IOPS Test Run
    - 10% of IOPS Test Run (LRT)
- **Repeatability Test**
  - Repeatability Test Phase 1
    - 10% of IOPS Test Run (LRT)
    - IOPS Test Run
  - Repeatability Test Phase 2
    - 10% of IOPS Test Run (LRT)
    - IOPS Test Run
- **Data Persistence Test**
  - Data Persistence Test Run 1
  - Data Persistence Test Run 2

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

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

## Primary Metrics Test – Sustainability Test Phase

### Clause 6.4.3.2

*The Sustainability Test Phase has exactly one Test Run and shall demonstrate the maximum sustainable I/O Request Throughput within a continuous one (1) hour Measurement Interval.*

### Clause 6.4.3.2.6

*The computed I/O Request Throughput of the Sustainability Test Run must be no less than 95% of the reported SPC-1C IOPS™ result or the Test Run is invalid.*

### Clause 6.4.3.2.7

*The Average Response Time, as defined in Clause 0, will be computed and reported for the Sustainability Test Run and cannot exceed 30 milliseconds. If the Average Response Time exceeds that 30-millisecond constraint, the Test Run is invalid.*

### Clause 10.4.8.1

*For the Sustainability Test Phase the FDR shall contain:*

- 1. A Data Rate Distribution graph and data table.*
- 2. I/O Request Throughput Distribution graph and data table.*
- 3. A Response Time Frequency Distribution graph and table.*
- 4. An Average Response Time Distribution graph and table.*
- 5. The human readable Test Run Results File produced by the Workload Generator (may be included in an appendix).*
- 6. A listing or screen image of all input parameters supplied to the Workload Generator (may be included in an appendix).*
- 7. The Measured Intensity Multiplier for each I/O stream.*
- 8. The variability of the Measured Intensity Multiplier, as defined in Clause 5.3.13.3.*

## SPC-1C Workload Generator Input Parameters

The SPC-1C Workload Generator input parameters for the Sustainability, IOPS, Response Time Ramp, Repeatability, and Persistence Test Runs are documented in “Appendix E: SPC-1C Workload Generator Input Parameters” on Page 65.

## Sustainability Test Results File

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

[Sustainability Test Results File](#)

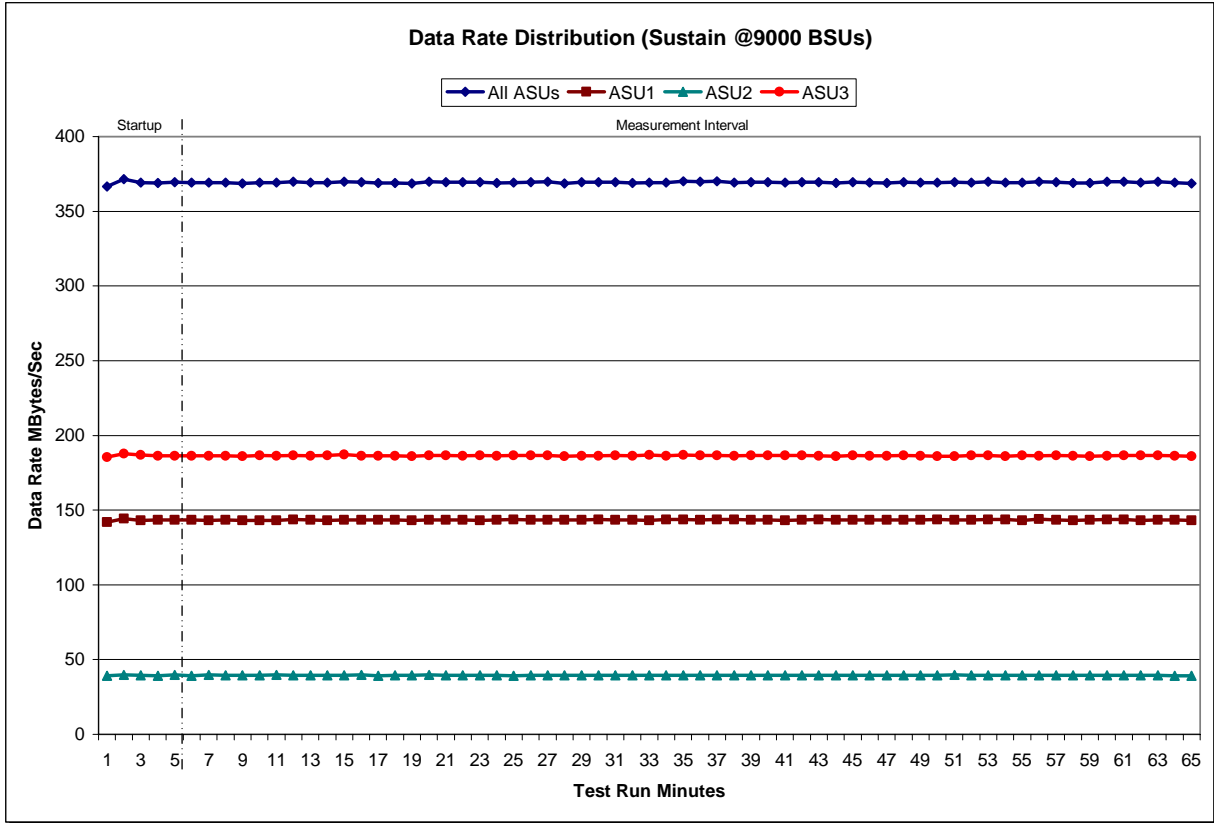
**Sustainability – Data Rate Distribution Data (MB/second)**

	Start	Stop	Interval	Duration
Ramp-Up/Start-Up	17:43:24	17:48:24	0-4	0:05:00
Measurement Interval	17:48:24	18:48:24	5-64	1:00:00

Interval	All ASUs	ASU1	ASU2	ASU3	Interval	All ASUs	ASU1	ASU2	ASU3
0	366.70	142.11	39.23	185.36	33	369.27	143.57	39.49	186.21
1	371.50	144.27	39.60	187.63	34	369.92	143.60	39.55	186.77
2	369.19	143.03	39.32	186.85	35	369.64	143.55	39.46	186.64
3	368.83	143.33	39.26	186.25	36	369.92	143.67	39.53	186.72
4	369.44	143.50	39.60	186.34	37	369.29	143.61	39.50	186.18
5	369.13	143.51	39.16	186.46	38	369.45	143.47	39.35	186.63
6	369.09	143.11	39.65	186.34	39	369.53	143.39	39.48	186.66
7	369.18	143.45	39.38	186.35	40	369.13	143.13	39.42	186.58
8	368.72	143.21	39.34	186.17	41	369.40	143.54	39.33	186.53
9	369.30	143.26	39.43	186.61	42	369.45	143.57	39.41	186.46
10	369.19	143.21	39.62	186.37	43	368.97	143.47	39.60	185.91
11	369.82	143.62	39.56	186.63	44	369.41	143.36	39.50	186.54
12	369.19	143.43	39.51	186.26	45	369.29	143.47	39.37	186.45
13	369.20	143.15	39.38	186.67	46	368.95	143.35	39.41	186.18
14	369.83	143.36	39.32	187.15	47	369.39	143.38	39.45	186.56
15	369.40	143.53	39.65	186.22	48	369.13	143.46	39.44	186.23
16	368.78	143.31	39.25	186.22	49	369.18	143.72	39.39	186.08
17	369.00	143.32	39.42	186.26	50	369.39	143.53	39.72	186.14
18	368.69	143.23	39.44	186.02	51	369.22	143.31	39.39	186.52
19	369.75	143.50	39.61	186.65	52	369.75	143.73	39.36	186.66
20	369.43	143.55	39.31	186.57	53	369.21	143.59	39.57	186.06
21	369.46	143.48	39.55	186.43	54	369.14	143.06	39.52	186.56
22	369.39	143.20	39.48	186.71	55	369.66	143.85	39.40	186.40
23	368.96	143.28	39.35	186.33	56	369.60	143.28	39.59	186.74
24	369.22	143.58	39.15	186.49	57	368.85	143.25	39.38	186.23
25	369.36	143.45	39.38	186.53	58	368.93	143.46	39.40	186.07
26	369.65	143.49	39.48	186.68	59	369.65	143.81	39.47	186.36
27	368.64	143.27	39.45	185.92	60	369.81	143.64	39.49	186.68
28	369.37	143.55	39.43	186.39	61	369.17	143.14	39.36	186.67
29	369.55	143.59	39.52	186.43	62	369.74	143.55	39.45	186.74
30	369.35	143.30	39.53	186.51	63	369.08	143.35	39.30	186.43
31	369.01	143.36	39.47	186.19	64	368.61	143.23	39.25	186.12
32	369.25	143.15	39.35	186.76					



### Sustainability – Data Rate Distribution Graph

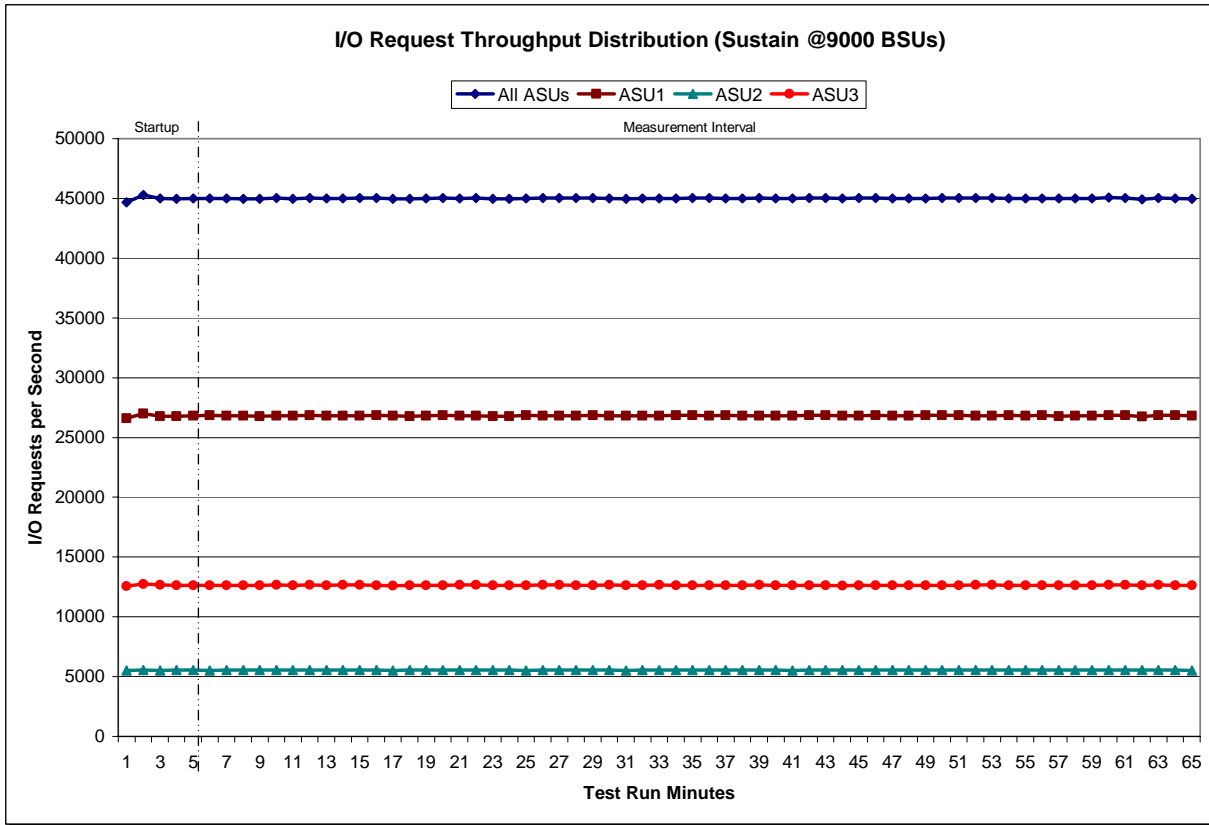


**Sustainability – I/O Request Throughput Distribution Data**

	Start	Stop	Interval	Duration
Ramp-Up/Start-Up	17:43:24	17:48:24	0-4	0:05:00
Measurement Interval	17:48:24	18:48:24	5-64	1:00:00

Interval	All ASUs	ASU1	ASU2	ASU3	Interval	All ASUs	ASU1	ASU2	ASU3
0	44,658.63	26,601.02	5,499.25	12,558.37	33	45,012.17	26,838.50	5,533.90	12,639.77
1	45,282.58	26,996.68	5,553.75	12,732.15	34	45,038.90	26,845.33	5,543.87	12,649.70
2	44,980.15	26,793.42	5,523.45	12,663.28	35	45,016.73	26,831.70	5,546.77	12,638.27
3	44,945.27	26,781.22	5,531.65	12,632.40	36	45,002.60	26,839.38	5,538.75	12,624.47
4	44,999.42	26,817.17	5,537.72	12,644.53	37	45,012.63	26,834.40	5,533.35	12,644.88
5	44,983.48	26,840.32	5,519.53	12,623.63	38	45,016.02	26,833.02	5,527.52	12,655.48
6	44,999.35	26,818.03	5,543.70	12,637.62	39	45,005.47	26,832.43	5,532.58	12,640.45
7	44,969.47	26,806.75	5,529.18	12,633.53	40	44,985.62	26,816.80	5,525.18	12,643.63
8	44,963.37	26,796.92	5,527.18	12,639.27	41	45,015.88	26,838.38	5,530.87	12,646.63
9	45,031.22	26,832.98	5,536.75	12,661.48	42	45,017.00	26,838.95	5,543.45	12,634.60
10	44,977.07	26,816.45	5,534.45	12,626.17	43	44,983.03	26,819.10	5,548.32	12,615.62
11	45,039.57	26,838.38	5,532.68	12,668.50	44	45,017.65	26,830.00	5,537.73	12,649.92
12	44,981.82	26,813.00	5,532.68	12,636.13	45	45,037.48	26,860.57	5,535.28	12,641.63
13	45,001.77	26,805.58	5,537.80	12,658.38	46	44,996.02	26,808.32	5,546.53	12,641.17
14	45,041.33	26,829.80	5,533.23	12,678.30	47	44,988.18	26,810.48	5,537.48	12,640.22
15	45,030.20	26,857.17	5,545.12	12,627.92	48	45,010.55	26,841.48	5,542.50	12,626.57
16	44,968.75	26,833.45	5,521.37	12,613.93	49	45,021.98	26,867.37	5,527.15	12,627.47
17	44,965.10	26,796.52	5,538.27	12,630.32	50	45,032.75	26,842.18	5,548.48	12,642.08
18	45,005.33	26,817.90	5,542.03	12,645.40	51	45,020.22	26,829.32	5,534.50	12,656.40
19	45,039.58	26,850.10	5,541.33	12,648.15	52	45,025.47	26,826.37	5,534.80	12,664.30
20	45,009.05	26,803.35	5,540.28	12,665.42	53	45,011.48	26,845.55	5,532.43	12,633.50
21	45,027.77	26,817.80	5,554.02	12,655.95	54	44,979.73	26,805.68	5,530.53	12,643.52
22	44,976.50	26,792.27	5,539.53	12,644.70	55	45,009.07	26,850.90	5,528.98	12,629.18
23	44,963.48	26,780.95	5,531.70	12,650.83	56	44,985.07	26,798.10	5,541.52	12,645.45
24	44,984.45	26,838.90	5,513.77	12,631.78	57	44,986.35	26,808.63	5,525.90	12,651.82
25	45,019.73	26,817.63	5,535.68	12,666.42	58	45,000.45	26,828.23	5,533.13	12,639.08
26	45,031.23	26,825.03	5,532.25	12,673.95	59	45,065.83	26,850.58	5,556.93	12,658.32
27	45,020.92	26,835.68	5,540.37	12,644.87	60	45,019.75	26,837.78	5,526.30	12,655.67
28	45,021.63	26,845.18	5,546.95	12,629.50	61	44,931.35	26,757.88	5,535.60	12,637.87
29	45,013.65	26,827.55	5,532.10	12,654.00	62	45,019.20	26,838.62	5,526.57	12,654.02
30	44,970.13	26,809.60	5,519.23	12,641.30	63	45,009.02	26,838.88	5,535.08	12,635.05
31	44,991.30	26,824.65	5,539.70	12,626.95	64	44,972.75	26,822.65	5,524.52	12,625.58
32	45,008.10	26,821.27	5,526.30	12,660.53	Average	45,004.70	26,826.01	5,535.23	12,643.45

### Sustainability – I/O Request Throughput Distribution Graph

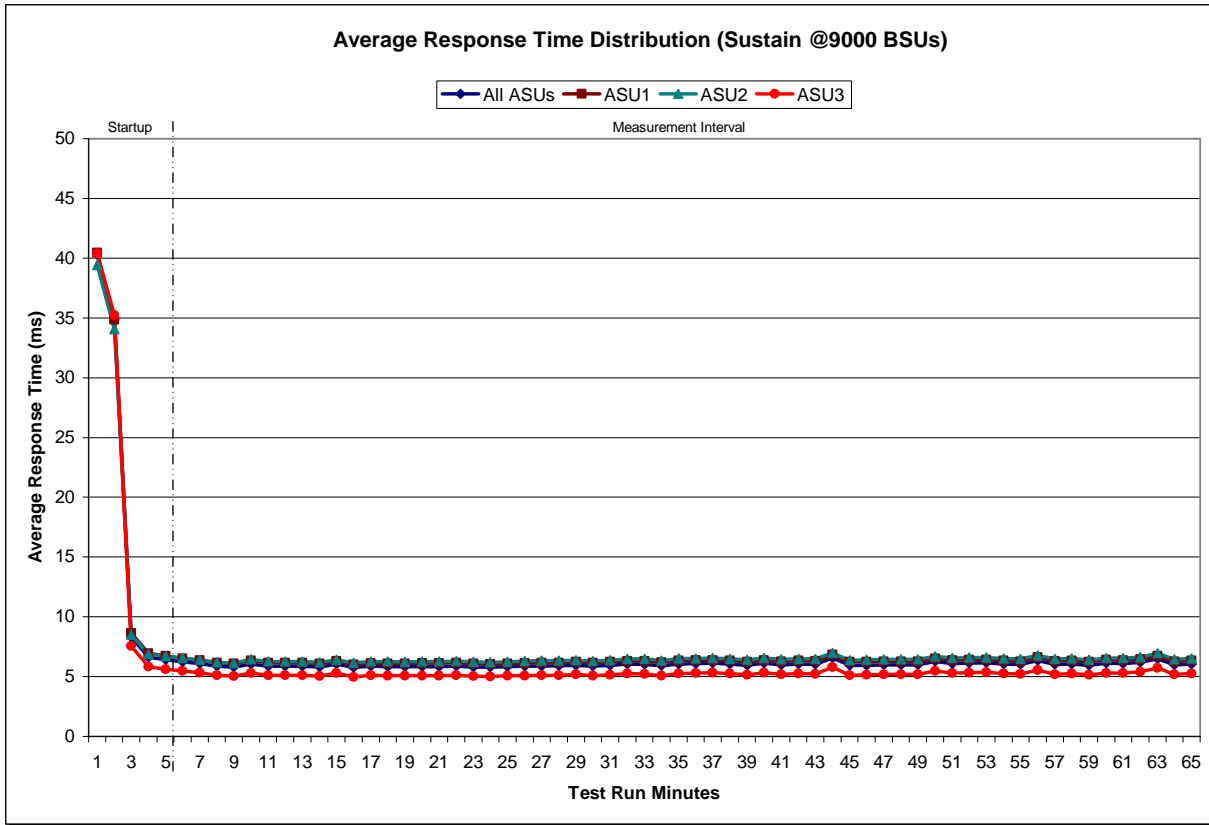


**Sustainability – Average Response Time (ms) Distribution Data**

	Start	Stop	Interval	Duration
Ramp-Up/Start-Up	17:43:24	17:48:24	0-4	0:05:00
Measurement Interval	17:48:24	18:48:24	5-64	1:00:00

Interval	All ASUs	ASU1	ASU2	ASU3	Interval	All ASUs	ASU1	ASU2	ASU3
0	40.30	40.45	39.41	40.38	33	5.89	6.18	6.35	5.08
1	34.86	34.85	34.04	35.23	34	6.06	6.34	6.52	5.27
2	8.31	8.63	8.48	7.55	35	6.07	6.35	6.53	5.28
3	6.62	6.94	6.88	5.84	36	6.10	6.38	6.54	5.32
4	6.41	6.73	6.70	5.62	37	6.06	6.34	6.50	5.26
5	6.23	6.53	6.54	5.46	38	5.95	6.23	6.41	5.16
6	6.08	6.37	6.42	5.32	39	6.10	6.38	6.56	5.31
7	5.87	6.16	6.19	5.11	40	5.99	6.27	6.44	5.20
8	5.79	6.08	6.14	5.03	41	6.04	6.33	6.48	5.25
9	6.05	6.33	6.45	5.30	42	6.02	6.30	6.48	5.23
10	5.87	6.15	6.28	5.11	43	6.56	6.82	7.00	5.80
11	5.87	6.15	6.26	5.12	44	5.93	6.21	6.38	5.13
12	5.87	6.15	6.27	5.11	45	5.93	6.21	6.39	5.14
13	5.80	6.08	6.18	5.05	46	5.99	6.27	6.44	5.20
14	6.03	6.30	6.42	5.30	47	5.97	6.26	6.44	5.17
15	5.74	6.03	6.14	4.97	48	5.98	6.26	6.44	5.18
16	5.85	6.12	6.25	5.10	49	6.26	6.53	6.71	5.48
17	5.82	6.09	6.25	5.08	50	6.10	6.38	6.56	5.29
18	5.82	6.09	6.24	5.06	51	6.12	6.39	6.58	5.33
19	5.83	6.11	6.27	5.07	52	6.15	6.42	6.60	5.36
20	5.85	6.13	6.26	5.08	53	6.06	6.33	6.52	5.26
21	5.87	6.14	6.29	5.13	54	6.00	6.27	6.48	5.22
22	5.81	6.08	6.23	5.06	55	6.33	6.61	6.77	5.54
23	5.78	6.06	6.19	5.02	56	6.00	6.29	6.47	5.20
24	5.82	6.10	6.23	5.06	57	6.05	6.33	6.50	5.25
25	5.86	6.13	6.29	5.08	58	5.95	6.23	6.42	5.16
26	5.88	6.16	6.34	5.10	59	6.11	6.40	6.56	5.30
27	5.89	6.17	6.34	5.10	60	6.08	6.36	6.54	5.28
28	5.94	6.22	6.36	5.17	61	6.17	6.45	6.61	5.39
29	5.86	6.15	6.30	5.07	62	6.48	6.75	6.93	5.71
30	5.94	6.22	6.38	5.15	63	5.99	6.27	6.43	5.18
31	6.03	6.31	6.47	5.25	64	6.06	6.34	6.50	5.27
32	6.03	6.31	6.47	5.24	Average	5.99	6.27	6.42	5.21

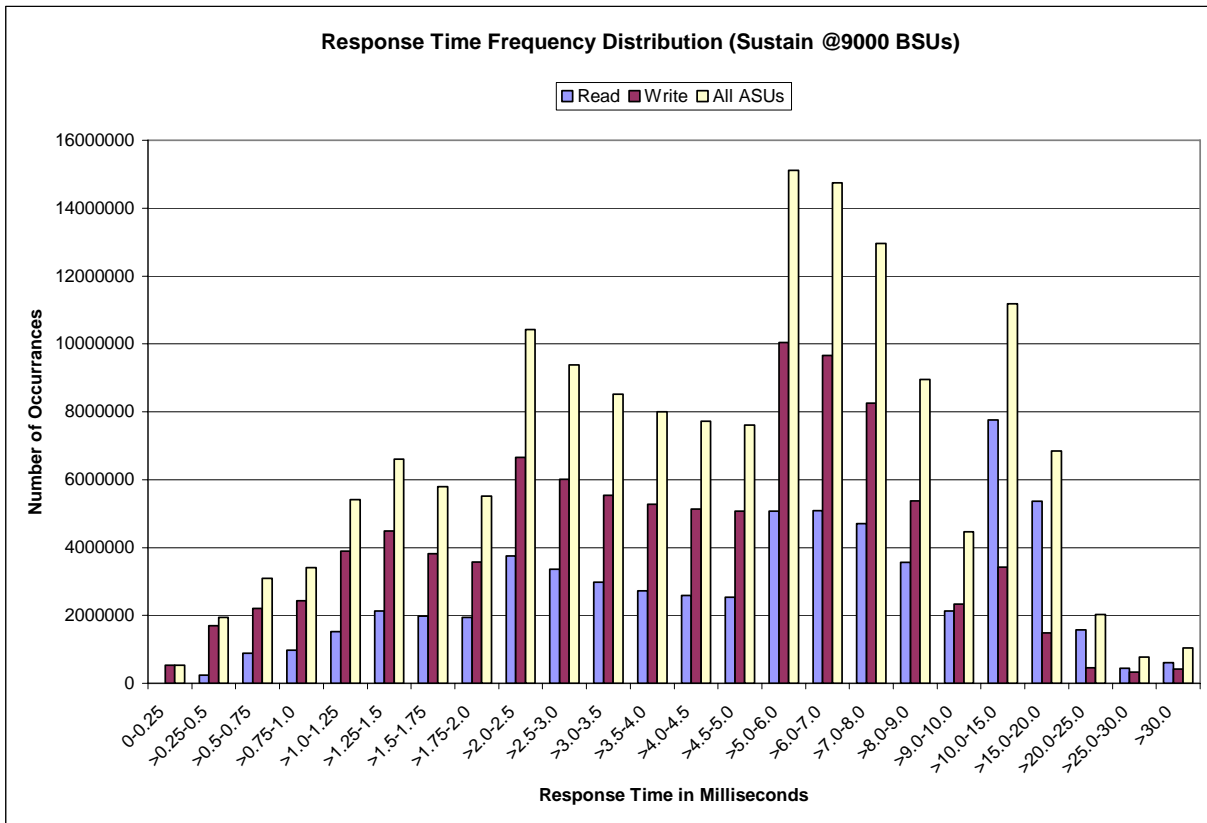
### Sustainability – Average Response Time (ms) Distribution Graph



**Sustainability – Response Time Frequency Distribution Data**

Response Time (ms)	0-0.25	>0.25-0.5	>0.5-0.75	>0.75-1.0	>1.0-1.25	>1.25-1.5	>1.5-1.75	>1.75-2.0
Read	2,969	242,279	891,473	970,857	1,519,788	2,124,059	1,978,179	1,939,068
Write	526,933	1,696,979	2,202,794	2,440,456	3,897,332	4,484,219	3,817,019	3,576,433
All ASUs	529,902	1,939,258	3,094,267	3,411,313	5,417,120	6,608,278	5,795,198	5,515,501
ASU1	293,164	1,023,712	1,771,336	1,942,690	3,099,572	3,875,026	3,483,109	3,350,290
ASU2	67,995	221,967	357,821	396,150	632,316	775,554	688,787	660,756
ASU3	168,743	693,579	965,110	1,072,473	1,685,232	1,957,698	1,623,302	1,504,455
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	3,756,424	3,366,018	2,981,154	2,720,747	2,585,550	2,531,789	5,066,222	5,080,538
Write	6,661,830	6,009,991	5,538,420	5,274,800	5,139,838	5,069,024	10,040,062	9,663,986
All ASUs	10,418,254	9,376,009	8,519,574	7,995,547	7,725,388	7,600,813	15,106,284	14,744,524
ASU1	6,317,290	5,599,923	4,969,948	4,564,538	4,350,569	4,259,032	8,496,448	8,373,774
ASU2	1,264,427	1,149,762	1,051,843	984,051	940,590	913,738	1,774,431	1,686,281
ASU3	2,836,537	2,626,324	2,497,783	2,446,958	2,434,229	2,428,043	4,835,405	4,684,469
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	4,701,658	3,565,789	2,126,527	7,755,680	5,367,219	1,568,075	448,960	610,574
Write	8,254,274	5,381,112	2,336,352	3,420,813	1,480,408	454,644	323,766	423,575
All ASUs	12,955,932	8,946,901	4,462,879	11,176,493	6,847,627	2,022,719	772,726	1,034,149
ASU1	7,445,879	5,246,951	2,719,005	7,819,465	4,943,868	1,452,352	510,532	665,019
ASU2	1,434,627	977,076	510,804	1,655,203	1,188,802	323,153	115,631	155,017
ASU3	4,075,426	2,722,874	1,233,070	1,701,825	714,957	247,214	146,563	214,113

**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 6.1.0

**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).*

Clause 6.3.13.3

**COV – Coefficient of Variation:** *This measure of variation for the Measured Intensity Multiplier cannot exceed 0.5.*

	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	0.2809
COV	0.003	0.001	0.002	0.001	0.005	0.002	0.004	0.001

## Primary Metrics Test – IOPS Test Phase

### Clause 6.4.3.3

*The IOPS Test Phase consists of one Test Run at the 100% load point with a Measurement Interval of five (5) minutes. The IOPS Test Phase immediately follows the Sustainability Test Phase without any interruption or manual intervention.*

*The IOPS Test Run generates the SPC-1C 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 10.4.8.2

*For the IOPS Test Phase the FDR shall contain:*

- 1. I/O Request Throughput Distribution (data and graph).*
- 2. Response Time Frequency Distribution (data and graph).*
- 3. Average Response Time Distribution (data and graph).*
- 4. The human readable SPC-1C Test Run Results File produced by the SPC-1C Workload Generator.*
- 5. A listing of all input parameters supplied to the SPC-1C Workload Generator.*
- 6. The Measured Intensity Multiplier for each I/O Stream.*
- 7. The variability of the Measured Intensity Multiplier, as defined in Clause 6.3.13.3.*
- 8. 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-1C Workload Generator Input Parameters

The SPC-1C Workload Generator input parameters for the Sustainability, IOPS, Response Time Ramp, Repeatability, and Persistence Test Runs are documented in “Appendix E: SPC-1C Workload Generator Input Parameters” on Page 65.

## IOPS Test Results File

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

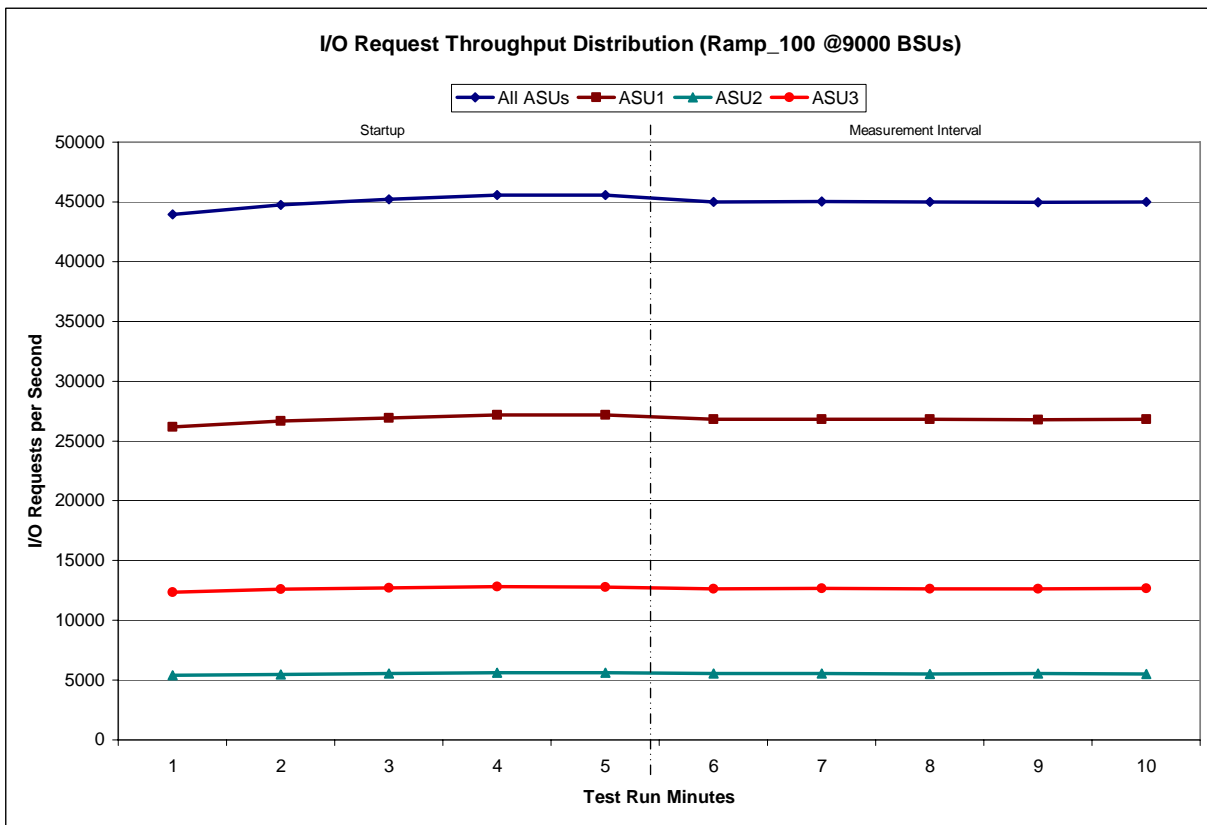
[IOPS Test Results File](#)



**IOPS Test Run – I/O Request Throughput Distribution Data**

9000 BSUs	Start	Stop	Interval	Duration
<i>Start-Up/Ramp-Up</i>	18:48:50	18:53:51	0-4	0:05:01
<i>Measurement Interval</i>	18:53:51	18:58:51	5-9	0:05:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	43,940.12	26,176.90	5,406.27	12,356.95
1	44,751.08	26,680.98	5,485.58	12,584.52
2	45,208.22	26,937.68	5,550.73	12,719.80
3	45,575.28	27,171.80	5,599.62	12,803.87
4	45,576.00	27,164.57	5,619.75	12,791.68
5	45,006.62	26,819.65	5,546.50	12,640.47
6	45,033.05	26,813.45	5,544.95	12,674.65
7	44,994.02	26,831.13	5,523.83	12,639.05
8	44,973.65	26,799.45	5,543.87	12,630.33
9	44,993.68	26,810.82	5,523.47	12,659.40
<b>Average</b>	<b>45,000.20</b>	<b>26,814.90</b>	<b>5,536.52</b>	<b>12,648.78</b>

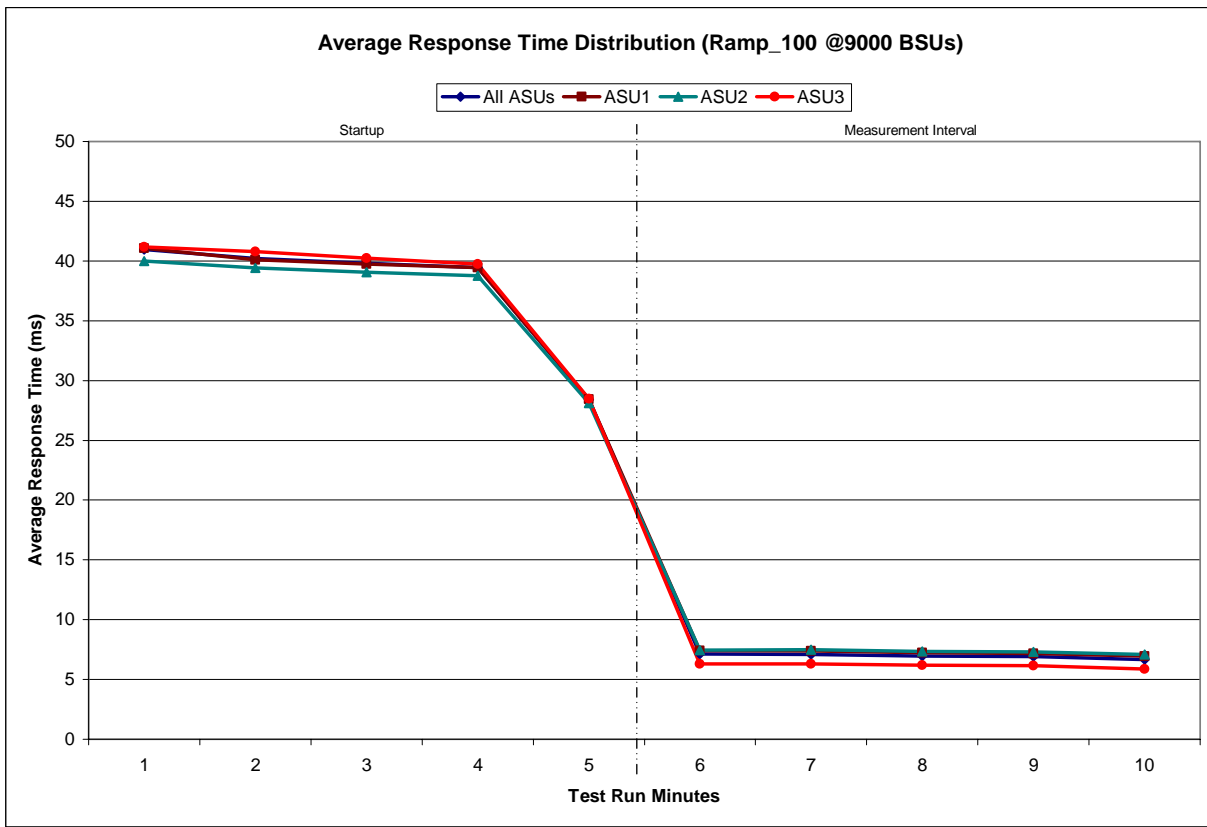
**IOPS Test Run – I/O Request Throughput Distribution Graph**



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

9000 BSUs	Start	Stop	Interval	Duration
<i>Start-Up/Ramp-Up</i>	18:48:50	18:53:51	0-4	0:05:01
<i>Measurement Interval</i>	18:53:51	18:58:51	5-9	0:05:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	40.96	41.06	39.99	41.18
1	40.21	40.10	39.41	40.79
2	39.81	39.76	39.06	40.24
3	39.44	39.44	38.76	39.75
4	28.40	28.44	28.10	28.46
5	7.11	7.41	7.46	6.31
6	7.10	7.39	7.47	6.31
7	6.96	7.24	7.35	6.18
8	6.91	7.18	7.33	6.14
9	6.66	6.94	7.08	5.87
<b>Average</b>	6.95	7.23	7.34	6.16

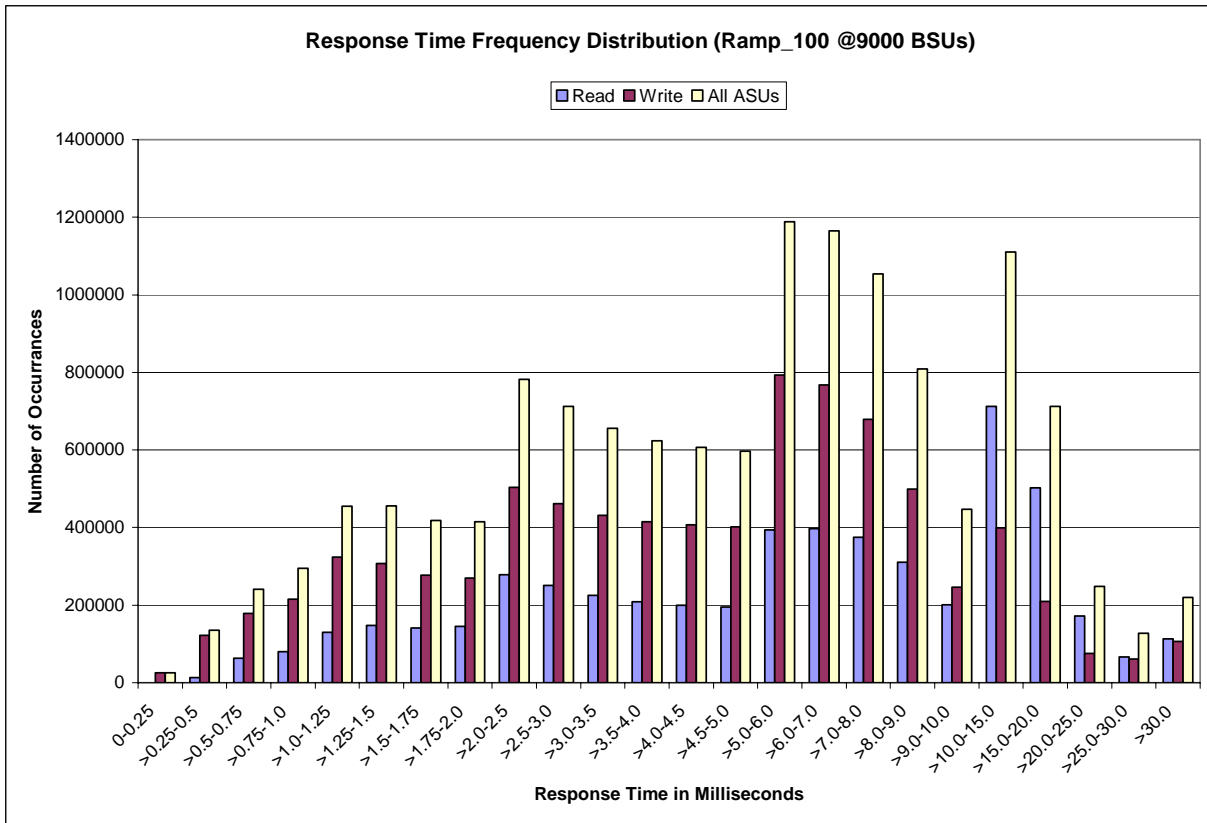
**IOPS Test Run – Average Response Time (ms) Distribution Graph**



**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	244	13,775	62,748	79,852	130,142	147,945	141,155	145,144
Write	25639	121,873	178,124	215,416	324,270	307,525	277,356	269,476
All ASUs	25883	135,648	240,872	295,268	454,412	455,470	418,511	414,620
ASU1	14565	71,414	135,909	166,935	260,028	268,765	252,325	252,534
ASU2	3315	15,708	28,021	34,391	53,315	53,898	49,984	49,654
ASU3	8003	48,526	76,942	93,942	141,069	132,807	116,202	112,432
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	278,795	250,342	225,079	209,057	199,670	195,798	394,291	396,880
Write	503,809	461,308	431,051	414,819	407,619	401,149	793,537	767,810
All ASUs	782,604	711,650	656,130	623,876	607,289	596,947	1,187,828	1,164,690
ASU1	474,584	423,514	382,039	356,536	341,160	333,792	668,011	660,138
ASU2	95,206	87,751	81,553	76,307	74,480	72,197	140,338	134,975
ASU3	212,814	200,385	192,538	191,033	191,649	190,958	379,479	369,577
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	374,408	310,347	200,510	711,787	502,692	172,294	66,080	112,872
Write	679,289	498,823	246,435	399,063	209,394	75,694	61,456	106,753
All ASUs	1,053,697	809,170	446,945	1,110,850	712,086	247,988	127,536	219,625
ASU1	601,583	468,049	267,170	760,096	497,387	170,629	81,729	135,293
ASU2	119,468	90,133	50,067	151,642	114,168	36,007	17,858	30,484
ASU3	332,646	250,988	129,708	199,112	100,531	41,352	27,949	53,848

**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
13,499,595	13,279,970	219,625

**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 6.1.0

**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).

Clause 6.3.13.3

**COV – Coefficient of Variation:** This measure of variation for the Measured Intensity Multiplier cannot exceed 0.5.

	ASU1-1	ASU1-2	ASU1-3	ASU1-4	ASU2-1	ASU2-2	ASU2-3	ASU3-1
<b>IM</b>	<b>0.0350</b>	<b>0.2810</b>	<b>0.0700</b>	<b>0.2100</b>	<b>0.0180</b>	<b>0.0700</b>	<b>0.0350</b>	<b>0.2810</b>
MIM	0.0351	0.2809	0.0699	0.2099	0.0179	0.0701	0.0350	0.2811
COV	0.003	0.002	0.001	0.002	0.004	0.002	0.002	0.001

## Primary Metrics Test – Response Time Ramp Test Phase

### Clause 6.4.3.4

*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-1C IOPS™ primary metric. Each of the five Test Runs has a Measurement Interval of five (5) minutes. The Response Time Ramp Test Phase immediately follows the IOPS Test Phase without any interruption or manual intervention.*

*The five Response Time Ramp Test Runs, in conjunction with the IOPS Test Run (100%), demonstrate the relationship between Average Response Time and I/O Request Throughput for the Tested Storage Configuration (TSC) as illustrated in the response time/throughput curve on page 13.*

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

### Clause 10.4.8.3

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

- 1. A Response Time Ramp Distribution graph.*
- 2. The human readable Test Run Results File produced by the SPC-1C C Workload Generator for each Test Run within the Response Time Ramp Test Phase.*
- 3. An Average Response Time Distribution graph and table for the 10% BSU Level Test Run (the SPC-1C LRT™ metric).*
- 4. A listing of all input parameters supplied to the SPC-1C Workload Generator.*

## SPC-1C Workload Generator Input Parameters

The SPC-1C Workload Generator input parameters for the Sustainability, IOPS, Response Time Ramp, Repeatability, and Persistence Test Runs are documented in “Appendix E: SPC-1C Workload Generator Input Parameters” on Page 65.

## 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](#)

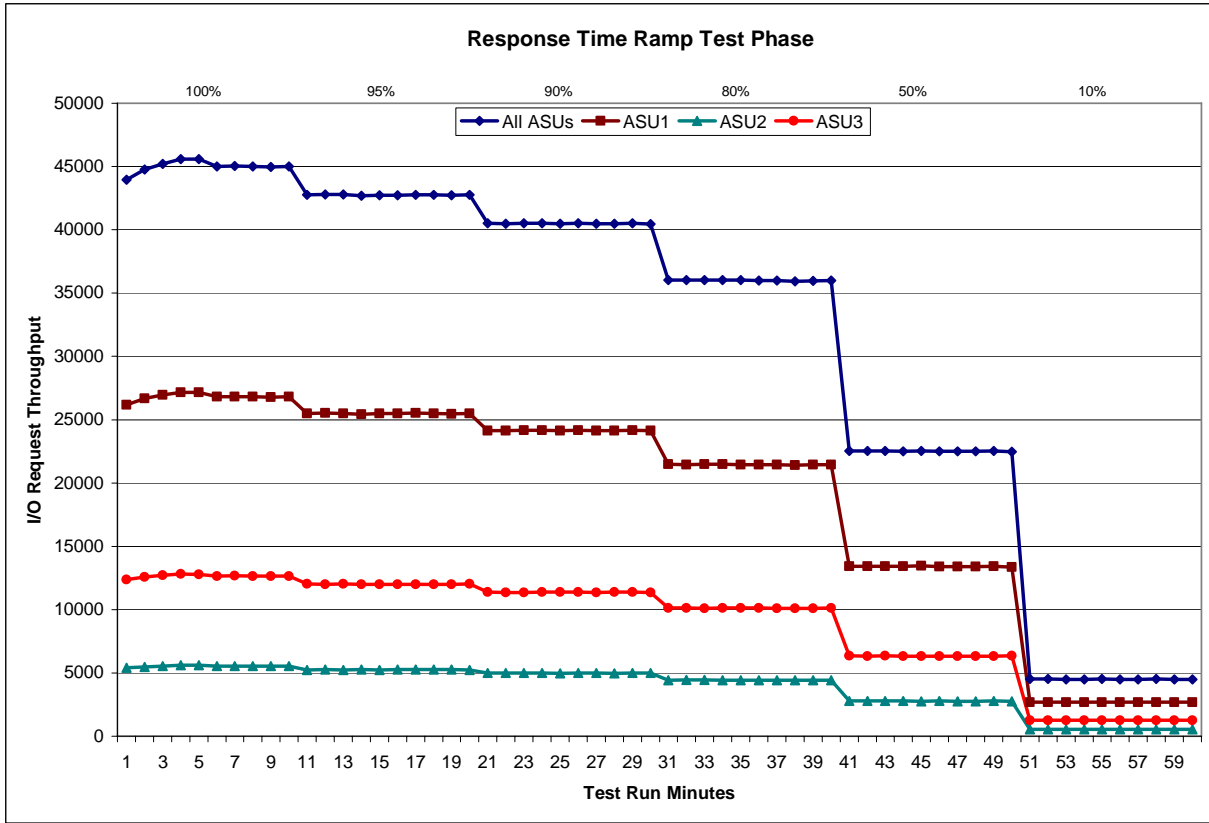
[10% Load Level](#)

**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-1C 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 - 9000 BSUs					95% Load Level - 8550 BSUs				
	Start	Stop	Interval	Duration		Start	Stop	Interval	Duration
Start-Up/Ramp-Up	18:48:50	18:53:51	0-4	0:05:01	Start-Up/Ramp-Up	18:59:13	19:04:14	0-4	0:05:01
Measurement Interval	18:53:51	18:58:51	4-9	0:05:00	Measurement Interval	19:04:14	19:09:14	4-9	0:05:00
(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3	(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3
0	43,940.12	26,176.90	5,406.27	12,356.95	0	42,761.80	25,482.87	5,251.52	12,027.42
1	44,751.08	26,680.98	5,485.58	12,584.52	1	42,788.85	25,527.73	5,251.72	12,009.40
2	45,208.22	26,937.68	5,550.73	12,719.80	2	42,789.40	25,496.57	5,249.12	12,043.72
3	45,575.28	27,171.80	5,599.62	12,803.87	3	42,701.75	25,426.73	5,260.80	12,014.22
4	45,576.00	27,164.57	5,619.75	12,791.68	4	42,732.08	25,486.33	5,245.13	12,000.62
5	45,006.62	26,819.65	5,546.50	12,640.47	5	42,734.03	25,476.25	5,262.17	11,995.62
6	45,033.05	26,813.45	5,544.95	12,674.65	6	42,776.32	25,514.43	5,261.42	12,000.47
7	44,994.02	26,831.13	5,523.83	12,639.05	7	42,749.57	25,484.55	5,271.00	11,994.02
8	44,973.65	26,799.45	5,543.87	12,630.33	8	42,711.12	25,453.70	5,256.35	12,001.07
9	44,993.68	26,810.82	5,523.47	12,659.40	9	42,754.15	25,489.13	5,249.30	12,015.72
Average	45,000.20	26,814.90	5,536.52	12,648.78	Average	42,745.04	25,483.61	5,260.05	12,001.38
90% Load Level - 8100 BSUs					80% Load Level - 7200 BSUs				
	Start	Stop	Interval	Duration		Start	Stop	Interval	Duration
Start-Up/Ramp-Up	19:09:35	19:14:36	0-4	0:05:01	Start-Up/Ramp-Up	19:19:56	19:24:57	0-4	0:05:01
Measurement Interval	19:14:36	19:19:36	4-9	0:05:00	Measurement Interval	19:24:57	19:29:57	4-9	0:05:00
(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3	(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3
0	40,513.30	24,116.82	5,000.98	11,395.50	0	36,029.65	21,486.18	4,426.02	10,117.45
1	40,482.53	24,148.17	4,979.65	11,354.72	1	36,015.65	21,453.52	4,438.80	10,123.33
2	40,512.08	24,166.75	4,979.72	11,365.62	2	36,038.02	21,484.93	4,452.92	10,100.17
3	40,512.85	24,150.85	4,986.68	11,375.32	3	36,022.87	21,474.30	4,432.57	10,116.00
4	40,496.72	24,130.93	4,973.92	11,391.87	4	36,014.22	21,454.70	4,429.88	10,129.63
5	40,515.47	24,151.23	4,985.35	11,378.88	5	35,978.93	21,438.05	4,420.55	10,120.33
6	40,479.67	24,141.20	4,983.33	11,355.13	6	35,986.45	21,457.88	4,420.18	10,108.38
7	40,484.42	24,142.08	4,962.63	11,379.70	7	35,937.08	21,419.58	4,411.00	10,106.50
8	40,528.17	24,172.33	4,982.27	11,373.57	8	35,958.77	21,450.12	4,426.37	10,082.28
9	40,449.60	24,120.12	4,986.35	11,343.13	9	35,986.53	21,435.70	4,433.08	10,117.75
Average	40,491.46	24,145.39	4,979.99	11,366.08	Average	35,969.55	21,440.27	4,422.24	10,107.05
50% Load Level - 4500 BSUs					10% Load Level - 900 BSUs				
	Start	Stop	Interval	Duration		Start	Stop	Interval	Duration
Start-Up/Ramp-Up	19:30:10	19:35:11	0-4	0:05:01	Start-Up/Ramp-Up	19:40:16	19:45:17	0-4	0:05:01
Measurement Interval	19:35:11	19:40:11	4-9	0:05:00	Measurement Interval	19:45:17	19:50:17	4-9	0:05:00
(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3	(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3
0	22,545.13	13,425.88	2,779.48	6,339.77	0	4,511.48	2,691.98	554.32	1,265.18
1	22,535.43	13,428.92	2,785.33	6,321.18	1	4,506.90	2,675.45	559.35	1,272.10
2	22,531.22	13,414.50	2,773.97	6,342.75	2	4,495.63	2,678.53	551.20	1,265.90
3	22,507.05	13,415.50	2,773.58	6,317.97	3	4,499.32	2,682.00	553.43	1,263.88
4	22,534.80	13,443.75	2,769.82	6,321.23	4	4,508.48	2,686.50	555.17	1,266.82
5	22,498.72	13,399.63	2,771.63	6,327.45	5	4,485.77	2,668.32	555.57	1,261.88
6	22,497.60	13,403.87	2,768.30	6,325.43	6	4,494.63	2,679.87	553.48	1,261.28
7	22,488.10	13,398.28	2,762.62	6,327.20	7	4,515.35	2,689.77	554.78	1,270.80
8	22,532.25	13,437.43	2,774.68	6,320.13	8	4,490.18	2,678.05	553.67	1,258.47
9	22,467.77	13,367.77	2,758.50	6,341.50	9	4,499.53	2,680.57	554.75	1,264.22
Average	22,496.89	13,401.40	2,767.15	6,328.34	Average	4,497.09	2,679.31	554.45	1,263.33

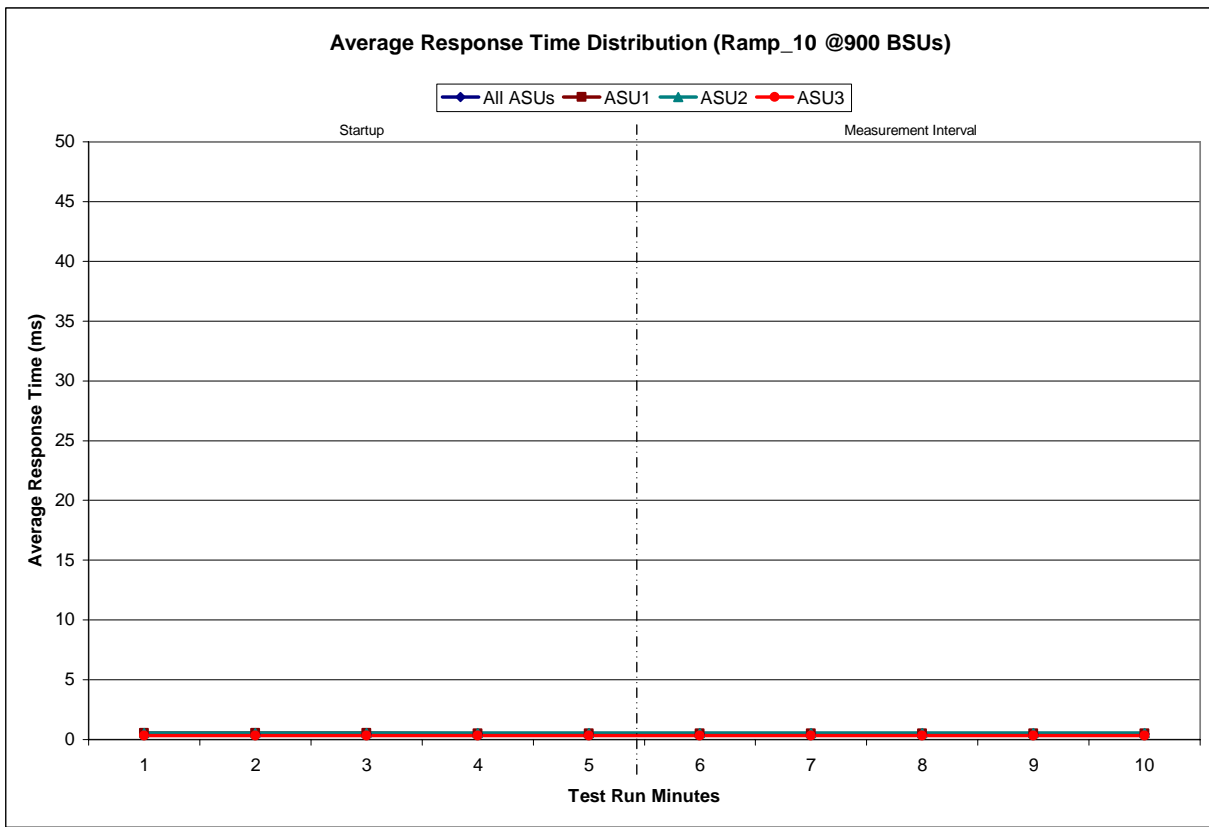
### Response Time Ramp Distribution (IOPS) Graph



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

900 BSUs	Start	Stop	Interval	Duration
<i>Start-Up/Ramp-Up</i>	19:40:16	19:45:17	0-4	0:05:01
<i>Measurement Interval</i>	19:45:17	19:50:17	5-9	0:05:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	0.48	0.54	0.56	0.32
1	0.47	0.52	0.54	0.31
2	0.47	0.52	0.55	0.31
3	0.46	0.52	0.54	0.31
4	0.47	0.52	0.55	0.31
5	0.47	0.52	0.55	0.32
6	0.46	0.52	0.54	0.31
7	0.46	0.52	0.53	0.31
8	0.47	0.52	0.54	0.32
9	0.46	0.52	0.54	0.31
<b>Average</b>	0.46	0.52	0.54	0.31

**SPC-1C LRT™ Average Response Time (ms) Distribution Graph**





**SPC-1C 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 6.1.0

*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).*

Clause 6.3.13.3

*COV – Coefficient of Variation: This measure of variation for the Measured Intensity Multiplier cannot exceed 0.5.*

	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	0.0701	0.2095	0.0182	0.0700	0.0351	0.2809
COV	0.002	0.003	0.010	0.002	0.017	0.006	0.012	0.002

## Repeatability Test

### Clause 6.4.4

*The Repeatability Test demonstrates the repeatability and reproducibility of the SPC-1C IOPS™ primary metric and SPC-1C 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 five (5) 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-1C LRT™ metric. Each Average Response Time value must be less than the SPC-1C LRT™ metric plus 5%.*

*The second Test Run in each Test Phase is executed at the 100% load point. The I/O Request Throughput from the Test Runs is compared to the SPC-1C IOPS™ primary metric. Each I/O Request Throughput value must be greater than the SPC-1C 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 10.4.8.4

*The FDR shall contain the following for the Repeatability Test:*

- 1. A table containing the results of the Repeatability Test.*
- 2. I/O Request Throughput Distribution graph and table for each Repeatability Test Run.*
- 3. An Average Response Time Distribution graph and table for each Repeatability Test Run.*
- 4. The human readable Test Run Results File produced by the Workload Generator. The human readable Test Run Results File produced by the SPC-1C C Workload Generator.*
- 5. A listing of all input parameters supplied to the SPC-1C Workload Generator.*

## SPC-1C Workload Generator Input Parameters

The SPC-1C Workload Generator input parameters for the Sustainability, IOPS, Response Time Ramp, Repeatability, and Persistence Test Runs are documented in “Appendix E: SPC-1C Workload Generator Input Parameters” on Page 65.

**Repeatability Test Results File**

The values for the SPC-1C IOPS™, SPC-1C LRT™, and the Repeatability Test measurements are listed in the tables below.

	SPC-1C IOPS™
<b>Primary Metrics</b>	<b>45,000.20</b>
Repeatability Test Phase 1	45,020.85
Repeatability Test Phase 2	45,124.53

The SPC-1C 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-1C IOPS™ must be greater than 95% of the reported SPC-1C IOPS™ Primary Metric.

	SPC-1C LRT™
<b>Primary Metrics</b>	<b>0.46 ms</b>
Repeatability Test Phase 1	0.45 ms
Repeatability Test Phase 2	0.46 ms

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

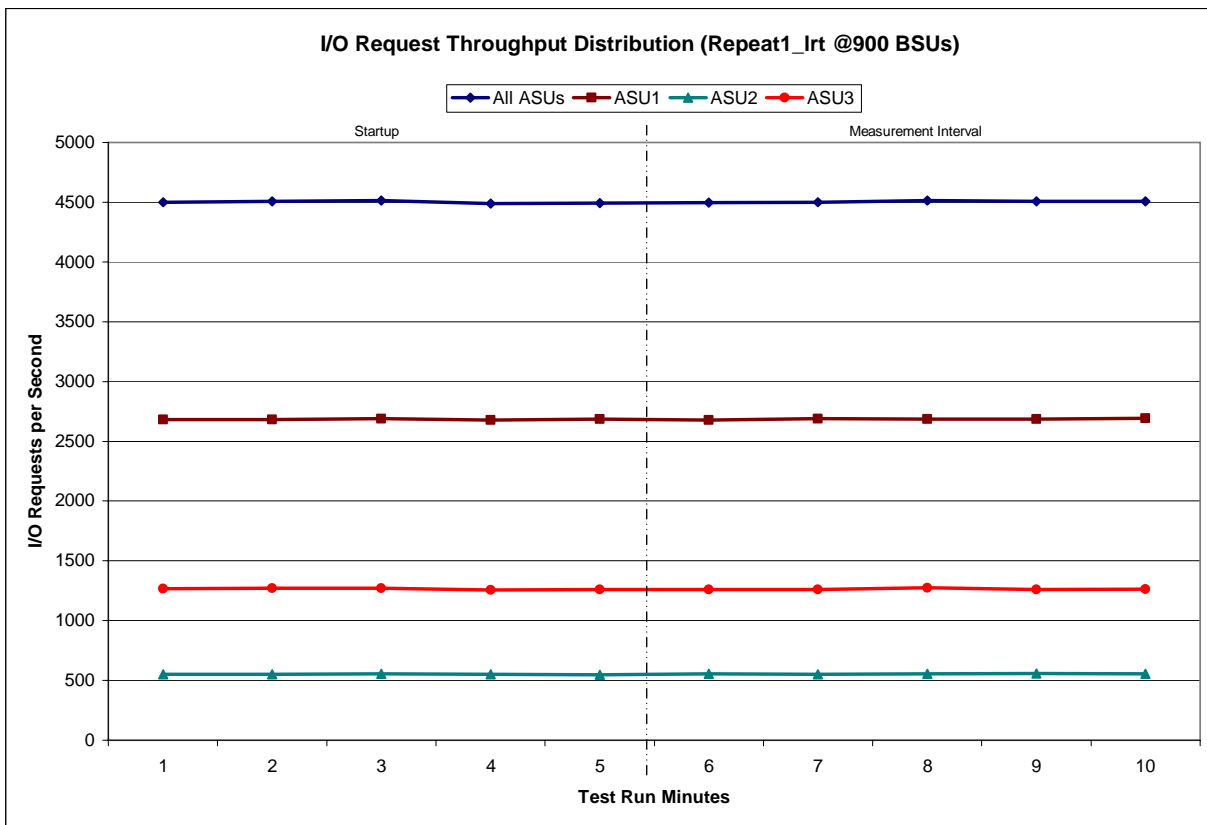
A link to the test result file generated from each Repeatability Test Run is listed below.

- [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**

900 BSUs	Start	Stop	Interval	Duration
<i>Start-Up/Ramp-Up</i>	19:50:32	19:55:32	0-4	0:05:00
<i>Measurement Interval</i>	19:55:32	20:00:32	5-9	0:05:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	4,500.17	2,682.65	551.42	1,266.10
1	4,506.57	2,683.07	551.02	1,272.48
2	4,515.72	2,689.52	553.88	1,272.32
3	4,488.25	2,679.97	550.58	1,257.70
4	4,492.12	2,684.33	547.77	1,260.02
5	4,495.37	2,679.62	554.40	1,261.35
6	4,499.67	2,688.60	552.05	1,259.02
7	4,512.82	2,683.93	554.80	1,274.08
8	4,505.68	2,687.08	557.17	1,261.43
9	4,508.33	2,691.07	553.15	1,264.12
<b>Average</b>	<b>4,504.37</b>	<b>2,686.06</b>	<b>554.31</b>	<b>1,264.00</b>

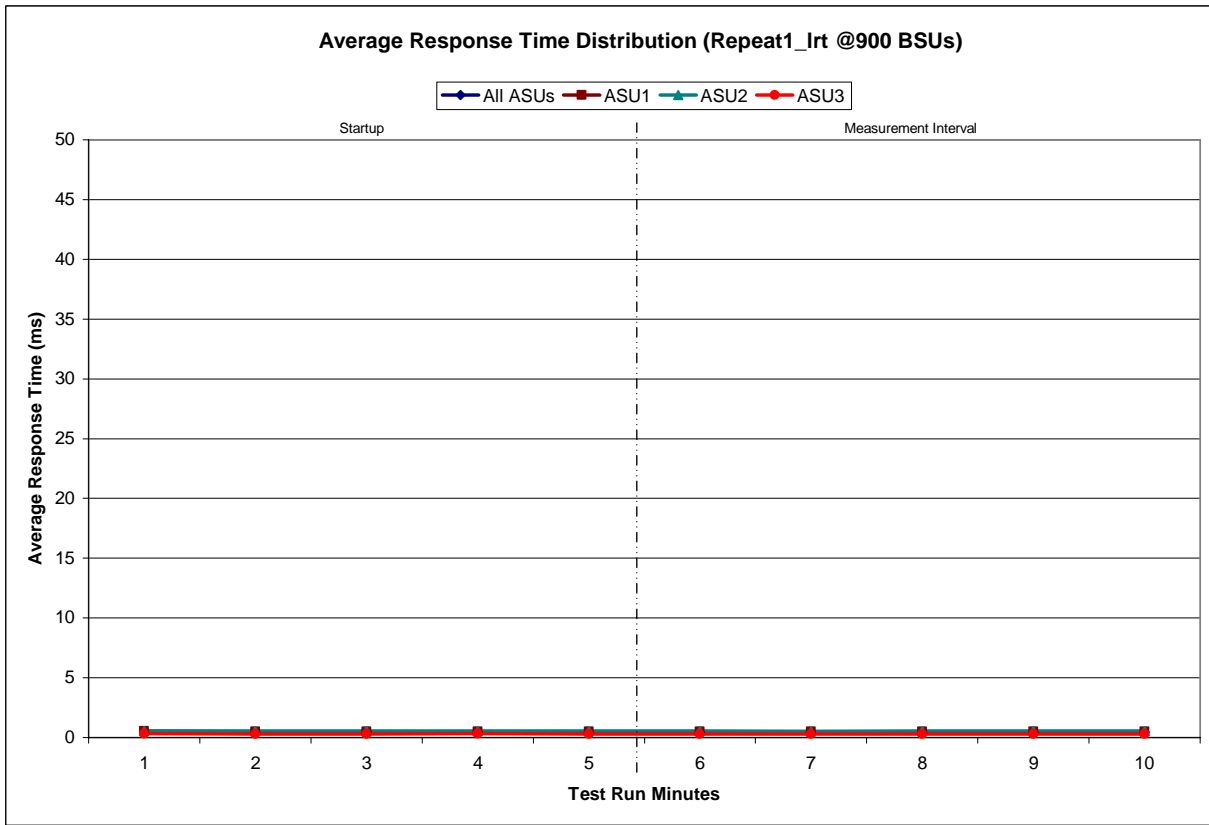
**Repeatability 1 LRT - I/O Request Throughput Distribution Graph**



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

900 BSUs	Start	Stop	Interval	Duration
<i>Start-Up/Ramp-Up</i>	19:50:32	19:55:32	0-4	0:05:00
<i>Measurement Interval</i>	19:55:32	20:00:32	5-9	0:05:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	0.47	0.53	0.52	0.31
1	0.46	0.52	0.53	0.30
2	0.46	0.52	0.53	0.30
3	0.46	0.52	0.55	0.31
4	0.46	0.52	0.54	0.30
5	0.45	0.51	0.53	0.30
6	0.45	0.51	0.52	0.30
7	0.45	0.51	0.53	0.30
8	0.46	0.51	0.53	0.30
9	0.45	0.50	0.53	0.30
<b>Average</b>	0.45	0.51	0.53	0.30

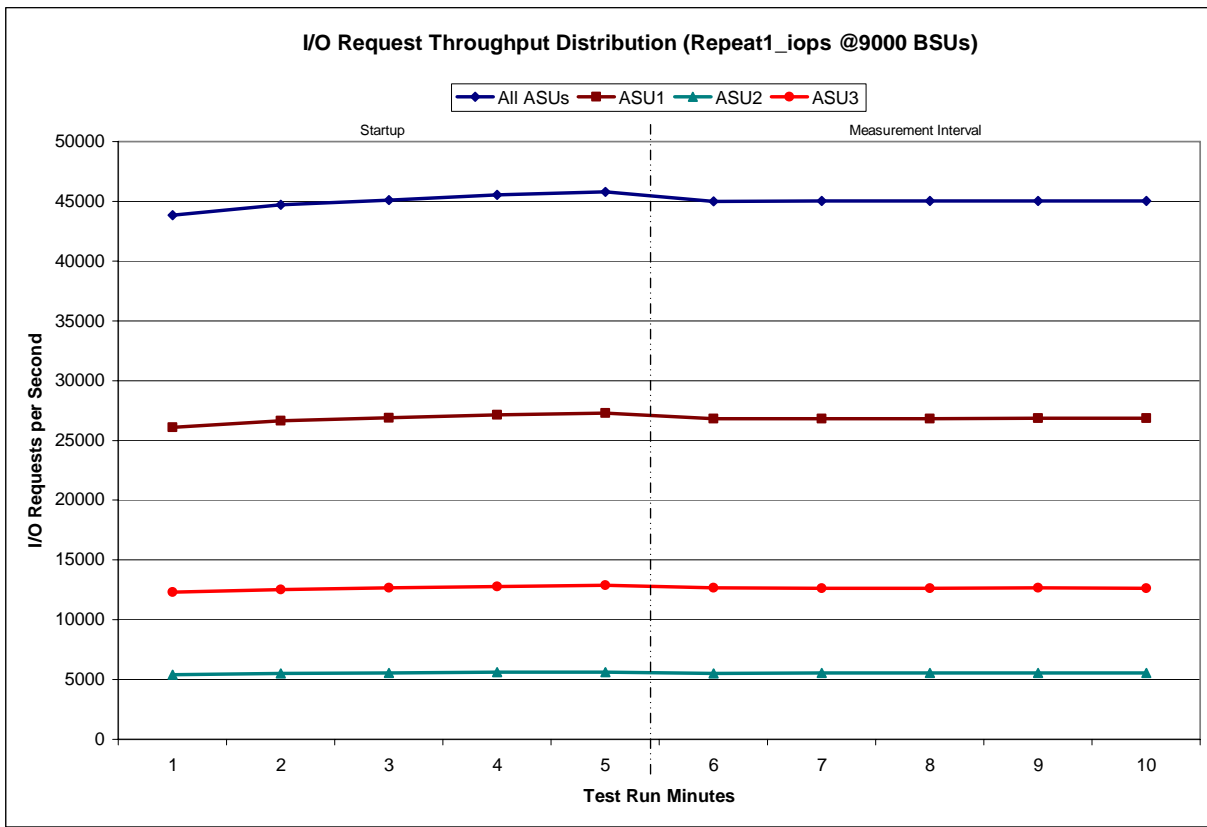
**Repeatability 1 LRT –Average Response Time (ms) Distribution Graph**



**Repeatability 1 IOPS - I/O Request Throughput Distribution Data**

9000 BSUs	Start	Stop	Interval	Duration
<i>Start-Up/Ramp-Up</i>	20:00:56	20:05:57	0-4	0:05:01
<i>Measurement Interval</i>	20:05:57	20:10:57	5-9	0:05:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	43,840.52	26,105.93	5,405.88	12,328.70
1	44,691.98	26,655.43	5,501.65	12,534.90
2	45,114.88	26,896.58	5,535.02	12,683.28
3	45,532.40	27,146.00	5,601.33	12,785.07
4	45,789.00	27,297.88	5,620.70	12,870.42
5	44,999.32	26,829.75	5,514.82	12,654.75
6	45,022.67	26,833.02	5,539.63	12,650.02
7	45,015.83	26,820.42	5,543.33	12,652.08
8	45,034.15	26,841.98	5,533.03	12,659.13
9	45,032.30	26,843.77	5,537.03	12,651.50
<b>Average</b>	45,020.85	26,833.79	5,533.57	12,653.50

**Repeatability 1 IOPS - I/O Request Throughput Distribution Graph**



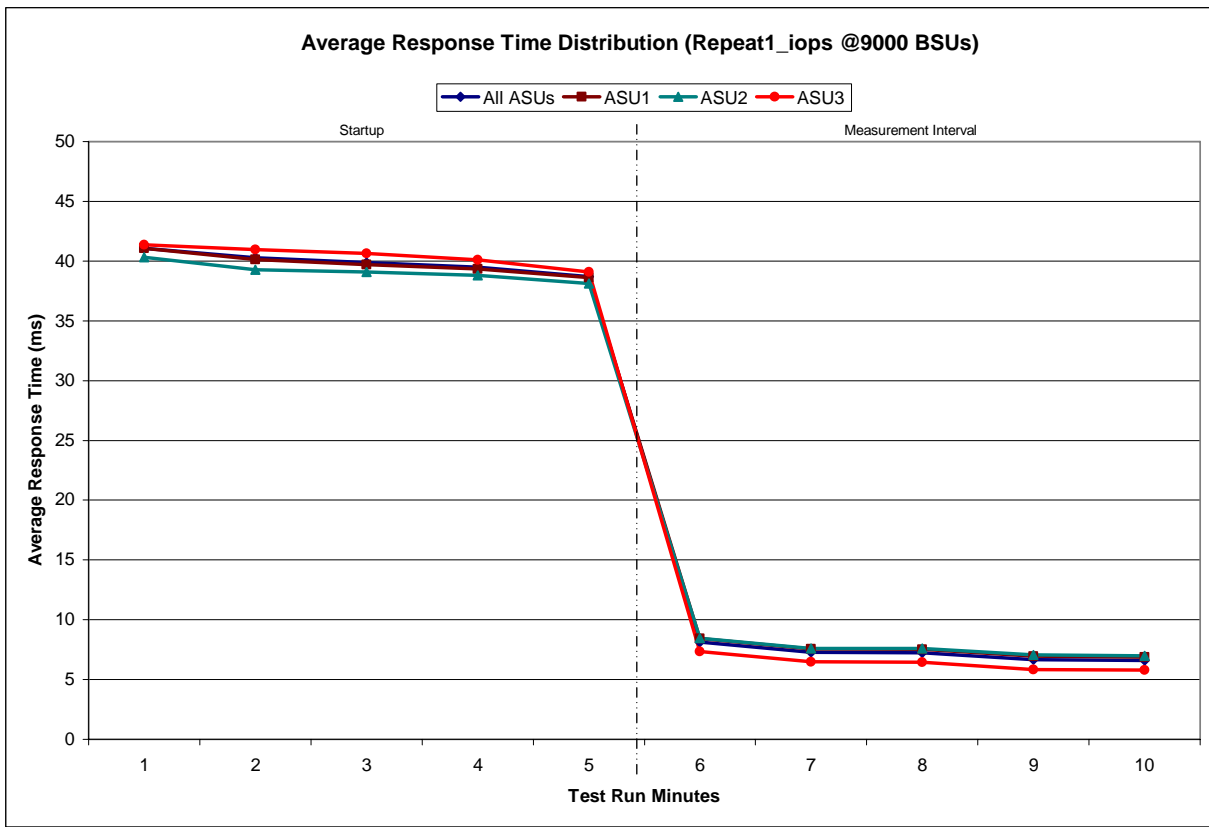
**Repeatability 1 IOPS –Average Response Time (ms) Distribution Data**

9000 BSUs	Start	Stop	Interval	Duration
<i>Start-Up/Ramp-Up</i>	20:00:56	20:05:57	0-4	0:05:01
<i>Measurement Interval</i>	20:05:57	20:10:57	5-9	0:05:00

60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	41.06	41.07	40.30	41.36
1	40.27	40.15	39.26	40.98
2	39.90	39.71	39.09	40.65
3	39.49	39.35	38.81	40.08
4	38.69	38.61	38.11	39.10
5	8.12	8.41	8.46	7.34
6	7.26	7.56	7.60	6.48
7	7.24	7.54	7.61	6.45
8	6.64	6.94	7.06	5.84
9	6.59	6.89	7.00	5.78
<b>Average</b>	7.17	7.47	7.55	6.38

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



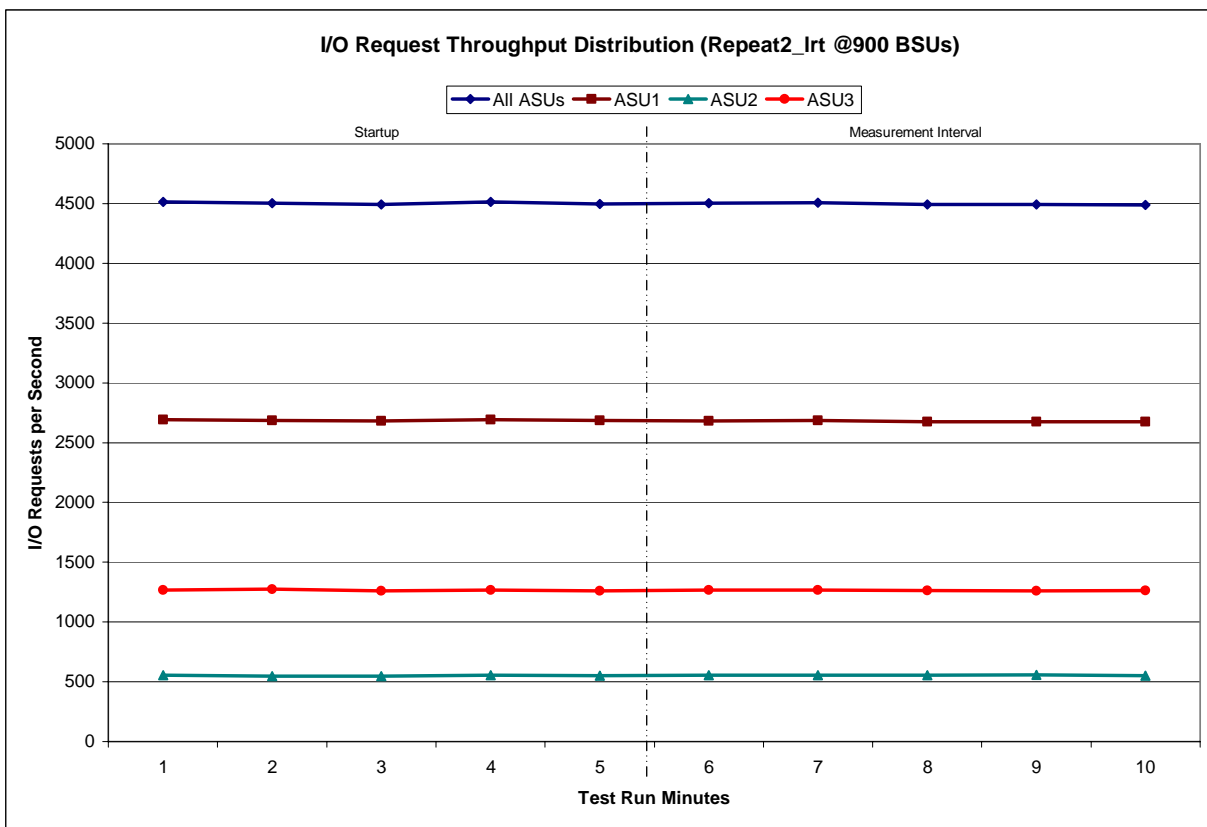
**Repeatability 2 LRT - I/O Request Throughput Distribution Data**

900 BSUs	Start	Stop	Interval	Duration
<i>Start-Up/Ramp-Up</i>	20:11:13	20:16:13	0-4	0:05:00
<i>Measurement Interval</i>	20:16:13	20:21:13	5-9	0:05:00

60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	4,514.30	2,692.07	553.43	1,268.80
1	4,504.68	2,684.62	547.22	1,272.85
2	4,492.57	2,682.05	548.92	1,261.60
3	4,512.32	2,690.97	555.47	1,265.88
4	4,495.18	2,685.95	551.10	1,258.13
5	4,501.82	2,680.12	556.08	1,265.62
6	4,505.97	2,684.20	555.48	1,266.28
7	4,492.13	2,673.68	554.10	1,264.35
8	4,493.40	2,676.05	556.30	1,261.05
9	4,488.03	2,673.18	551.37	1,263.48
<b>Average</b>	<b>4,496.27</b>	<b>2,677.45</b>	<b>554.67</b>	<b>1,264.16</b>

**Repeatability 2 LRT - I/O Request Throughput Distribution Graph**





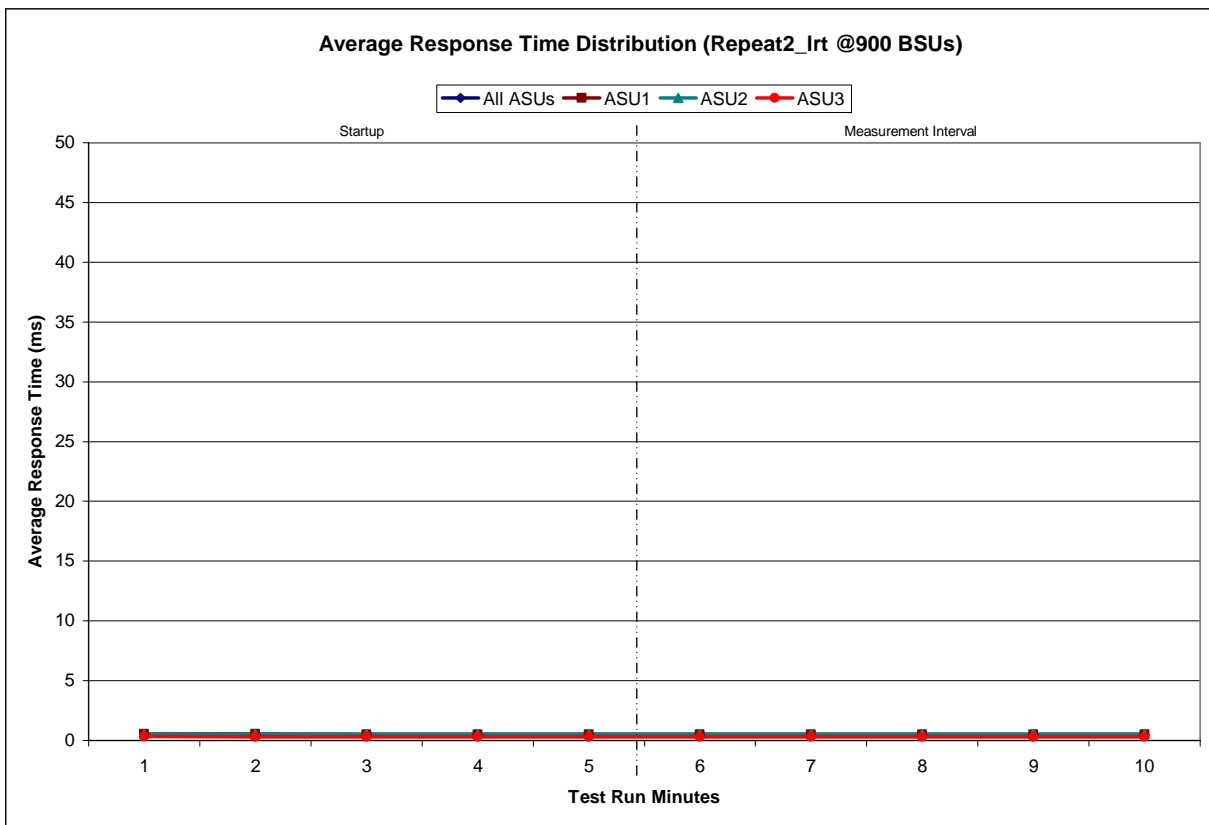
**Repeatability 2 LRT –Average Response Time (ms) Distribution Data**

900 BSUs	Start	Stop	Interval	Duration
<i>Start-Up/Ramp-Up</i>	20:11:13	20:16:13	0-4	0:05:00
<i>Measurement Interval</i>	20:16:13	20:21:13	5-9	0:05:00

60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	0.47	0.54	0.55	0.31
1	0.46	0.53	0.53	0.30
2	0.46	0.52	0.55	0.30
3	0.46	0.51	0.53	0.30
4	0.46	0.51	0.54	0.30
5	0.46	0.51	0.54	0.30
6	0.46	0.52	0.54	0.30
7	0.46	0.51	0.53	0.30
8	0.45	0.51	0.53	0.30
9	0.45	0.51	0.52	0.30
<b>Average</b>	0.46	0.51	0.53	0.30

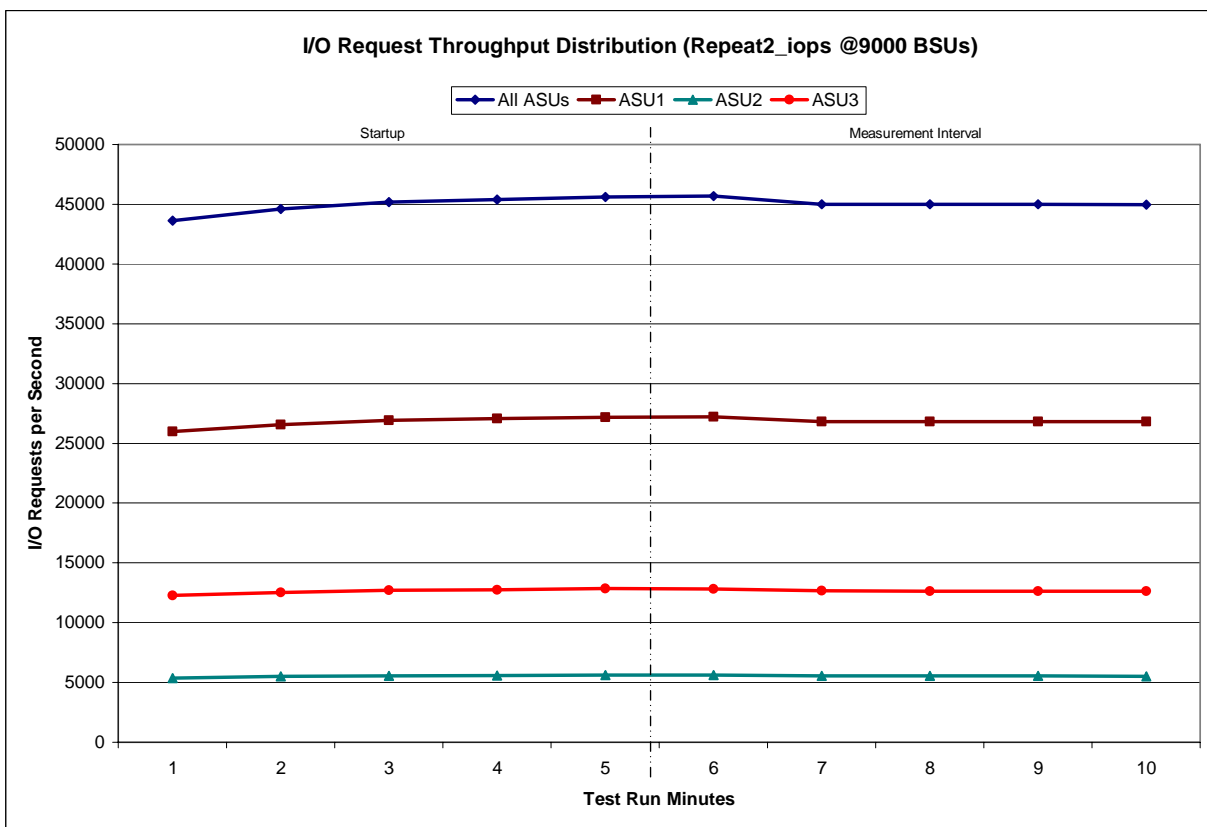
**Repeatability 2 LRT –Average Response Time (ms) Distribution Graph**



**Repeatability 2 IOPS - I/O Request Throughput Distribution Data**

9000 BSUs	Start	Stop	Interval	Duration
<i>Start-Up/Ramp-Up</i>	20:21:37	20:26:38	0-4	0:05:01
<i>Measurement Interval</i>	20:26:38	20:31:38	5-9	0:05:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	43,621.52	25,977.27	5,373.20	12,271.05
1	44,594.50	26,571.55	5,493.70	12,529.25
2	45,182.80	26,919.28	5,557.05	12,706.47
3	45,407.92	27,059.42	5,596.20	12,752.30
4	45,625.32	27,172.63	5,606.75	12,845.93
5	45,671.72	27,226.53	5,614.08	12,831.10
6	44,998.52	26,801.67	5,533.33	12,663.52
7	44,985.15	26,805.22	5,545.00	12,634.93
8	45,001.28	26,818.68	5,536.25	12,646.35
9	44,965.98	26,808.17	5,512.85	12,644.97
<b>Average</b>	<b>45,124.53</b>	<b>26,892.05</b>	<b>5,548.30</b>	<b>12,684.17</b>

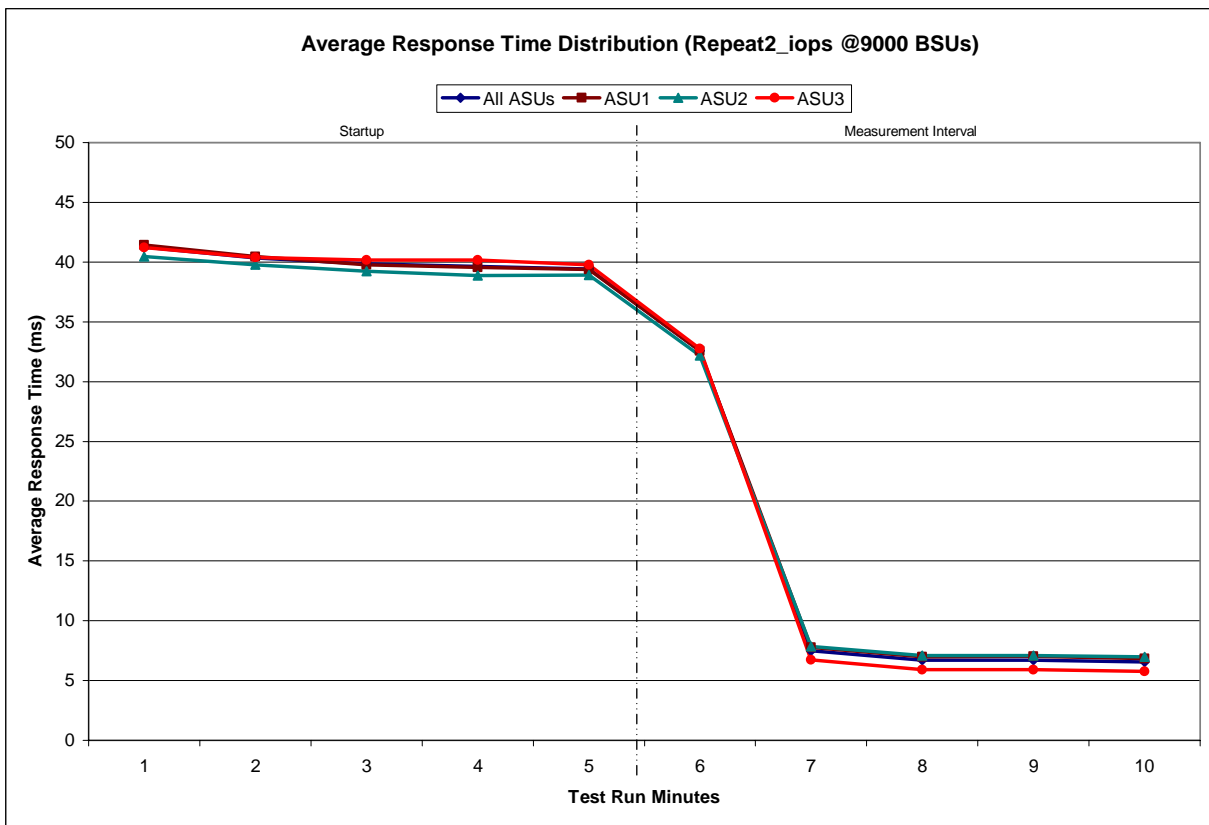
**Repeatability 2 IOPS - I/O Request Throughput Distribution Graph**



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

9000 BSUs	Start	Stop	Interval	Duration
<i>Start-Up/Ramp-Up</i>	20:21:37	20:26:38	0-4	0:05:01
<i>Measurement Interval</i>	20:26:38	20:31:38	5-9	0:05:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	41.25	41.44	40.46	41.20
1	40.36	40.47	39.77	40.39
2	39.83	39.79	39.22	40.18
3	39.64	39.55	38.89	40.16
4	39.43	39.38	38.92	39.77
5	32.58	32.58	32.18	32.76
6	7.49	7.78	7.85	6.72
7	6.71	7.00	7.11	5.91
8	6.71	7.00	7.11	5.91
9	6.56	6.85	6.98	5.76
<b>Average</b>	12.01	12.24	12.24	11.41

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



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

*Clause 3.4.3*

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

*Clauses 6.1.0*

*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).*

*Clause 6.3.13.3*

*COV – Coefficient of Variation: This measure of variation for the Measured Intensity Multiplier cannot exceed 0.5.*

	ASU1-1	ASU1-2	ASU1-3	ASU1-4	ASU2-1	ASU2-2	ASU2-3	ASU3-1
<b>IM</b>	<b>0.0350</b>	<b>0.2810</b>	<b>0.0700</b>	<b>0.2100</b>	<b>0.0180</b>	<b>0.0700</b>	<b>0.0350</b>	<b>0.2810</b>
MIM	0.0351	0.2811	0.0700	0.2101	0.0182	0.0699	0.0350	0.2806
COV	0.014	0.003	0.007	0.005	0.015	0.005	0.006	0.004

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

	ASU1-1	ASU1-2	ASU1-3	ASU1-4	ASU2-1	ASU2-2	ASU2-3	ASU3-1
<b>IM</b>	<b>0.0350</b>	<b>0.2810</b>	<b>0.0700</b>	<b>0.2100</b>	<b>0.0180</b>	<b>0.0700</b>	<b>0.0350</b>	<b>0.2810</b>
MIM	0.0349	0.2812	0.0700	0.2100	0.0180	0.0700	0.0350	0.2811
COV	0.004	0.001	0.003	0.001	0.004	0.002	0.003	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
<b>IM</b>	<b>0.0350</b>	<b>0.2810</b>	<b>0.0700</b>	<b>0.2100</b>	<b>0.0180</b>	<b>0.0700</b>	<b>0.0350</b>	<b>0.2810</b>
MIM	0.0353	0.2806	0.0701	0.2095	0.0180	0.0702	0.0351	0.2812
COV	0.011	0.002	0.008	0.004	0.011	0.002	0.012	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
<i>IM</i>	<i>0.0350</i>	<i>0.2810</i>	<i>0.0700</i>	<i>0.2100</i>	<i>0.0180</i>	<i>0.0700</i>	<i>0.0350</i>	<i>0.2810</i>
MIM	0.0350	0.2810	0.0700	0.2100	0.0180	0.0700	0.0350	0.2811
COV	0.002	0.000	0.003	0.001	0.005	0.002	0.003	0.001

## Data Persistence Test

### Clause 7

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

### Clause 10.4.8.5

*The FDR shall contain the following for the Data Persistence Test:*

1. *A listing of the SPC-1C Workload Generator commands and parameters used to execute each of the Test Runs in the Persistence Test.*
2. *The human readable SPC-1C Test Results File for each of the Test Runs in the Data Persistence Test.*
3. *A table from the successful Persistence Test, which contains the results from the test.*

## SPC-1C Workload Generator Input Parameters

The SPC-1C Workload Generator input parameters for the Sustainability, IOPS, Response Time Ramp, Repeatability, and Persistence Test Runs are documented in “Appendix E: SPC-1C Workload Generator Input Parameters” on Page 65.

## 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

<b>Data Persistence Test Results</b>	
Data Persistence Test Run Number: 1	
Total Number of Logical Blocks Written	107,768,016
Total Number of Logical Blocks Verified	53,516,688
Total Number of Logical Blocks that Failed Verification	0
Time Duration for Writing Test Logical Blocks	10 minutes
Size in Bytes of each Logical Block	512
Number of Failed I/O Requests in the process of the Test	0

In some cases the same address was the target of multiple writes, which resulted in more Logical Blocks Written than Logical Blocks Verified. In the case of multiple writes to the same address, the pattern written and verified must be associated with the last write to that address.

## **PRICED STORAGE CONFIGURATION AVAILABILITY DATE**

### **Clause 10.4.9**

*The committed delivery date for general availability (Availability Date) of all products that comprise the Priced Storage Configuration must be reported. When the Priced Storage Configuration includes products or components with different availability dates, the reported Availability Date must be the date at which all components are committed to be available. All availability dates, whether for individual components or for the Priced Storage Configuration as a whole, must be disclosed to a precision of one day.*

*The Availability Date shall be stated in the FDR by either a combination of specific alphanumeric month, numeric day, and numeric year or as "Currently Available" in the case where all components that comprise the Priced Storage Configuration are currently available for customer order and shipment.*

The IBM System Storage™ EXP 12S as documented in this Full Disclosure Report will become May 22, 2009 for customer purchase and shipment.

## **ANOMALIES OR IRREGULARITIES**

### **Clause 10.4.10**

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

There were no anomalies or irregularities encountered during the SPC-1C Onsite Audit of the IBM System Storage™ EXP 12S.



## **APPENDIX A: SPC-1C 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 gibibyte (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-1C Data Repository Definitions**

**Total ASU Capacity:** The total storage capacity read and written in the course of executing the SPC-1C benchmark.

**Application Storage Unit (ASU):** The logical interface between the storage and SPC-1C 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-1C 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-1C 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-1C Data Protection Levels

**Protected:** Data protection in the event of a single point of failure of any of the configured storage devices.

**Unprotected:** The Test Sponsor asserts no claim of data protection in the event of a single point of failure.

## SPC-1C 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-1C 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-1C 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-1C test result or support an SPC-1C 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.

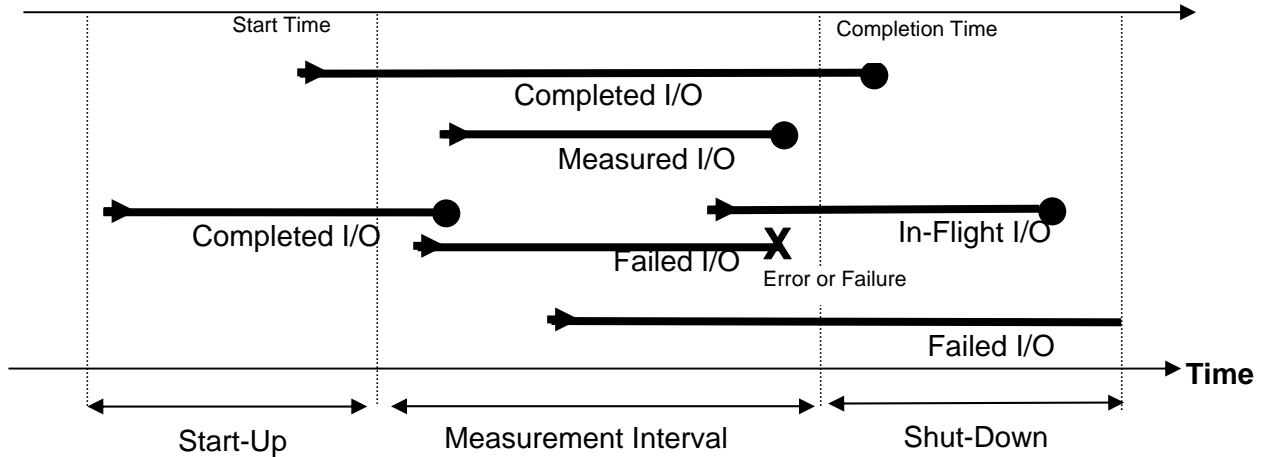
**Steady State:** The consistent and sustainable throughput of the TSC. During this period the load presented to the TSC by the Workload Generator is constant.

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

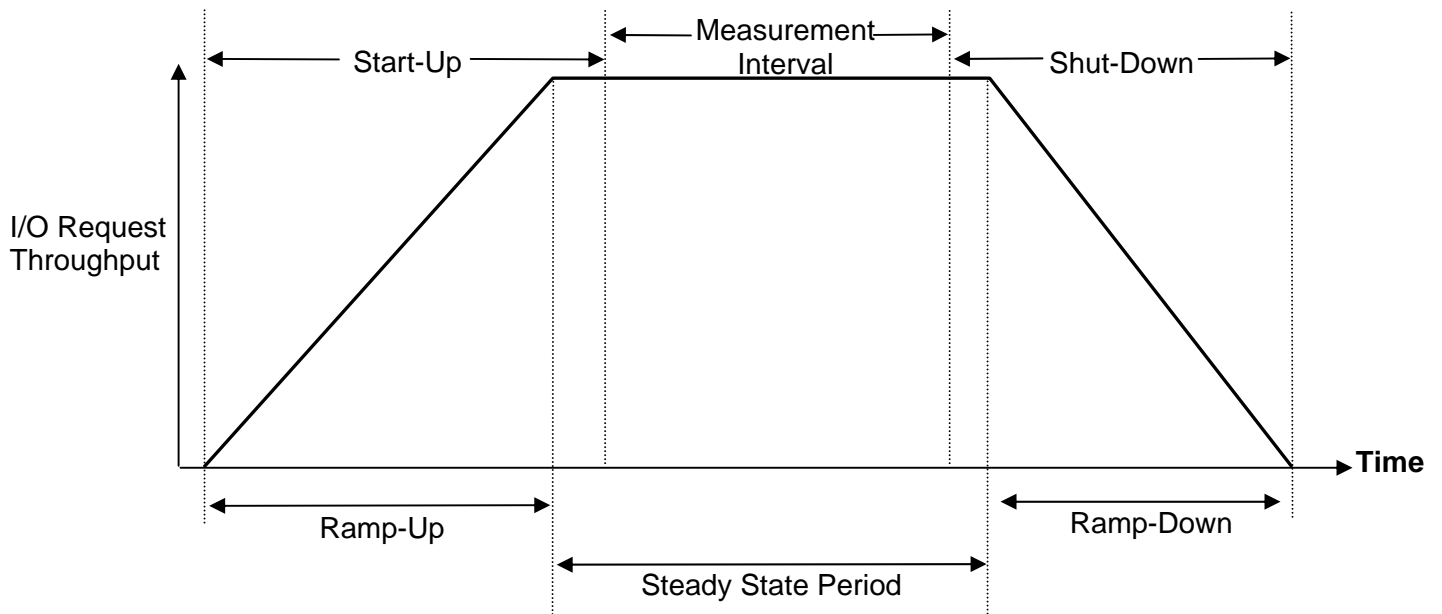
**Test Run:** The execution of SPC-1C for the purpose of producing or supporting an SPC-1C test result. SPC-1C Test Runs may have a finite and measured Ramp-Up period, Start-Up period, Shut-Down period, and Ramp-Down period as illustrated in the “SPC-1C Test Run Components” below. All SPC-1C Test Runs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

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

**I/O Completion Types**



**SPC-1C Test Run Components**



## **APPENDIX B: CUSTOMER TUNABLE PARAMETERS AND OPTIONS**

The queue depth for each SSD was changed from a default of 4 to 16 and the adapter cache function was turned off. Both of those changes are documented in “*Appendix C: Tested Storage Configuration (TSC) Creation*” on page 62.

## **APPENDIX C: TESTED STORAGE CONFIGURATION (TSC) CREATION**

### **Specify SSD Queue Depth**

A macro was defined, using AIX command, to specify queue depth per SSD in the SAS RAID adapter as follows:

- At the AIX prompt, type ***odmadd***, then enter the following:
  - Knorr:
  - PdAT:
    - **uniquetype** = "adapter/pci/1410c302"
    - **attribute** = "qdpth\_per\_pdisk"
    - **deflt** = "4"
    - **values** = "1-64,1"
    - **width** = ""
    - **type** = "R"
    - **generic** = "DU"
    - **rep** = "nr"
    - **nls\_index** = 0
  - Press ***Cntl-D***
  - Type ***-l sissasA -a qdpth\_per\_pdisk=16***, where ***A*** is the adapter number of the SAS RAID adapter.

### **Turn Off Adapter Cache Function**

At the AIX prompt, type the command ***sissasraidmgr -K 4 -l sissasA -o 1***, where ***A*** is the adapter number of the SAS RAID adapter.

### **Format the SSDs**

Format each SSD so it appears to AIX as a "RAID 0 SSD Array" (note: the array size is 1 SSD), as follows:

- At the AIX prompt, type ***smitty sasdam***
  - Select ***create an array candidate pdisk and format to 528 byte sectors***
  - Select ***sissasA***, where ***A*** is the adapter number of the SAS RAID adapter.
  - Select ***RAID-0***
  - Select ***256K***
- This results in a selection panel for selecting the individual SSDs.
- Select a single SSD and press ***Enter***.
- Repeat the selection of individual SSDs until all eight have been formatted.

## Create the Striped Logical Volume Group

At the AIX prompt, type ***stripethem.sh 40 256***. That command invokes the following script to form a striped logical volume group from the available SSDs, then defines logical volumes “thin1”, “thin2”,... “thin51” based upon the logical volume group.

### **stripethem.sh**

```
# makes striped volume group from available hdisks; makes vols with a specified
number of specified meg partitions.
# important: assumes MPIO, assumes no. of hdisks divides no. of partitions.
if [[ ($# -lt 2) ]]
then
    echo "usage: stripethem partitions psize. Partitions should be divisible by
hdisks"
    exit
fi
partspervol=$1
psize=$2

hfield=$(lsdev -Cc disk | grep 'RAID0 SSD' | awk '{print $1}')
mkvg -fy thinstripevg -S -s $psize $hfield

hnum=`echo $hfield | wc -w`
parts=`lsvg thinstripevg | grep "FREE PPs:" | awk '{print $6}'`
let numlv="parts / partspervol"
let usedparts="partspervol * numlv"
print "creating $numlv logical volumes"
print "these will use $usedparts out of $parts available partitions"
l=1
while [[ $l -le $numlv ]]
do
    mklv -b n -y thin$l -x 32512 -u $hnum -S 256K thinstripevg $partspervol
    l=$((l+1))
done
```

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

The content of SPC-1C Workload Generator command and parameter files, used in this benchmark, is listed below.

```
javaparms="-Xmx768m -Xss128k -Xgcpolicy:optavgpause"  
sd=default,size=10737418240  
sd=asu1_1,lun=/dev/rthin1  
sd=asu1_2,lun=/dev/rthin2  
sd=asu1_3,lun=/dev/rthin3  
sd=asu1_4,lun=/dev/rthin4  
sd=asu1_5,lun=/dev/rthin5  
sd=asu1_6,lun=/dev/rthin6  
sd=asu1_7,lun=/dev/rthin7  
sd=asu1_8,lun=/dev/rthin8  
sd=asu1_9,lun=/dev/rthin9  
sd=asu1_10,lun=/dev/rthin10  
sd=asu1_11,lun=/dev/rthin11  
sd=asu1_12,lun=/dev/rthin12  
sd=asu1_13,lun=/dev/rthin13  
sd=asu1_14,lun=/dev/rthin14  
sd=asu1_15,lun=/dev/rthin15  
sd=asu1_16,lun=/dev/rthin16  
sd=asu1_17,lun=/dev/rthin17  
sd=asu1_18,lun=/dev/rthin18  
sd=asu1_19,lun=/dev/rthin19  
sd=asu1_20,lun=/dev/rthin20  
sd=asu1_21,lun=/dev/rthin21  
sd=asu1_22,lun=/dev/rthin22  
sd=asu1_23,lun=/dev/rthin23  
sd=asu2_1,lun=/dev/rthin24  
sd=asu2_2,lun=/dev/rthin25  
sd=asu2_3,lun=/dev/rthin26  
sd=asu2_4,lun=/dev/rthin27  
sd=asu2_5,lun=/dev/rthin28  
sd=asu2_6,lun=/dev/rthin29  
sd=asu2_7,lun=/dev/rthin30  
sd=asu2_8,lun=/dev/rthin31  
sd=asu2_9,lun=/dev/rthin32  
sd=asu2_10,lun=/dev/rthin33  
sd=asu2_11,lun=/dev/rthin34  
sd=asu2_12,lun=/dev/rthin35  
sd=asu2_13,lun=/dev/rthin36  
sd=asu2_14,lun=/dev/rthin37  
sd=asu2_15,lun=/dev/rthin38  
sd=asu2_16,lun=/dev/rthin39  
sd=asu2_17,lun=/dev/rthin40  
sd=asu2_18,lun=/dev/rthin41  
sd=asu2_19,lun=/dev/rthin42  
sd=asu2_20,lun=/dev/rthin43  
sd=asu2_21,lun=/dev/rthin44  
sd=asu2_22,lun=/dev/rthin45  
sd=asu2_23,lun=/dev/rthin46  
sd=asu3_1,lun=/dev/rthin47  
sd=asu3_2,lun=/dev/rthin48  
sd=asu3_3,lun=/dev/rthin49  
sd=asu3_4,lun=/dev/rthin50  
sd=asu3_5,lun=/dev/rthin51
```



## **APPENDIX E: SPC-1C WORKLOAD GENERATOR INPUT PARAMETERS**

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

The following script was used to execute the Idle Test (*Conditioning Phase, Application Idle Phase, and Recovery Phase*) Primary Metrics Test (*Sustainability Test Phase, IOPS Test Phase, and Response Time Ramp Test Phase*), Repeatability Test (*Repeatability Test Phase 1 and Repeatability Test Phase 2*), and Persistence Test Run 1 in an uninterrupted sequence.

```
export PATH=$PATH:/usr/java5/bin
export SPC1CHOME=/home/spc1cinstall
export CLASSPATH=$SPC1CHOME
export LIBPATH=$SPC1CHOME/aix
export IBM_JAVADUMP_OUTOFMEMORY=false
export IBM_HEAPDUMP_OUTOFMEMORY=false
rm -fr rangetest 2> /dev/null
rm -fr range_cndn 2> /dev/null
rm -fr range_rcvr 2> /dev/null
rm -fr metrics 2> /dev/null
rm -fr SPCOut 2> /dev/null
rm -fr repeatability1 2> /dev/null
rm -fr repeatability2 2> /dev/null
rm -fr persistencel 2> /dev/null
mkdir range_cndn
mkdir range_rcvr
java -Xoptionsfile=javaopts.cfg range -b 9000 -t 420
mv rangetest/* range_cndn
echo "Beginning idle test (note temperature)..."
sleep 2160
java -Xoptionsfile=javaopts.cfg range -b 900 -t 420
mv rangetest/* range_rcvr
java -Xoptionsfile=javaopts.cfg metrics -b 9000 -t 3600 -r 300 -s 300
echo "End of metrics test (note temperature)..."
java -Xoptionsfile=javaopts.cfg repeat1 -b 9000 -t 300 -s 300
java -Xoptionsfile=javaopts.cfg repeat2 -b 9000 -t 300 -s 300
echo "Run ended"
java -Xoptionsfile=javaoptsp.cfg persist1 -b 9000
```

### **Persistence Test Run 2**

The following script was used to execute Persistence Test Run 2 after the above execution sequence and the required power-off cycle, which followed successful completion of Persistence Test Run 1.

```
export PATH=$PATH:/usr/java5/bin
export SPC1CHOME=/home/spc1cinstall
export CLASSPATH=$SPC1CHOME
export LIBPATH=$SPC1CHOME/aix
export IBM_JAVADUMP_OUTOFMEMORY=false
export IBM_HEAPDUMP_OUTOFMEMORY=false
rm -fr persistence2 2> /dev/null
java -Xoptionsfile=javaoptsp.cfg persist2
```