



**SPC BENCHMARK 1™  
FULL DISCLOSURE REPORT**

**IBM CORPORATION  
IBM TOTALSTORAGE DS4300 WITH TURBO OPTION  
(NON-MIRRORED WRITE CACHE)**

**SPC-1 V1.7**

**Submitted for Review: August 26, 2003**

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**First Edition – August 2003**

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**Notes**

The following terms, used in this document, are defined as:

- Kilobyte (KB) is equal to 1,000 ( $10^3$ ) bytes.
- Megabyte (MB) is equal to 1,000,000 ( $10^6$ ) bytes.
- Gigabyte (GB) is equal to 1,000,000,000 ( $10^9$ ) bytes.
- Terabyte (TB) is equal to 1,000,000,000,000 ( $10^{12}$ ) bytes.

## Table of Contents

|   |            |
|---|------------|
| <b>Audit Certification.....</b>   | <b>vii</b> |
| <b>Letter of Good Faith .....</b>   | <b>ix</b>  |
| <b>Executive Summary.....</b>   | <b>10</b>  |
| <b>Test Sponsor and Contact Information.....</b>  | <b>10</b>  |
| <b>Revision Information and Key Dates .....</b>   | <b>10</b>  |
| <b>Summary of Results .....</b>   | <b>11</b>  |
| <b>Response Time - Throughput Curve .....</b>   | <b>12</b>  |
| <b>Response Time - Throughput Data.....</b>   | <b>12</b>  |
| <b>Tested Storage Configuration Pricing (<i>Priced Storage Configuration</i>) .....</b>                 | <b>13</b>  |
| <b>Differences between the Tested Storage Configuration (TSC) and Priced Storage Configuration.....</b> | <b>13</b>  |
| <b>Benchmark Configuration/Tested Storage Configuration Diagram.....</b>                                | <b>14</b>  |
| <b>Configuration Information .....</b>  | <b>15</b>  |
| <b>Benchmark Configuration (BC)/Tested Storage Configuration (TSC) Diagram.....</b>                     | <b>15</b>  |
| <b>Storage Network Configuration .....</b>  | <b>15</b>  |
| <b>Host System Configuration.....</b>   | <b>16</b>  |
| <b>Customer Tuning Parameters and Options .....</b>   | <b>16</b>  |
| Windows 2000 Registry Changes .....   | 16         |
| Array Controller Options.....   | 16         |
| Host Bus Adapter Options.....   | 17         |
| <b>Tested Storage Configuration (TSC) Description .....</b>   | <b>18</b>  |
| <b>SPC-1 Workload Generator Storage Configuration.....</b>  | <b>18</b>  |
| <b>Data Repository.....</b>   | <b>19</b>  |
| <b>Definitions.....</b>   | <b>19</b>  |
| <b>Storage Capacities and Relationships .....</b>   | <b>20</b>  |
| SPC-1 Storage Capacities .....  | 20         |
| SPC-1 Storage Capacities and Relationships Illustration.....  | 20         |
| SPC-1 Storage Hierarchy Ratios .....  | 21         |
| <b>Logical Volume Capacity and ASU Mapping.....</b>   | <b>21</b>  |
| <b>SPC-1 Benchmark Execution Results.....</b>   | <b>22</b>  |
| <b>Definitions.....</b>   | <b>22</b>  |
| <b>Sustainability Test Phase.....</b>   | <b>22</b>  |
| SPC-1 Workload Generator Input Parameters .....   | 23         |
| Sustainability Test Results File.....   | 23         |

|   |           |
|---|-----------|
| Sustainability – Data Rate Distribution Data ( <i>MB/second</i> ).....              | 24        |
| Sustainability – Data Rate Distribution Graph .....                                 | 25        |
| Sustainability – I/O Request Throughput Distribution Data.....                      | 25        |
| Sustainability – I/O Request Throughput Distribution Data.....                      | 26        |
| Sustainability – I/O Request Throughput Distribution Graph .....                    | 27        |
| Sustainability – Measured Intensity Multiplier and Coefficient of Variation.....    | 27        |
| <b>IOPS Test Phase .....</b>  | <b>28</b> |
| SPC-1 Workload Generator Input Parameters .....                                     | 28        |
| IOPS Test Results File.....   | 28        |
| IOPS Test Run – I/O Request Throughput Distribution Data .....                      | 29        |
| IOPS Test Run – I/O Request Throughput Distribution Graph.....                      | 29        |
| IOPS Test Run – I/O Request Throughput Distribution Graph.....                      | 30        |
| IOPS Test Run – Response Time Frequency Distribution Data .....                     | 30        |
| IOPS Test Run – Response Time Frequency Distribution Data .....                     | 31        |
| IOPS Test Run –Response Time Frequency Distribution Graph.....                      | 31        |
| IOPS Test Run –Response Time Frequency Distribution Graph.....                      | 32        |
| IOPS Test Run – Average Response Time (ms) Distribution Data.....                   | 32        |
| IOPS Test Run – Average Response Time (ms) Distribution Data.....                   | 33        |
| IOPS Test Run – Average Response Time (ms) Distribution Graph .....                 | 34        |
| IOPS Test Run – I/O Request Information.....  | 34        |
| IOPS Test Run – I/O Request Information.....  | 35        |
| IOPS Test Run – Measured Intensity Multiplier and Coefficient of Variation.....     | 35        |
| <b>Response Time Ramp Test Phase .....</b>  | <b>36</b> |
| SPC-1 Workload Generator Input Parameters .....                                     | 36        |
| Response Time Ramp Test Results File.....   | 36        |
| Response Time Ramp Distribution (IOPS) Data.....                                    | 37        |
| Response Time Ramp Distribution (IOPS) Data (Continued) .....                       | 38        |
| Response Time Ramp Distribution (IOPS) Graph .....                                  | 39        |
| SPC-1 LRT™ Average Response Time (ms) Distribution Data.....                        | 39        |
| SPC-1 LRT™ Average Response Time (ms) Distribution Data.....                        | 40        |
| SPC-1 LRT™ Average Response Time (ms) Distribution Graph .....                      | 40        |
| SPC-1 LRT™ Average Response Time (ms) Distribution Graph .....                      | 41        |
| SPC-1 LRT™ (10%) – Measured Intensity Multiplier and Coefficient of Variation ..... | 42        |
| <b>Repeatability Test .....</b>   | <b>43</b> |
| SPC-1 Workload Generator Input Parameters .....                                     | 43        |
| Repeatability Test Results File .....   | 43        |
| Repeatability 1 LRT – I/O Request Throughput Distribution Data.....                 | 45        |
| Repeatability 1 LRT – I/O Request Throughput Distribution Graph .....               | 45        |
| Repeatability 1 LRT – I/O Request Throughput Distribution Graph .....               | 46        |

|  |           |
|--|-----------|
| Repeatability 1 LRT –Average Response Time (ms) Distribution Data .....                | 46        |
| Repeatability 1 LRT –Average Response Time (ms) Distribution Data .....                | 47        |
| Repeatability 1 LRT –Average Response Time (ms) Distribution Graph.....                | 47        |
| Repeatability 1 LRT –Average Response Time (ms) Distribution Graph.....                | 48        |
| Repeatability 1 IOPS – I/O Request Throughput Distribution Data .....                  | 48        |
| Repeatability 1 IOPS – I/O Request Throughput Distribution Data .....                  | 49        |
| Repeatability 1 IOPS – I/O Request Throughput Distribution Graph.....                  | 49        |
| Repeatability 1 IOPS – I/O Request Throughput Distribution Graph.....                  | 50        |
| Repeatability 1 IOPS –Average Response Time (ms) Distribution Data.....                | 50        |
| Repeatability 1 IOPS –Average Response Time (ms) Distribution Data.....                | 51        |
| Repeatability 1 IOPS –Average Response Time (ms) Distribution Graph .....              | 51        |
| Repeatability 1 IOPS –Average Response Time (ms) Distribution Graph .....              | 52        |
| Repeatability 2 LRT – I/O Request Throughput Distribution Data.....                    | 52        |
| Repeatability 2 LRT – I/O Request Throughput Distribution Data.....                    | 53        |
| Repeatability 2 LRT – I/O Request Throughput Distribution Graph .....                  | 53        |
| Repeatability 2 LRT – I/O Request Throughput Distribution Graph .....                  | 54        |
| Repeatability 2 LRT –Average Response Time (ms) Distribution Data .....                | 54        |
| Repeatability 2 LRT –Average Response Time (ms) Distribution Data .....                | 55        |
| Repeatability 2 LRT –Average Response Time (ms) Distribution Graph.....                | 55        |
| Repeatability 2 LRT –Average Response Time (ms) Distribution Graph.....                | 56        |
| Repeatability 2 IOPS – I/O Request Throughput Distribution Data .....                  | 56        |
| Repeatability 2 IOPS – I/O Request Throughput Distribution Data .....                  | 57        |
| Repeatability 2 IOPS – I/O Request Throughput Distribution Graph.....                  | 57        |
| Repeatability 2 IOPS – I/O Request Throughput Distribution Graph.....                  | 58        |
| Repeatability 2 IOPS – Average Response Time (ms) Distribution Data.....               | 58        |
| Repeatability 2 IOPS – Average Response Time (ms) Distribution Data.....               | 59        |
| Repeatability 2 IOPS – Average Response Time (ms) Distribution Graph .....             | 59        |
| Repeatability 2 IOPS – Average Response Time (ms) Distribution Graph .....             | 60        |
| Repeatability 1 (LRT) Measured Intensity Multiplier and Coefficient of Variation ..... | 60        |
| Repeatability 1 (LRT) Measured Intensity Multiplier and Coefficient of Variation ..... | 61        |
| Repeatability 1 (IOPS) Measured Intensity Multiplier and Coefficient of Variation .... | 61        |
| Repeatability 2 (LRT) Measured Intensity Multiplier and Coefficient of Variation ..... | 61        |
| Repeatability 2 (IOPS) Measured Intensity Multiplier and Coefficient of Variation .... | 61        |
| <b>Data Persistence Test.....</b>  | <b>62</b> |
| SPC-1 Workload Generator Input Parameters .....  | 62        |
| Data Persistence Test Results File .....   | 62        |
| Data Persistence Test Results.....   | 63        |
| <b>Tested Storage Configuration (TSC) Availability Date .....</b>                      | <b>64</b> |

**Pricing Information..... 64**  
**Anomalies or Irregularities ..... 64**  
**Appendix A: TSC Configuration Script..... 65**

**AUDIT CERTIFICATION**

IBM Corporation  
 Bruce McNutt  
 KBV/9062-2  
 9000 S. Rita Road  
 Tucson, AZ 85744

August 26, 2003

The SPC Benchmark 1™ results listed below for the IBM TotalStorage® FAStT600 with Turbo Option (*non-mirrored write cache*) were produced in compliance with the SPC Benchmark 1™ V1.7 Remote Audit requirements.

| SPC Benchmark 1™ V1.7 Results  |                    |
|--|--------------------|
| Tested Storage Configuration (TSC) Name:<br>IBM TotalStorage® FAStT600 with Turbo Option ( <i>non-mirrored write cache</i> ) |                    |
| Metric   | Reported Result    |
| SPC-1 IOPS™  | 12,102.97          |
| SPC-1 Price-Performance  | \$9.28/SPC-1 IOPS™ |
| Total ASU Capacity   | 478.43 GB          |
| Data Protection Level  | Mirroring          |
| SPC-1 LRT™   | 2.07 ms            |
| Total TSC Price (including three-year maintenance)   | \$112,360          |

The following SPC Benchmark 1™ Remote Audit requirements were reviewed and found compliant with V1.7 of the SPC Benchmark 1™ specification:

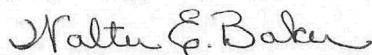
- A Letter of Good Faith, signed by a senior executive.
- The following Data Repository storage items were verified using information supplied by IBM Corporation:
  - ✓ Physical Storage Capacity and requirements.
  - ✓ Configured Storage Capacity and requirements.
  - ✓ Addressable Storage Capacity and requirements.
  - ✓ Capacity of each Logical Volume and requirements.
  - ✓ Capacity of each Application Storage Unit (ASU) and requirements.

- An appropriate diagram of the Benchmark Configuration (BC)/Tested Storage Configuration (TSC).
- Listings and commands to configure the Benchmark Configuration/Tested Storage Configuration, included customer tunable parameters.
- Commands and parameters used to configure the SPC-1 Workload Generator.
- The following Host System requirements were reviewed using documentation supplied by IBM Corporation:
  - ✓ The type of Host System including the number of processors and main memory.
  - ✓ The presence and version number of the Workload Generator on the Host System.
  - ✓ The TSC boundary within the Host System.
- The Test Results Files and resultant Summary Results Files received for each of following were authentic, accurate, and compliant with all of the requirements and constraints of Clauses 4 and 5 of the SPC-1 Benchmark Specification:
  - ✓ Data Persistence Test
  - ✓ Sustainability Test Phase
  - ✓ IOPS Test Phase
  - ✓ Response Time Ramp Test Phase
  - ✓ Repeatability Test
- The differences between the Tested Storage Configuration (TSC) used for the benchmark and Priced Storage Configuration are documented in the Executive Summary. The differences, if applied to the TSC, would not have a negative impact on the reported SPC-1 performance.
- The final version of the pricing spreadsheet 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.

**Audit Notes:**

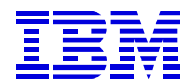
There were no additional audit notes or exceptions.

Respectfully,



Walter E. Baker  
SPC Auditor



**LETTER OF GOOD FAITH**

---

*P.O. Box 12195  
Research Triangle Park, NC 27709*

Date: *26 Aug 2003*

From: *IBM Corporation, Test Sponsor*

Submitted by:

*J.R. Hagan, Jr.  
VP, Storage Systems  
3039 Cornwallis  
RTP, NC 27709*

Contact Information:

*John Ponder / Bruce McNutt  
KBV/9062-2  
IBM Corporation  
9000 S. Rita Road  
Tucson, AZ 85744*

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

Subject: Letter of good faith for the SPC Benchmark-1™ results on the IBM TotalStorage® FAStT600 with Turbo Option (with cache mirroring disabled).

IBM sponsored testing of the above listed product in compliance with the SPC-Benchmark-1 Specification. To the best of our knowledge and belief, the associated test results, including the SPC-1 Full Disclosure Report documenting the SPC Benchmark-1 results (per Clause 10 of the SPC Benchmark-1 Specification), are accurate.

Signed:

A handwritten signature in black ink that reads "Roland Hagan".

---

J.R. Hagan, Jr.  
Vice President, Storage Systems  
26 Aug 2003

**EXECUTIVE SUMMARY****Test Sponsor and Contact Information**

| Test Sponsor and Contact Information      |  |
|---|--|
| <b>Test Sponsor<br/>Primary Contact</b>   | IBM Corporation. – <a href="http://www.ibm.com">www.ibm.com</a><br>John Ponder <a href="mailto:ponder@us.ibm.com">ponder@us.ibm.com</a><br>KBV/9062-2<br>9000 South Rita Road<br>Tucson, AZ 85744<br>Phone: (520) 799-4388<br>FAX: (520) 799-5530  |
| <b>Test Sponsor<br/>Alternate Contact</b> | IBM Corporation – <a href="http://www.ibm.com">www.ibm.com</a><br>Bruce McNutt <a href="mailto:bmcnutt@us.ibm.com">bmcnutt@us.ibm.com</a><br>KBV/9062-2<br>9000 South Rita Road<br>Tucson, AZ 85744<br>Phone: (520) 799-2460<br>FAX: (520) 799-5530  |
| <b>Auditor</b>                            | Storage Performance Council – <a href="http://www.storageperformance.org">www.storageperformance.org</a><br>Walter E. Baker <a href="mailto:AuditService@storageperformance.org">AuditService@storageperformance.org</a><br>643 Bair Island Road, Suite 103<br>Redwood City, CA 94063-2755<br>Phone: (650) 556-9384<br>FAX: (650) 556-9385 |

**Revision Information and Key Dates**

| Revision Information and Key Dates  |                                     |
|---|-------------------------------------|
| <b>SPC-1 Specification revision number</b>  | V1.7                                |
| <b>SPC-1 Workload Generator revision number</b>   | V2.00.03                            |
| <b>Date Results were first used publicly</b>  | August 26, 2003                     |
| <b>Date FDR was submitted to the SPC</b>  | August 26, 2003                     |
| <b>Date revised FDR was submitted to the SPC</b><br>Product name change from FASt600 to DS4300<br>Pricing was revised to include the price of the Turbo option. | September 5, 2006<br>April 15, 2004 |
| <b>Date the TSC is/was available for shipment to customers</b>  | September 12, 2003                  |
| <b>Date the TSC completed audit certification</b>   | August 26, 2003                     |

## Summary of Results

| SPC-1 Results  |                     |
|--|---------------------|
| Tested Storage Configuration (TSC) Name: IBM TotalStorage DS4300 with Turbo Option<br>(non-mirrored write cache) |                     |
| Metric   | Reported Result     |
| SPC-1 IOPS™  | 12,102.97           |
| SPC-1 Price-Performance  | \$11.07/SPC-1 IOPS™ |
| Total ASU Capacity   | 478.43GB            |
| Data Protection Level  | Mirroring           |
| SPC-1 LRT™   | 2.07ms              |
| Total TSC Price (including three-year maintenance)   | \$133,930           |

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

**Total ASU (Application Storage Unit) Capacity** represents the total storage capacity read and written in the course of executing the SPC-1 benchmark. The Addressable Storage Capacity, which contains the Total ASU Capacity, was 478.43 GB. The Total ASU Capacity utilized 100% of the Addressable Storage Capacity. The actual Configured Storage Capacity was 956.87 GB, which included the multiple copies of user data required by a Data Protection Level of Mirroring. The Configured Storage Capacity utilized 48.65% of the priced Physical Storage Capacity of 1,966.68 GB.

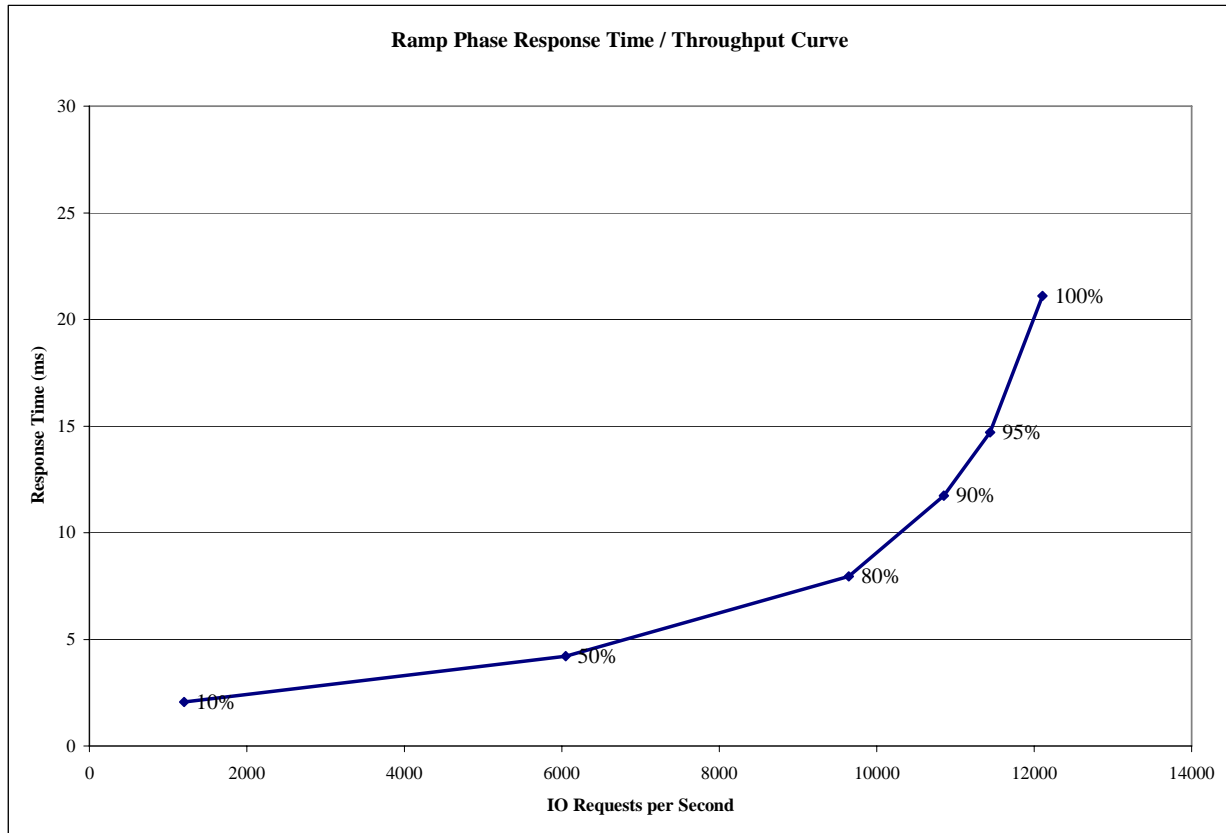
A **Data Protection Level** of Mirroring configures two or more identical copies of user data, maintained on separate disks.

The **SPC-1 LRT™** metric is the Average Response Time measured at the 10% load point, as illustrated on the next page. SPC-1 LRT™ represents the Average Response Time measured on a lightly loaded Tested Storage Configuration (TSC).

### 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 the 100% load point 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>      | 1201.04  | 6049.86  | 9643.46  | 10852.05 | 11440.44 | 12102.97  |
| <b>Average Response Time (ms):</b> |          |          |          |          |          |           |
| All ASUs                           | 2.07     | 4.21     | 7.96     | 11.74    | 14.70    | 21.09     |
| ASU-1                              | 2.77     | 5.54     | 10.67    | 16.39    | 20.78    | 30.49     |
| ASU-2                              | 2.25     | 4.63     | 7.12     | 8.22     | 9.19     | 10.82     |
| ASU-3                              | 0.53     | 1.21     | 2.59     | 3.39     | 4.25     | 5.65      |
| Reads                              | 4.48     | 8.82     | 15.10    | 21.04    | 25.46    | 35.20     |
| Writes                             | 0.51     | 1.21     | 3.32     | 5.68     | 7.70     | 11.90     |

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

| M/T/M    | fc#  | description  | Qty | US List Prices |                 | Total      |
|----------|------|--|-----|----------------|-----------------|------------|
|          |      |  |     | Unit Price     | Aggregate Price |            |
| 1722-60U |      | IBM TotalStorage FAStT600 Storage Server             | 1   | 14,999         | 14,999          |            |
|          | 2000 | FAStT600 Turbo feature                               | 1   | 21,570         | 21,570          |            |
|          | 2104 | FAStT FC-2/133 host bus adapter                      | 4   | 1,485          | 5,940           |            |
|          | 2210 | Shortwave SFP  | 6   | 499            | 2,994           |            |
|          | 5625 | 25 meter fiber optic cable                           | 4   | 189            | 756             |            |
|          | 7109 | FAStT Storage Manager v8.4 upgrade                   | 1   | 2,999          | 2,999           |            |
| 1740-1RU |      | IBM TotalStorage FAStT EXP700 Storage Expansion Unit | 3   | 6,000          | 18,000          |            |
|          | 2210 | Shortwave SFP  | 12  | 499            | 5,988           |            |
|          | 5211 | FAStT 36.4GB/15K rpm 2Gb FC Disk Drive Module        | 54  | 1,115          | 60,210          |            |
|          | 5601 | 1 meter fiber optic cable                            | 6   | 79             | 474             |            |
|          | 9006 | Attach to FAStT600                                   | 8   | 0              | 0               |            |
|          |      |  |     |                |                 | \$ 133,930 |

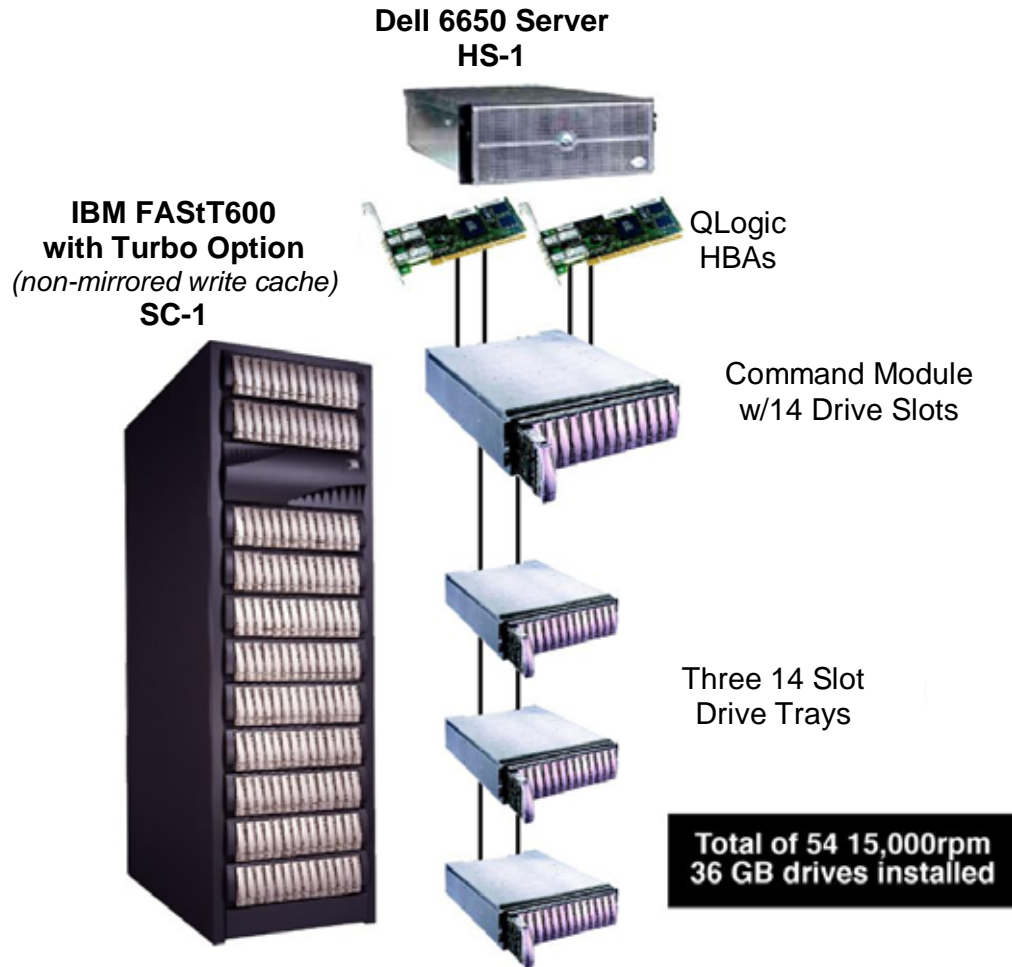
## Differences between the Tested Storage Configuration (TSC) and Priced Storage Configuration

The following are the differences between the TSC and Priced Storage Configuration:

- Four FAStT FC-2/133 HBAs (single port) were priced rather than the two QLogic 2342 dual channel HBAs used in the TSC.
- The priced disk drives have been configured to self-identify as a FAStT brand.
- The mounting of each drive is in an IBM drive carrier.
- The 'data scrubbing' option has a default setting of "off" in the TSC, but would need to be explicitly set to "off" in the Priced Storage Configuration.
- Twenty-five meter fiber optic cables were priced rather than the 30 meter cables used in the TSC.

The differences listed above, if applied to the TSC, would not have a negative performance impact on the reported SPC-1 performance.

**Benchmark Configuration/Tested Storage Configuration Diagram**



| Host System:  | Tested Storage Configuration (TSC):                       |
|---|---|
| UID=HS-   | UID=SC-1  |
| 1Dell 6650  | Command Module  |
| 4 – Pentium 4 Xeon 2GHz with Hyperthreading Enabled | 2 – Qlogic 2342 dual-port fibre channel host bus adapters |
| 3GB Main Memory                                     | 2 – Disk Array Controllers, 1GB RAM Each                  |
| Windows 2003, Service Pack 3                        | 4 – 2gb Fibre Channel host connections                    |
| WG  | 2 – 2gb Fibre Channel drive connections                   |
|   | 3 – Drive Modules   |
|   | 54 – 36GB 15K RPM Disk Drives                             |

## **CONFIGURATION INFORMATION**

### **Benchmark Configuration (BC)/Tested Storage Configuration (TSC) Diagram**

#### *Clause 9.2.4.4.1*

*A one page Benchmark Configuration (BC)/Tested Storage Configuration (TSC) diagram shall be included in the Executive Summary...*

A diagram of the benchmark configuration and tested storage configuration is included on the preceding page. The configuration consists of a single host system, with two Qlogic 2342 PCI to dual-channel 2gb fibre channel host adapters. The four host system, fibre channel connections are directly connected to the LSI command module. The host system is running Windows 2000, with Service Pack 3 applied.

### **Storage Network Configuration**

#### *Clause 9.2.4.4.2*

*If a storage network is employed in the BC/TSC, the FDR shall contain a topology diagram... . This diagram should include, but is not limited to the following components:*

- 1. Storage Controller and Domain Controllers (see Clause 9.2.4.4.1)*
- 2. Host Systems (see Clause 9.2.4.4.1)*
- 3. Routers and Bridges*
- 4. Hubs and Switches*
- 5. HBAs to Host Systems and Front End Port to Storage Controllers*

*Additionally the diagram shall:*

- Illustrate the physical connection between components.*
- Describe the type of each physical connection.*
- Describe the network protocol used over each physical connection.*
- The maximum theoretical transfer rate of each class of interconnect used in the configuration.*
- Correlate with the BC Configuration Diagram in Clause 9.2.4.4.1.*

*The Test Sponsor shall additionally supply (referenced in an appendix) a wiring diagram of the physical connections and physical port assignments used in the storage network. The diagram should allow anyone to exactly replicate the physical configuration of the storage network.*

A storage area network was not used for this test.

## Host System Configuration

### Clause 9.2.4.4.3

*The FDR shall minimally contain, for each Host System running the Workload Generator, a listing of the following:*

- 1. Number and type of CPUs.*
- 2. Main memory capacity.*
- 3. Cache memory capacity.*
- 4. Number and type of disk controllers or Host Bus Adapters.*

The details of the Host System configuration may be found on 14 (*Benchmark Configuration/ Tested Storage Configuration Diagram*).

## Customer Tuning Parameters and Options

### Clause 9.2.4.5.1

*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.*

## Windows 2000 Registry Changes

HKEY\_LOCAL\_MACHINE\SYSTEM\CurrentControlSet\Services\ql2300\Device\MaximumSGList=0xff

HKEY\_LOCAL\_MACHINE\SYSTEM\CurrentControlSet\Services\ql2300\Device\NumberOfRequests=0xe0

HKEY\_LOCAL\_MACHINE\SYSTEM\CurrentControlSet\Services\Disk\TimeOutValue=0x78

HKEY\_LOCAL\_MACHINE\SYSTEM\CurrentControlSet\Services\ql2300\Device\DriverParameters=UseSameNN=1;BusChange=0;

## Array Controller Options

All array controller configuration options were set by the configuration script list in “Appendix A: TSC Configuration Script” on page 65.



## Host Bus Adapter Options

The table below lists the Host Bus Adapter options that were changed from their default values.

| Host Bus Adapter Settings         |          |           |
|-----------------------------------|----------|-----------|
| Item                              | Default  | New Value |
| <b>Host Adapter Settings</b>      |          |           |
| Loop Reset Delay                  | 5        | 8         |
| Adapter Hard Loop ID              | Disabled | Enabled   |
| Hard Loop ID (unique for each)    | 0        | Eg. 22    |
| <b>Advanced Adapter Settings</b>  |          |           |
| Execution Throttle                | 16       | 255       |
| Fast Command Posting              | Disabled | Enabled   |
| LUNs per Target                   | 8        | 0         |
| Enable Target Reset               | No       | Yes       |
| Login Retry Count                 | 8        | 30        |
| Port Down Retry Count             | 8        | 70        |
| <b>Extended Firmware Settings</b> |          |           |
| Data Rate                         | 0        | 2         |

## Tested Storage Configuration (TSC) Description

### Clause 9.2.4.5.2

*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 Benchmark Configuration (BC) diagram in Clause 9.2.4.4.1 and, if applicable, 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.*

*In addition the FDR may include listings of scripts and/or commands used to configure the physical components that comprise the TSC.*

The TSC was configured as detailed in the “Benchmark Configuration/Tested Storage Configuration Diagram” on page 14 of this document. Each one of the host adapters was directly connected to a host port on the storage array command module. The disk drives were equally divided among the drive-side fibre channel connections of the storage array command module.

The configuration of the TSC was performed using a script, which is located in “Appendix A: TSC Configuration Script” on page 65. The LUNs created by the script comprise the reported Configured Storage Capacity, which contains both the Addressable Storage Capacity and a mirror of the Addressable Storage Capacity.

## SPC-1 Workload Generator Storage Configuration

### Clause 9.2.4.5.3

*The FDR must include all SPC-1 Workload Generator storage configuration commands and parameters.*

The following SPC-1 Workload Generator storage configuration commands and parameters were used:

```
javaparms="-Xmx64m -Xms64m"  
sd=asu1_1,lun=\\.\PhysicalDrive1,size=215296770048  
sd=asu2_1,lun=\\.\PhysicalDrive2,size=215296770048  
sd=asu3_1,lun=\\.\PhysicalDrive3,size=47843726677
```

## **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).

**User Data Copy:** An identical copy of user data maintained on separate disks.

**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.

### Storage Capacities and Relationships

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

#### SPC-1 Storage Capacities

| SPC-1 Storage Capacities                 |                |          |
|--|----------------|----------|
| Storage Hierarchy Component              | Units          | Capacity |
| Total ASU Capacity                       | Gigabytes (GB) | 478.43   |
| Addressable Storage Capacity             | Gigabytes (GB) | 478.43   |
| Configured Storage Capacity              | Gigabytes (GB) | 956.87   |
| Physical Storage Capacity                | Gigabytes (GB) | 1,966.68 |
| User Data Copy (Mirroring)               | Gigabytes (GB) | 478.43   |
| Required Storage (metadata) & Hot Spares | Gigabytes (GB) | 0.00     |
| Global Storage Overhead                  | Gigabytes (GB) | 28.99    |
| Total Unused Storage                     | Gigabytes (GB) | 980.81   |

The Physical Storage Capacity consisted of 54 disk drives with a formatted capacity of 36.420GB each. Each disk drive had 0.536GB reserved by the disk array management firmware, for a total of 28.99GB of Global Storage Overhead. The Total Unused Storage capacity was 980.81GB.

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

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

|                                  |                   |                                |  |                            |                            |
|----------------------------------|-------------------|--------------------------------|--|----------------------------|----------------------------|
| Physical Capacity<br>1,966.68 GB |                   |                                |  |                            |                            |
| Configured Capacity<br>956.87GB  |                   |                                |  | Unused Storage<br>980.81GB | Global Overhead<br>28.99GB |
| Addressable Capacity<br>478.43GB |                   | Addressable Mirror<br>478.43GB |  |                            |                            |
| ASU Capacity<br>478.43GB         |                   |                                |  |                            |                            |
| ASU 1<br>215.29GB                | ASU 2<br>215.29GB | ASU 3<br>47.84GB               |  |                            |                            |

## SPC-1 Storage Hierarchy Ratios

| SPC-1 Storage Hierarchy Ratios           |                              |                             |                           |
|--|------------------------------|-----------------------------|---------------------------|
|  | Addressable Storage Capacity | Configured Storage Capacity | Physical Storage Capacity |
| Total ASU Capacity                       | 100.00%                      | 50.00%                      | 24.32%                    |
| User Data Copy (Mirror)                  |                              | 50.00%                      | 24.32%                    |
| Addressable Storage Capacity             |                              | 50.00%                      | 24.32%                    |
| Required Storage (metadata) & Hot Spares |                              | 0%                          | 0%                        |
| Configured Storage Capacity              |                              |                             | 48.65%                    |
| Global Storage Overhead                  |                              |                             | 1.47%                     |
| Unused Storage                           | 0.00%                        | 0.00%                       | 49.87%                    |

The Addressable Storage Capacity and Configured Storage Capacity contained no Unused Storage. The Physical Storage Capacity contained 49.87% (980.81 GB) of Unused Storage.

## Logical Volume Capacity and ASU Mapping

### Clause 9.2.4.6.2

*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 2.4.5) used on each Logical Volume.*

| Logical Volume Capacity and Mapping   |   |   |
|---|---|---|
| ASU-1 (215.29 GB)   | ASU-2 (215.29 GB)   | ASU-3 (47.84 GB)  |
| 1 Logical Volume<br>215.29 GB per Logical Volume<br>(215.29 GB used/Logical Volume) | 1 Logical Volume<br>215.29 GB per Logical Volume<br>(215.29 GB used/Logical Volume) | 1 Logical Volume<br>47.84 GB per Logical Volume<br>(47.84 GB used/Logical Volume) |

The Data Protection Level used for all Logical Volumes was Mirroring as described on page 11. See "ASU Configuration" in the [IOPS Test Results File](#) for more detailed configuration information.

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

### **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.*

***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.*

***Measurement Interval:** The finite and contiguous time period, after the Tested Storage Configuration (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.*

***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. Comment: Steady Stated is achieved only after caches in the TSC have filled and as a result the I/O Request throughput of the TSC has stabilized.*

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

***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.*

***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 Figure 5-1 below. All SPC-1 Test Runs shall have a Steady State period and a Measurement Interval.*

### **Sustainability Test Phase**

#### **Clause 5.4.2.1**

*The Sustainability Test Phase consists of one Test Run at the 100% load point with a Measurement Interval of three (3) hours. The intent is to demonstrate a sustained maximum I/O Request Throughput as well as insuring the Tested Storage Configuration (TSC) has reached steady state prior to measuring the maximum I/O Request Throughput (SPC-1™ IOPS).*

*The reported I/O Request Throughput of the Sustainability Test Run must be within 5% of the reported SPC-1™ IOPS primary metric. The Average Response Time measured in Sustainability Test Run cannot exceed thirty (30) milliseconds.*

#### **Clause 9.2.4.7.1**

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

- 1. A Data Rate Distribution (data table and graph).*
- 2. I/O Request Throughput Distribution (data table and graph).*
- 3. The human readable Test Run Results File produced by the Workload Generator.*
- 4. A listing or screen image of all input parameters supplied to the Workload Generator.*
- 5. The Measured Intensity Multiplier for each I/O stream.*
- 6. 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, and Response Time Ramp Test Runs are listed below.

```
java -Xmx64m -Xms64m metrics -b 242 -s 1200
```

### **Sustainability Test Results File**

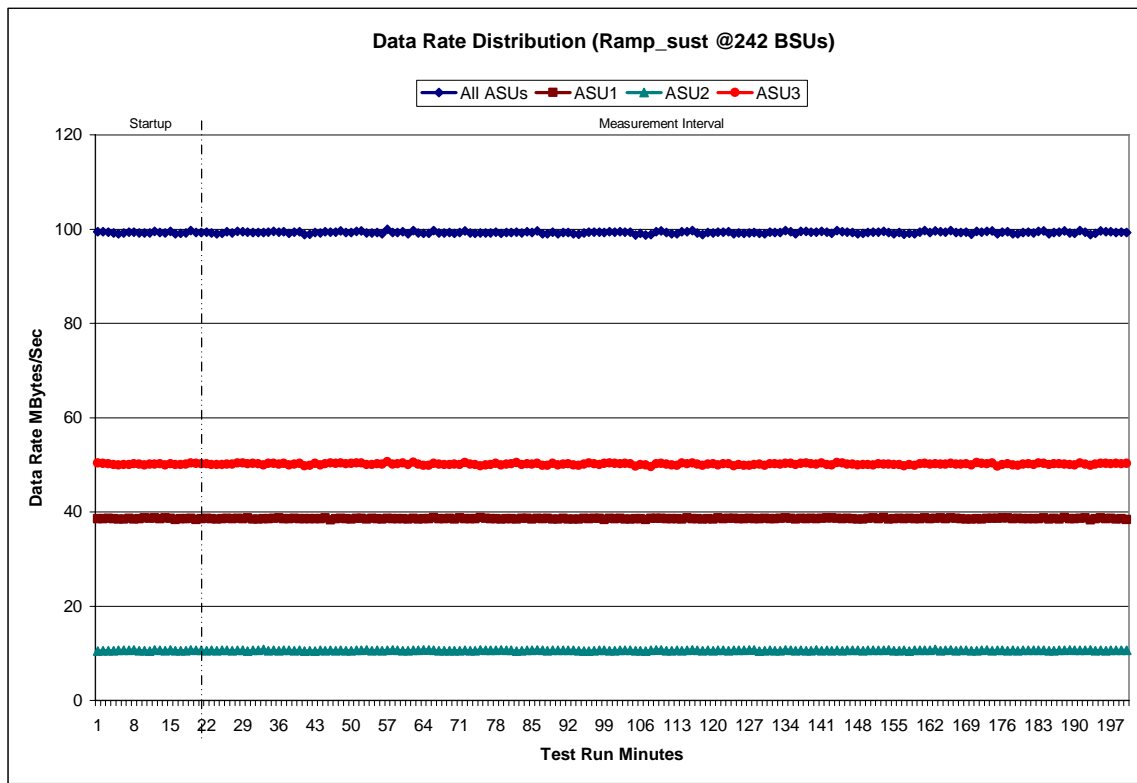
A link to the test results file generated from the Sustainability Test Run is listed below.

[Sustainability Test Results File](#)



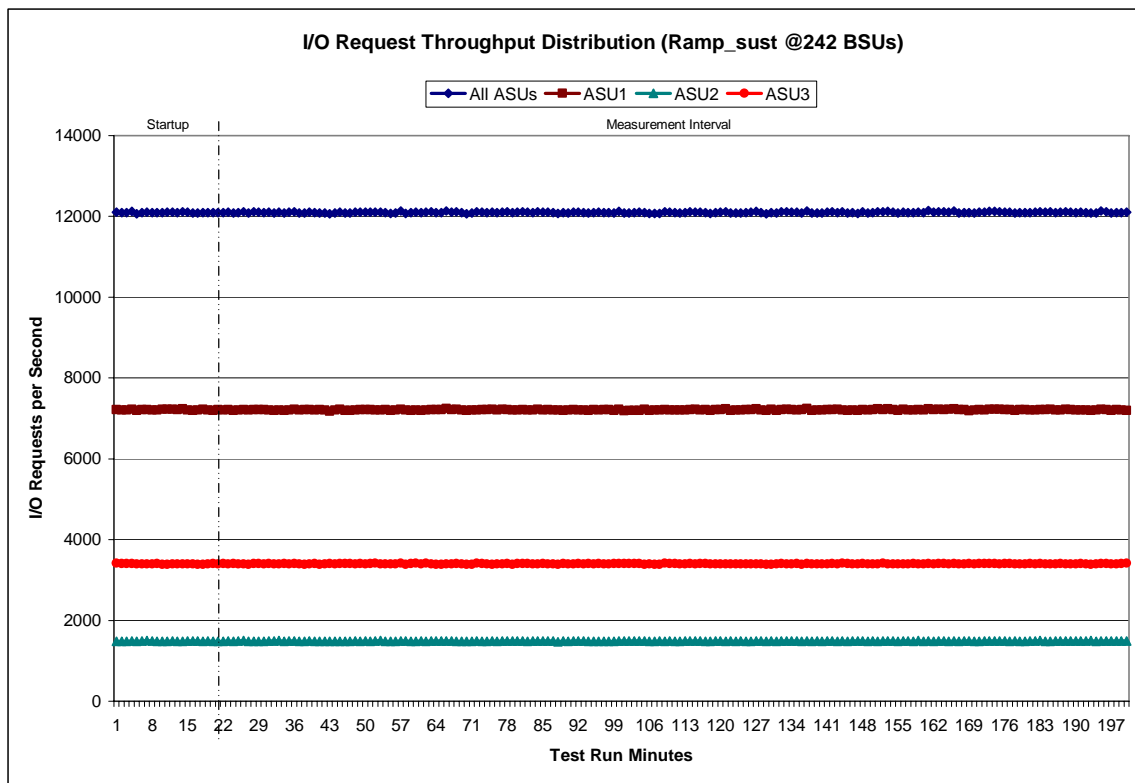


### Sustainability - Data Rate Distribution Graph





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



### Sustainability - 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 | .0350  | .2810  | .0700  | .2100  | .0180  | .0700  | .0350  | .2810  |
| COV | .0061  | .0018  | .0041  | .0022  | .0087  | .0042  | .0059  | .0019  |

**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.

**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%.

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

## IOPS Test Phase

### Clause 5.4.2.2

*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 9.2.4.7.2

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

- 1. I/O Request Throughput Distribution (data and graph).*
- 2. A Response Time Frequency Distribution.*
- 3. An Average Response Time Distribution.*
- 4. The human readable Test Run Results File produced by the Workload Generator.*
- 5. A listing or screen image of all input parameters supplied 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, and Response Time Ramp Test Runs are listed below.

```
java -Xmx64m -Xms64m metrics -b 242 -s 1200
```

## IOPS Test Results File

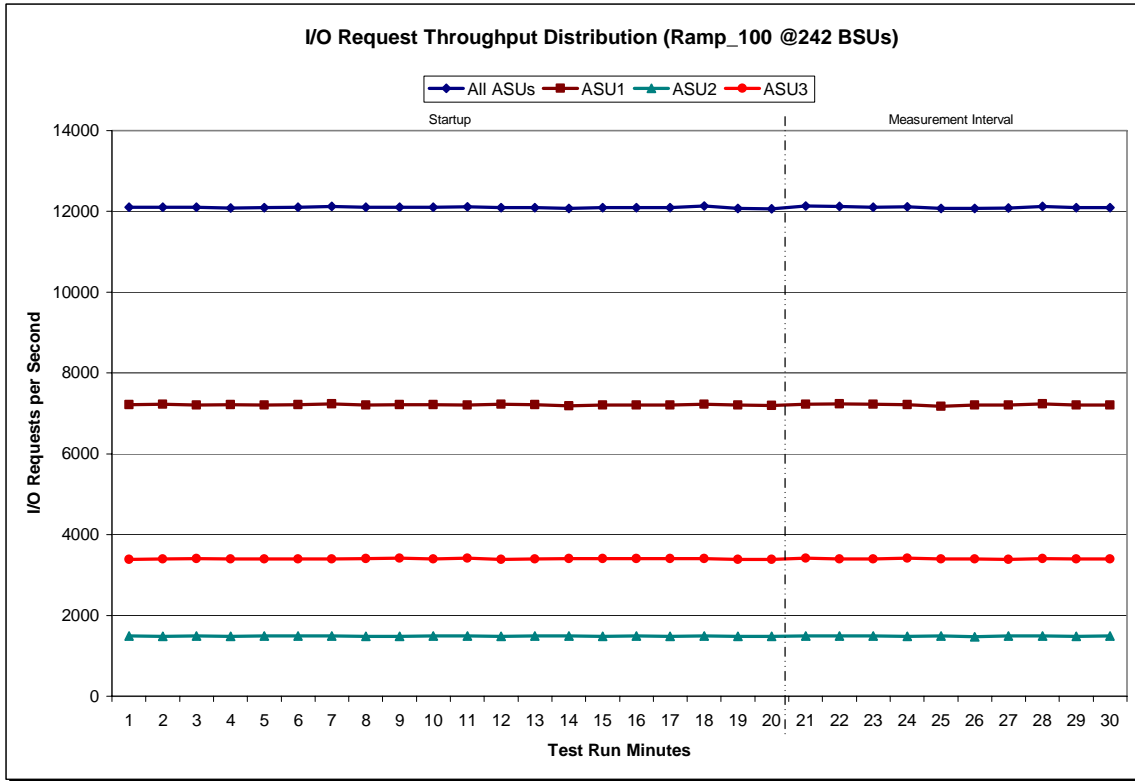
A link to the test results file generated from the IOPS Test Run is listed below.

[IOPS Test Results File](#)

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

| 242 BSUs<br>Start-Up/Ramp-Up<br>Measurement Interval | Start     | Stop     | Interval | Duration |
|--|-----------|----------|----------|----------|
| 60 second intervals                                  | All ASUs  | ASU1     | ASU2     | ASU3     |
| 0  | 12,102.33 | 7,220.27 | 1,493.33 | 3,388.73 |
| 1  | 12,107.68 | 7,223.72 | 1,484.12 | 3,399.85 |
| 2  | 12,107.65 | 7,208.40 | 1,495.10 | 3,404.15 |
| 3  | 12,086.73 | 7,212.35 | 1,476.70 | 3,397.68 |
| 4  | 12,095.23 | 7,208.00 | 1,489.75 | 3,397.48 |
| 5  | 12,106.13 | 7,216.30 | 1,492.25 | 3,397.58 |
| 6  | 12,124.55 | 7,238.17 | 1,490.00 | 3,396.38 |
| 7  | 12,100.32 | 7,205.07 | 1,484.18 | 3,411.07 |
| 8  | 12,109.12 | 7,215.32 | 1,478.50 | 3,415.30 |
| 9  | 12,102.78 | 7,214.05 | 1,489.03 | 3,399.70 |
| 10   | 12,114.25 | 7,210.28 | 1,488.92 | 3,415.05 |
| 11   | 12,098.57 | 7,222.70 | 1,485.78 | 3,390.08 |
| 12   | 12,099.72 | 7,213.40 | 1,487.32 | 3,399.00 |
| 13   | 12,079.77 | 7,184.15 | 1,491.28 | 3,404.33 |
| 14   | 12,090.58 | 7,203.08 | 1,482.02 | 3,405.48 |
| 15   | 12,097.77 | 7,204.03 | 1,490.80 | 3,402.93 |
| 16   | 12,098.40 | 7,211.05 | 1,477.13 | 3,410.22 |
| 17   | 12,131.13 | 7,228.05 | 1,493.02 | 3,410.07 |
| 18   | 12,075.23 | 7,202.12 | 1,482.37 | 3,390.75 |
| 19   | 12,068.70 | 7,200.25 | 1,482.45 | 3,386.00 |
| 20   | 12,131.45 | 7,226.80 | 1,490.08 | 3,414.57 |
| 21   | 12,126.27 | 7,234.48 | 1,494.18 | 3,397.60 |
| 22   | 12,109.45 | 7,221.75 | 1,487.57 | 3,400.13 |
| 23   | 12,111.22 | 7,218.00 | 1,479.37 | 3,413.85 |
| 24   | 12,071.92 | 7,178.73 | 1,496.65 | 3,396.53 |
| 25   | 12,079.57 | 7,211.08 | 1,472.38 | 3,396.10 |
| 26   | 12,083.10 | 7,205.33 | 1,489.33 | 3,388.43 |
| 27   | 12,129.38 | 7,232.85 | 1,488.40 | 3,408.13 |
| 28   | 12,092.78 | 7,207.57 | 1,483.62 | 3,401.60 |
| 29   | 12,094.52 | 7,209.62 | 1,487.07 | 3,397.83 |
| <b>Average</b>                                       | 12,102.97 | 7,214.62 | 1,486.87 | 3,401.48 |

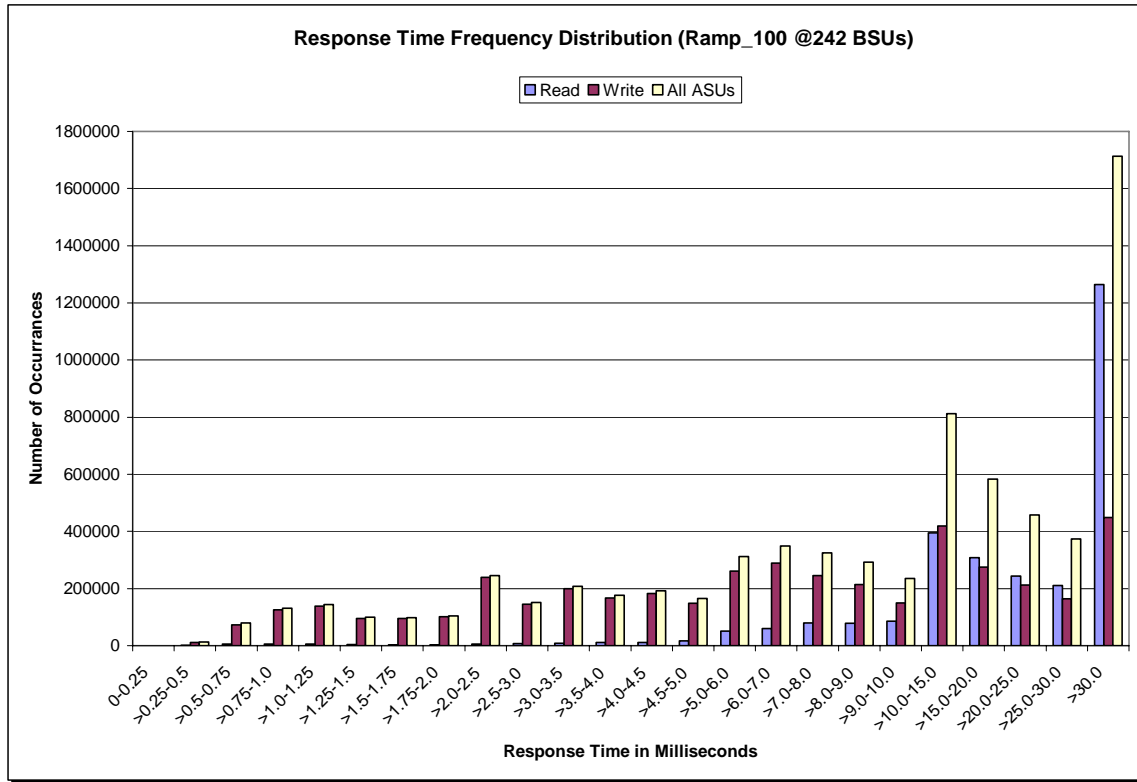
### IOPS Test Run - I/O Request Throughput Distribution Graph



**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               | 2        | 1,894     | 6,093     | 6,297      | 5,590      | 4,476      | 3,483      | 2,675     |
| Write              | 1        | 11,321    | 73,137    | 124,952    | 138,808    | 95,257     | 95,534     | 100,661   |
| All ASUs           | 3        | 13,215    | 79,230    | 131,249    | 144,398    | 99,733     | 99,017     | 103,336   |
| ASU1               | 1        | 1,828     | 10,503    | 24,899     | 41,154     | 31,163     | 30,723     | 33,196    |
| ASU2               | 2        | 3,374     | 14,931    | 20,697     | 18,560     | 12,173     | 12,404     | 12,856    |
| ASU3               | -        | 8,013     | 53,796    | 85,653     | 84,684     | 56,397     | 55,890     | 57,284    |
| 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               | 5,859    | 6,506     | 8,217     | 10,714     | 10,995     | 16,604     | 50,804     | 59,655    |
| Write              | 239,600  | 144,891   | 199,702   | 166,300    | 182,066    | 148,204    | 260,649    | 288,917   |
| All ASUs           | 245,459  | 151,397   | 207,919   | 177,014    | 193,061    | 164,808    | 311,453    | 348,572   |
| ASU1               | 84,694   | 41,463    | 53,253    | 42,432     | 44,489     | 45,261     | 91,870     | 104,877   |
| ASU2               | 29,494   | 20,802    | 29,614    | 26,163     | 29,140     | 25,260     | 50,867     | 58,323    |
| ASU3               | 131,271  | 89,132    | 125,052   | 108,419    | 119,432    | 94,287     | 168,716    | 185,372   |
| 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               | 80,235   | 77,991    | 85,498    | 394,492    | 308,040    | 244,330    | 210,301    | 1,264,338 |
| Write              | 245,328  | 213,556   | 149,015   | 418,431    | 274,560    | 212,654    | 163,795    | 449,200   |
| All ASUs           | 325,563  | 291,547   | 234,513   | 812,923    | 582,600    | 456,984    | 374,096    | 1,713,538 |
| ASU1               | 110,103  | 103,296   | 96,936    | 486,203    | 442,847    | 396,236    | 342,673    | 1,668,554 |
| ASU2               | 58,490   | 54,471    | 47,804    | 165,005    | 92,001     | 46,573     | 24,970     | 38,128    |
| ASU3               | 156,970  | 133,780   | 89,773    | 161,715    | 47,752     | 14,175     | 6,453      | 6,856     |

### IOPS Test Run -Response Time Frequency Distribution Graph

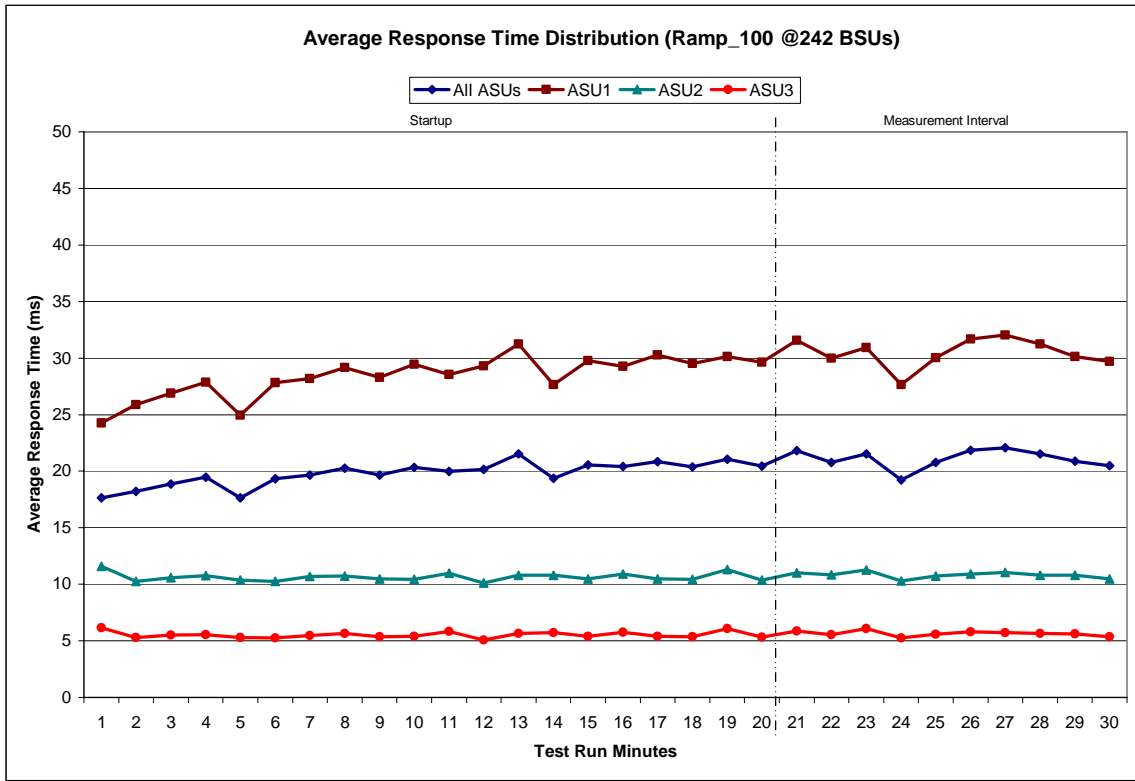




**IOPS Test Run - Average Response Time (ms) Distribution Data**

| <b>242 BSUs<br/>Start-Up/Ramp-Up<br/>Measurement Interval</b> | <b>Start</b>    | <b>Stop</b> | <b>Interval</b> | <b>Duration</b> |
|---|-----------------|-------------|-----------------|-----------------|
|   | 2:38:29         | 2:58:30     | 0-19            | 0:20:01         |
|   | 2:58:30         | 3:08:30     | 20-29           | 0:10:00         |
| <b>60 second intervals</b>                                    | <b>All ASUs</b> | <b>ASU1</b> | <b>ASU2</b>     | <b>ASU3</b>     |
| <b>0</b>  | 17.62           | 24.25       | 11.59           | 6.17            |
| <b>1</b>  | 18.20           | 25.90       | 10.27           | 5.30            |
| <b>2</b>  | 18.87           | 26.89       | 10.60           | 5.51            |
| <b>3</b>  | 19.49           | 27.84       | 10.76           | 5.54            |
| <b>4</b>  | 17.62           | 24.93       | 10.36           | 5.30            |
| <b>5</b>  | 19.33           | 27.84       | 10.25           | 5.24            |
| <b>6</b>  | 19.67           | 28.18       | 10.67           | 5.49            |
| <b>7</b>  | 20.27           | 29.15       | 10.73           | 5.66            |
| <b>8</b>  | 19.66           | 28.30       | 10.48           | 5.37            |
| <b>9</b>  | 20.35           | 29.44       | 10.45           | 5.39            |
| <b>10</b>   | 19.97           | 28.53       | 10.96           | 5.83            |
| <b>11</b>   | 20.16           | 29.30       | 10.12           | 5.08            |
| <b>12</b>   | 21.53           | 31.23       | 10.81           | 5.65            |
| <b>13</b>   | 19.37           | 27.63       | 10.78           | 5.71            |
| <b>14</b>   | 20.54           | 29.76       | 10.49           | 5.40            |
| <b>15</b>   | 20.39           | 29.27       | 10.89           | 5.77            |
| <b>16</b>   | 20.85           | 30.29       | 10.47           | 5.40            |
| <b>17</b>   | 20.37           | 29.50       | 10.43           | 5.37            |
| <b>18</b>   | 21.06           | 30.13       | 11.30           | 6.07            |
| <b>19</b>   | 20.44           | 29.61       | 10.35           | 5.34            |
| <b>20</b>   | 21.81           | 31.57       | 11.02           | 5.86            |
| <b>21</b>   | 20.77           | 29.97       | 10.83           | 5.55            |
| <b>22</b>   | 21.54           | 30.93       | 11.26           | 6.07            |
| <b>23</b>   | 19.22           | 27.66       | 10.28           | 5.27            |
| <b>24</b>   | 20.76           | 30.03       | 10.74           | 5.59            |
| <b>25</b>   | 21.86           | 31.66       | 10.90           | 5.80            |
| <b>26</b>   | 22.08           | 32.05       | 11.04           | 5.72            |
| <b>27</b>   | 21.54           | 31.23       | 10.81           | 5.66            |
| <b>28</b>   | 20.86           | 30.14       | 10.79           | 5.60            |
| <b>29</b>   | 20.50           | 29.70       | 10.48           | 5.36            |
| <b>Average</b>  | 21.09           | 30.49       | 10.82           | 5.65            |

### IOPS Test Run - Average Response Time (ms) 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 |
|--|--|---|
| 7,261,628  | 5,548,090  | 1,713,538   |

**IOPS Test Run – 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 | .0351  | .2806  | .0701  | .2103  | .0180  | .0699  | .0349  | .2810  |
| COV | .0091  | .0020  | .0044  | .0026  | .0087  | .0051  | .0080  | .0018  |

**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.

**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%.

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

## Response Time Ramp Test Phase

### Clause 5.4.2.3

*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 12.*

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

### Clause 9.2.4.7.3

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

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

## SPC-1 Workload Generator Input Parameters

The SPC-1 Workload Generator input parameters for the Sustainability, IOPS, and Response Time Ramp Test Runs are listed below.

```
java -Xmx64m -Xms64m metrics -b 242 -s 1200
```

## 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](#)

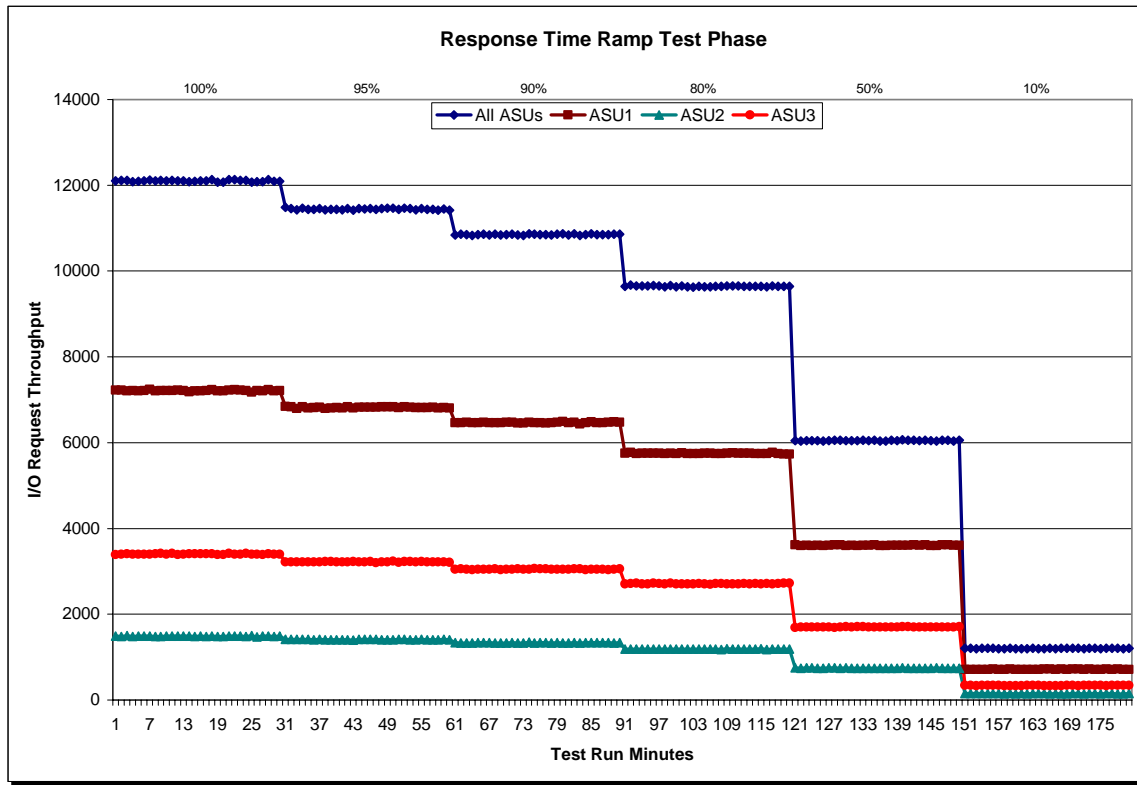
**Response Time Ramp Distribution (IOPS) Data**

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 - 242 BSUs   | Start           | Stop         | Interval     | Duration     | 95% Load Level - 229 BSUs    | Start           | Stop         | Interval     | Duration     |
|------------------------------|-----------------|--------------|--------------|--------------|------------------------------|-----------------|--------------|--------------|--------------|
| <b>Start-Up/Ramp-Up</b>      | 2:38:29         | 2:58:30      | 0-19         | 0:20:01      | <b>Start-Up/Ramp-Up</b>      | 3:08:34         | 3:28:35      | 0-19         | 0:20:01      |
| <b>Measurement Interval</b>  | 2:58:30         | 3:08:30      | 20-29        | 0:10:00      | <b>Measurement Interval</b>  | 3:28:35         | 3:38:35      | 20-29        | 0:10:00      |
| <i>(60 second intervals)</i> | <b>All ASUs</b> | <b>ASU-1</b> | <b>ASU-2</b> | <b>ASU-3</b> | <i>(60 second intervals)</i> | <b>All ASUs</b> | <b>ASU-1</b> | <b>ASU-2</b> | <b>ASU-3</b> |
| <b>0</b>                     | 12,102.33       | 7,220.27     | 1,493.33     | 3,388.73     | <b>0</b>                     | 11,481.97       | 6,847.62     | 1,414.82     | 3,219.53     |
| <b>1</b>                     | 12,107.68       | 7,223.72     | 1,484.12     | 3,399.85     | <b>1</b>                     | 11,458.33       | 6,833.52     | 1,410.33     | 3,214.48     |
| <b>2</b>                     | 12,107.65       | 7,208.40     | 1,495.10     | 3,404.15     | <b>2</b>                     | 11,429.90       | 6,800.15     | 1,413.47     | 3,216.28     |
| <b>3</b>                     | 12,086.73       | 7,212.35     | 1,476.70     | 3,397.68     | <b>3</b>                     | 11,462.58       | 6,832.43     | 1,415.13     | 3,215.02     |
| <b>4</b>                     | 12,095.23       | 7,208.00     | 1,489.75     | 3,397.48     | <b>4</b>                     | 11,440.22       | 6,808.05     | 1,411.03     | 3,221.13     |
| <b>5</b>                     | 12,106.13       | 7,216.30     | 1,492.25     | 3,397.58     | <b>5</b>                     | 11,437.40       | 6,818.40     | 1,402.85     | 3,216.15     |
| <b>6</b>                     | 12,124.55       | 7,238.17     | 1,490.00     | 3,396.38     | <b>6</b>                     | 11,457.77       | 6,825.87     | 1,417.52     | 3,214.38     |
| <b>7</b>                     | 12,100.32       | 7,205.07     | 1,484.18     | 3,411.07     | <b>7</b>                     | 11,428.10       | 6,799.38     | 1,402.70     | 3,226.02     |
| <b>8</b>                     | 12,109.12       | 7,215.32     | 1,478.50     | 3,415.30     | <b>8</b>                     | 11,437.43       | 6,805.90     | 1,403.08     | 3,228.45     |
| <b>9</b>                     | 12,102.78       | 7,214.05     | 1,489.03     | 3,399.70     | <b>9</b>                     | 11,439.87       | 6,813.65     | 1,408.58     | 3,217.63     |
| <b>10</b>                    | 12,114.25       | 7,210.28     | 1,488.92     | 3,415.05     | <b>10</b>                    | 11,431.52       | 6,809.83     | 1,405.30     | 3,216.38     |
| <b>11</b>                    | 12,098.57       | 7,222.70     | 1,485.78     | 3,390.08     | <b>11</b>                    | 11,459.03       | 6,830.90     | 1,406.02     | 3,222.12     |
| <b>12</b>                    | 12,099.72       | 7,213.40     | 1,487.32     | 3,399.00     | <b>12</b>                    | 11,419.42       | 6,802.18     | 1,394.28     | 3,222.95     |
| <b>13</b>                    | 12,079.77       | 7,184.15     | 1,491.28     | 3,404.33     | <b>13</b>                    | 11,460.77       | 6,827.22     | 1,414.53     | 3,219.02     |
| <b>14</b>                    | 12,090.58       | 7,203.08     | 1,482.02     | 3,405.48     | <b>14</b>                    | 11,443.92       | 6,819.78     | 1,410.82     | 3,213.32     |
| <b>15</b>                    | 12,097.77       | 7,204.03     | 1,490.80     | 3,402.93     | <b>15</b>                    | 11,458.60       | 6,823.68     | 1,410.12     | 3,224.80     |
| <b>16</b>                    | 12,098.40       | 7,211.05     | 1,477.13     | 3,410.22     | <b>16</b>                    | 11,435.72       | 6,821.65     | 1,414.30     | 3,199.77     |
| <b>17</b>                    | 12,131.13       | 7,228.05     | 1,493.02     | 3,410.07     | <b>17</b>                    | 11,455.02       | 6,832.38     | 1,404.17     | 3,218.47     |
| <b>18</b>                    | 12,075.23       | 7,202.12     | 1,482.37     | 3,390.75     | <b>18</b>                    | 11,464.33       | 6,835.87     | 1,408.18     | 3,220.28     |
| <b>19</b>                    | 12,068.70       | 7,200.25     | 1,482.45     | 3,386.00     | <b>19</b>                    | 11,468.93       | 6,835.33     | 1,400.10     | 3,233.50     |
| <b>20</b>                    | 12,131.45       | 7,226.80     | 1,490.08     | 3,414.57     | <b>20</b>                    | 11,438.57       | 6,815.82     | 1,414.23     | 3,208.52     |
| <b>21</b>                    | 12,126.27       | 7,234.48     | 1,494.18     | 3,397.60     | <b>21</b>                    | 11,465.70       | 6,829.87     | 1,412.28     | 3,223.55     |
| <b>22</b>                    | 12,109.45       | 7,221.75     | 1,487.57     | 3,400.13     | <b>22</b>                    | 11,453.85       | 6,823.57     | 1,407.65     | 3,222.63     |
| <b>23</b>                    | 12,111.22       | 7,218.00     | 1,479.37     | 3,413.85     | <b>23</b>                    | 11,431.35       | 6,815.43     | 1,402.15     | 3,213.77     |
| <b>24</b>                    | 12,071.92       | 7,178.73     | 1,496.65     | 3,396.53     | <b>24</b>                    | 11,452.30       | 6,816.25     | 1,411.57     | 3,224.48     |
| <b>25</b>                    | 12,079.57       | 7,211.08     | 1,472.38     | 3,396.10     | <b>25</b>                    | 11,434.80       | 6,815.23     | 1,402.05     | 3,217.52     |
| <b>26</b>                    | 12,083.10       | 7,205.33     | 1,489.33     | 3,388.43     | <b>26</b>                    | 11,441.73       | 6,822.17     | 1,403.08     | 3,216.48     |
| <b>27</b>                    | 12,129.38       | 7,232.85     | 1,488.40     | 3,408.13     | <b>27</b>                    | 11,418.45       | 6,801.62     | 1,402.70     | 3,214.13     |
| <b>28</b>                    | 12,092.78       | 7,207.57     | 1,483.62     | 3,401.60     | <b>28</b>                    | 11,444.65       | 6,818.05     | 1,411.85     | 3,214.75     |
| <b>29</b>                    | 12,094.52       | 7,209.62     | 1,487.07     | 3,397.83     | <b>29</b>                    | 11,423.03       | 6,808.43     | 1,407.58     | 3,207.02     |
| <b>Average</b>               | 12,102.97       | 7,214.62     | 1,486.87     | 3,401.48     | <b>Average</b>               | 11,440.44       | 6,816.64     | 1,407.52     | 3,216.29     |



### Response Time Ramp Distribution (IOPS) Graph

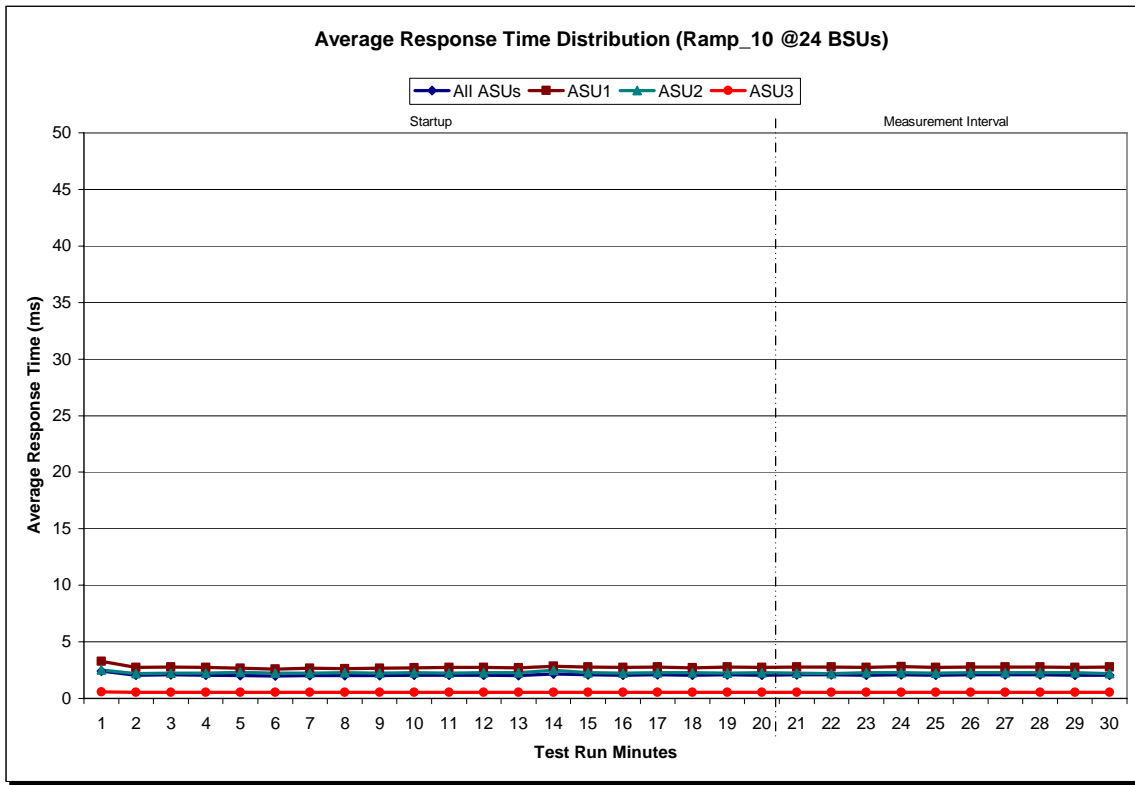


**SPC-1 LRT™ Average Response Time (ms) Distribution Data**

| 24 BSUs                     | Start    | Stop    | Interval | Duration |
|-----------------------------|----------|---------|----------|----------|
| <i>Start-Up/Ramp-Up</i>     | 5:08:52  | 5:28:53 | 0-19     | 0:20:01  |
| <i>Measurement Interval</i> | 5:28:53  | 5:38:53 | 20-29    | 0:10:00  |
| 60 second intervals         | All ASUs | ASU1    | ASU2     | ASU3     |
| <b>0</b>                    | 2.42     | 3.26    | 2.54     | 0.58     |
| <b>1</b>                    | 2.05     | 2.74    | 2.18     | 0.53     |
| <b>2</b>                    | 2.08     | 2.77    | 2.25     | 0.53     |
| <b>3</b>                    | 2.05     | 2.73    | 2.24     | 0.53     |
| <b>4</b>                    | 2.02     | 2.67    | 2.31     | 0.53     |
| <b>5</b>                    | 1.97     | 2.60    | 2.23     | 0.53     |
| <b>6</b>                    | 2.01     | 2.66    | 2.23     | 0.53     |
| <b>7</b>                    | 2.00     | 2.64    | 2.26     | 0.54     |
| <b>8</b>                    | 2.02     | 2.66    | 2.24     | 0.54     |
| <b>9</b>                    | 2.05     | 2.71    | 2.28     | 0.53     |
| <b>10</b>                   | 2.06     | 2.74    | 2.22     | 0.53     |
| <b>11</b>                   | 2.05     | 2.72    | 2.28     | 0.53     |
| <b>12</b>                   | 2.03     | 2.69    | 2.27     | 0.53     |
| <b>13</b>                   | 2.16     | 2.86    | 2.48     | 0.53     |
| <b>14</b>                   | 2.07     | 2.75    | 2.25     | 0.53     |
| <b>15</b>                   | 2.05     | 2.72    | 2.24     | 0.53     |
| <b>16</b>                   | 2.08     | 2.77    | 2.28     | 0.53     |
| <b>17</b>                   | 2.03     | 2.69    | 2.28     | 0.53     |
| <b>18</b>                   | 2.07     | 2.78    | 2.24     | 0.53     |
| <b>19</b>                   | 2.05     | 2.73    | 2.26     | 0.53     |
| <b>20</b>                   | 2.08     | 2.76    | 2.22     | 0.53     |
| <b>21</b>                   | 2.08     | 2.78    | 2.20     | 0.53     |
| <b>22</b>                   | 2.06     | 2.74    | 2.28     | 0.54     |
| <b>23</b>                   | 2.09     | 2.80    | 2.25     | 0.53     |
| <b>24</b>                   | 2.05     | 2.74    | 2.23     | 0.53     |
| <b>25</b>                   | 2.08     | 2.77    | 2.28     | 0.53     |
| <b>26</b>                   | 2.09     | 2.79    | 2.28     | 0.53     |
| <b>27</b>                   | 2.08     | 2.77    | 2.27     | 0.53     |
| <b>28</b>                   | 2.06     | 2.74    | 2.27     | 0.53     |
| <b>29</b>                   | 2.07     | 2.76    | 2.20     | 0.53     |
| <b>Average</b>              | 2.07     | 2.77    | 2.25     | 0.53     |



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



**SPC-1 LRT™ (10%) – 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>  | 0.0350 | 0.2810 | 0.0700 | 0.2100 | 0.0180 | 0.0700 | 0.0350 | 0.2810 |
| <i>MIM</i> | .0353  | .2815  | .0698  | .2092  | .0177  | .0699  | .0354  | .2813  |
| <i>COV</i> | .0123  | .0043  | .0153  | .0120  | .0147  | .0171  | .0210  | .0058  |

***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.

***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%.

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

## Repeatability Test

### Clause 5.4.3

*The Repeatability Test demonstrates the repeatability and reproducibility of the SPC-1 IOPS™ and SPC-1 LRT™ primary metrics 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™ primary metric. Each Average Response Time value must be less than the SPC-1 LRT™ primary 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-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 9.2.4.7.3

*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 two Repeatability Test Phases. The content, appearance, and format of the table are specified in Table 9-11.*
- 2. An I/O Request Throughput Distribution (data and graph).*
- 3. An Average Response Time Distribution (data and graph).*
- 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 Repeatability Test Runs are listed below.

```
java -Xmx64m -Xms64m repeat1 -b 242 -s 1200
java -Xmx64m -Xms64m repeat2 -b 242 -s 1200
```

## Repeatability Test Results File

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

|                                   | SPC-1 IOPS™ | SPC-1 LRT™ |
|-----------------------------------|-------------|------------|
| <b>Primary Metrics</b>            | 12,102.97   | 2.07       |
| <b>Repeatability Test Phase 1</b> | 12,106.47   | 2.05       |
| <b>Repeatability Test Phase 2</b> | 12,102.28   | 2.06       |

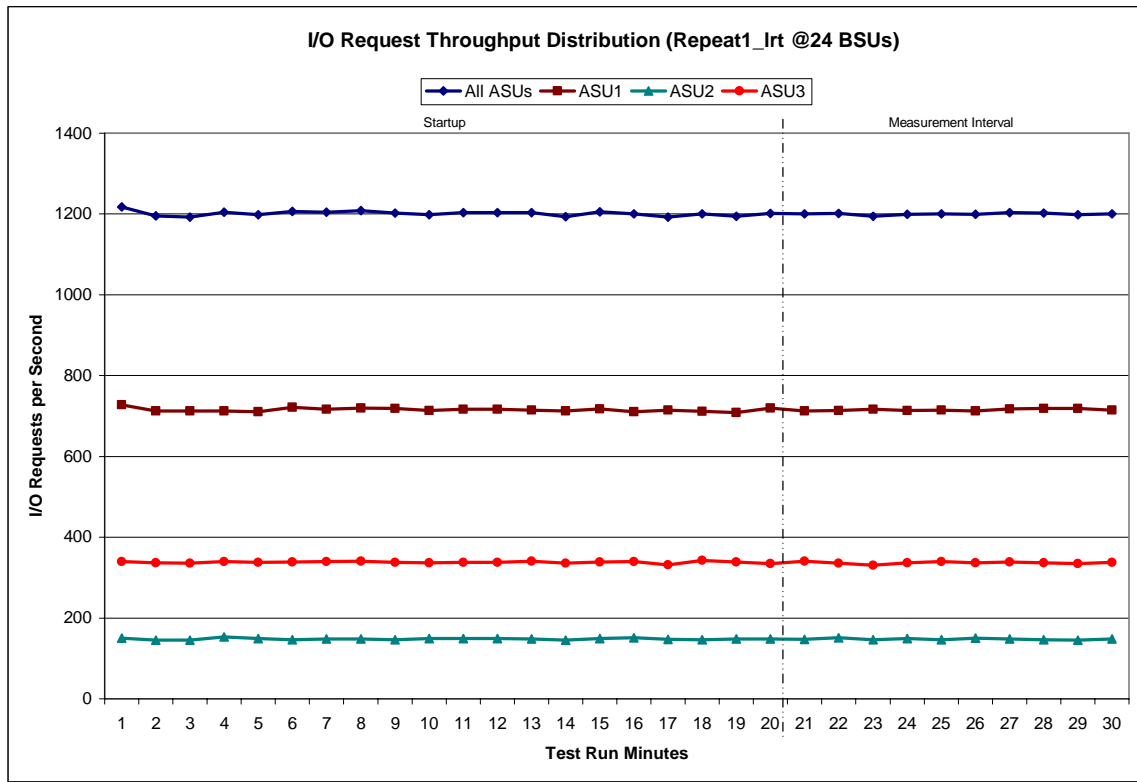
A link to the test result file generated from each Repeatability Test Run list is listed below.

[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**

| 24 BSUs                     | Start    | Stop     | Interval | Duration |
|-----------------------------|----------|----------|----------|----------|
| <i>Start-Up/Ramp-Up</i>     | 16:07:40 | 16:27:40 | 0-19     | 0:20:00  |
| <i>Measurement Interval</i> | 16:27:40 | 16:37:40 | 20-29    | 0:10:00  |
| 60 second intervals         | All ASUs | ASU1     | ASU2     | ASU3     |
| 0                           | 1,217.52 | 727.73   | 149.78   | 340.00   |
| 1                           | 1,194.95 | 713.02   | 145.47   | 336.47   |
| 2                           | 1,192.50 | 712.28   | 144.82   | 335.40   |
| 3                           | 1,204.73 | 712.42   | 152.92   | 339.40   |
| 4                           | 1,198.03 | 710.92   | 149.17   | 337.95   |
| 5                           | 1,206.77 | 722.10   | 146.18   | 338.48   |
| 6                           | 1,204.57 | 716.43   | 148.48   | 339.65   |
| 7                           | 1,208.93 | 719.38   | 148.62   | 340.93   |
| 8                           | 1,202.47 | 719.10   | 145.75   | 337.62   |
| 9                           | 1,198.63 | 713.12   | 148.82   | 336.70   |
| 10                          | 1,203.93 | 717.02   | 149.60   | 337.32   |
| 11                          | 1,203.47 | 717.05   | 148.83   | 337.58   |
| 12                          | 1,203.18 | 714.32   | 148.47   | 340.40   |
| 13                          | 1,193.38 | 712.63   | 145.50   | 335.25   |
| 14                          | 1,205.15 | 717.97   | 148.68   | 338.50   |
| 15                          | 1,200.48 | 710.43   | 150.80   | 339.25   |
| 16                          | 1,192.47 | 714.50   | 146.72   | 331.25   |
| 17                          | 1,200.37 | 711.92   | 145.80   | 342.65   |
| 18                          | 1,194.73 | 708.20   | 148.05   | 338.48   |
| 19                          | 1,201.28 | 719.32   | 147.75   | 334.22   |
| 20                          | 1,199.95 | 712.73   | 146.90   | 340.32   |
| 21                          | 1,201.17 | 713.82   | 151.43   | 335.92   |
| 22                          | 1,194.62 | 717.08   | 146.45   | 331.08   |
| 23                          | 1,199.88 | 713.73   | 149.38   | 336.77   |
| 24                          | 1,200.77 | 714.73   | 146.35   | 339.68   |
| 25                          | 1,199.75 | 712.93   | 149.68   | 337.13   |
| 26                          | 1,203.85 | 717.28   | 148.25   | 338.32   |
| 27                          | 1,202.07 | 718.63   | 146.47   | 336.97   |
| 28                          | 1,198.05 | 718.67   | 145.10   | 334.28   |
| 29                          | 1,200.17 | 714.93   | 147.68   | 337.55   |
| <b>Average</b>              | 1,200.03 | 715.46   | 147.77   | 336.80   |

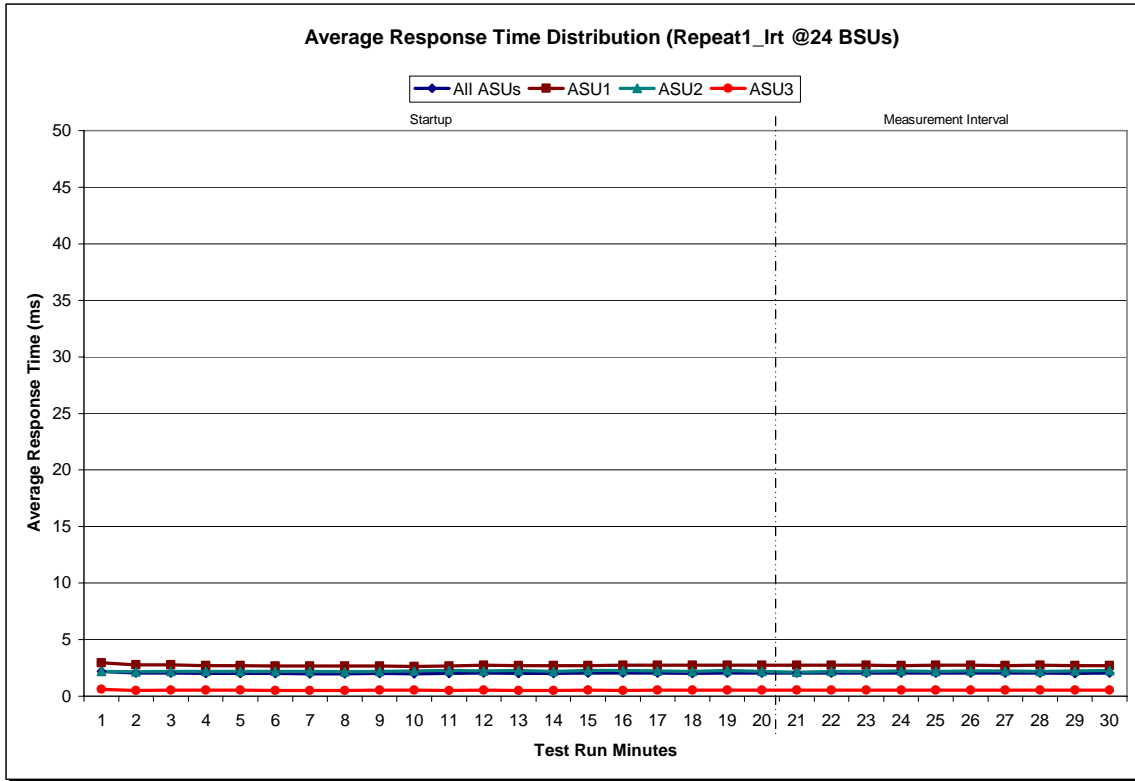
### Repeatability 1 LRT - I/O Request Throughput Distribution Graph



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

| 24 BSUs                     | Start    | Stop     | Interval | Duration |
|-----------------------------|----------|----------|----------|----------|
| <i>Start-Up/Ramp-Up</i>     | 16:07:40 | 16:27:40 | 0-19     | 0:20:00  |
| <i>Measurement Interval</i> | 16:27:40 | 16:37:40 | 20-29    | 0:10:00  |
| 60 second intervals         | All ASUs | ASU1     | ASU2     | ASU3     |
| <b>0</b>                    | 2.20     | 2.95     | 2.20     | 0.60     |
| <b>1</b>                    | 2.07     | 2.77     | 2.18     | 0.52     |
| <b>2</b>                    | 2.07     | 2.77     | 2.19     | 0.52     |
| <b>3</b>                    | 2.03     | 2.71     | 2.19     | 0.53     |
| <b>4</b>                    | 2.01     | 2.69     | 2.18     | 0.52     |
| <b>5</b>                    | 2.00     | 2.66     | 2.18     | 0.52     |
| <b>6</b>                    | 2.00     | 2.65     | 2.20     | 0.52     |
| <b>7</b>                    | 2.00     | 2.66     | 2.16     | 0.52     |
| <b>8</b>                    | 2.02     | 2.68     | 2.20     | 0.52     |
| <b>9</b>                    | 2.00     | 2.64     | 2.22     | 0.53     |
| <b>10</b>                   | 2.01     | 2.65     | 2.27     | 0.52     |
| <b>11</b>                   | 2.06     | 2.75     | 2.23     | 0.53     |
| <b>12</b>                   | 2.03     | 2.70     | 2.26     | 0.52     |
| <b>13</b>                   | 2.03     | 2.70     | 2.20     | 0.52     |
| <b>14</b>                   | 2.04     | 2.71     | 2.27     | 0.52     |
| <b>15</b>                   | 2.05     | 2.73     | 2.27     | 0.52     |
| <b>16</b>                   | 2.05     | 2.72     | 2.22     | 0.52     |
| <b>17</b>                   | 2.03     | 2.73     | 2.19     | 0.53     |
| <b>18</b>                   | 2.05     | 2.73     | 2.25     | 0.53     |
| <b>19</b>                   | 2.04     | 2.72     | 2.18     | 0.53     |
| <b>20</b>                   | 2.03     | 2.73     | 2.14     | 0.52     |
| <b>21</b>                   | 2.06     | 2.74     | 2.21     | 0.52     |
| <b>22</b>                   | 2.06     | 2.74     | 2.19     | 0.53     |
| <b>23</b>                   | 2.03     | 2.70     | 2.25     | 0.52     |
| <b>24</b>                   | 2.06     | 2.75     | 2.21     | 0.53     |
| <b>25</b>                   | 2.04     | 2.72     | 2.22     | 0.53     |
| <b>26</b>                   | 2.04     | 2.71     | 2.23     | 0.52     |
| <b>27</b>                   | 2.06     | 2.75     | 2.18     | 0.53     |
| <b>28</b>                   | 2.03     | 2.69     | 2.22     | 0.53     |
| <b>29</b>                   | 2.05     | 2.72     | 2.27     | 0.53     |
| <b>Average</b>              | 2.05     | 2.73     | 2.21     | 0.53     |

### Repeatability 1 LRT -Average Response Time (ms) Distribution Graph

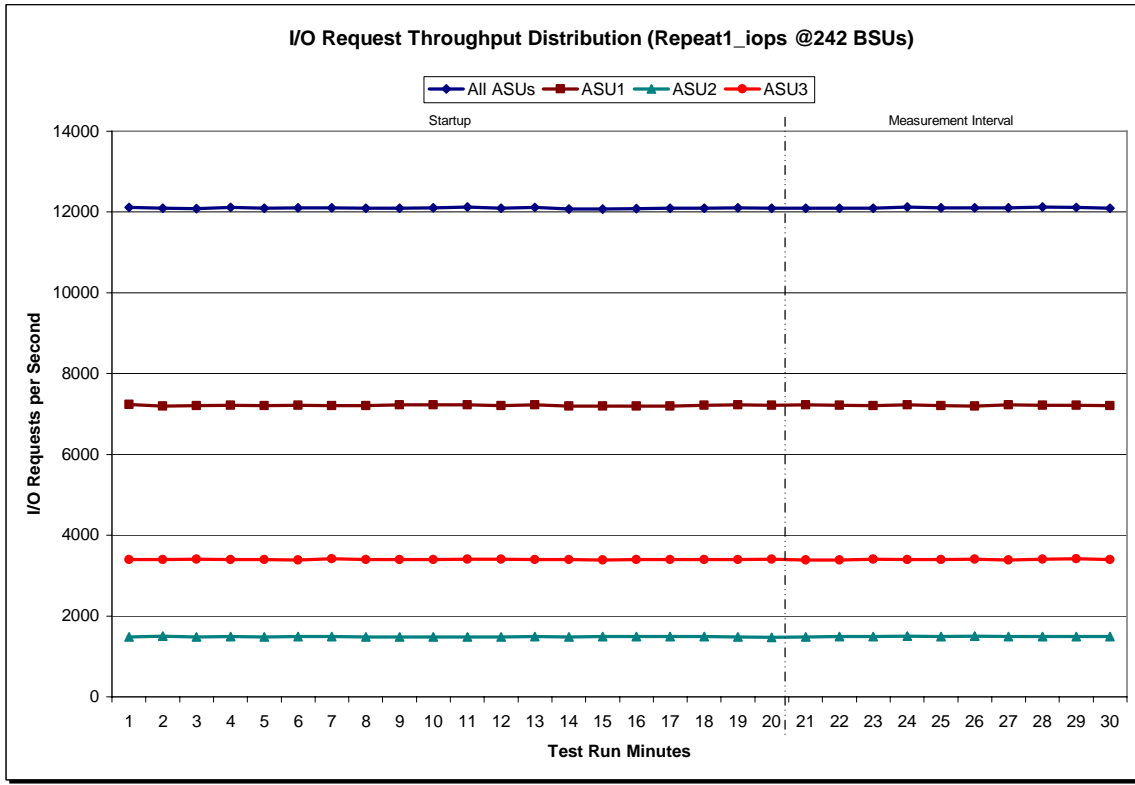




**Repeatability 1 IOPS - I/O Request Throughput Distribution Data**

| 242 BSUs                    | Start     | Stop     | Interval | Duration |
|-----------------------------|-----------|----------|----------|----------|
| <i>Start-Up/Ramp-Up</i>     | 16:37:43  | 16:57:44 | 0-19     | 0:20:01  |
| <i>Measurement Interval</i> | 16:57:44  | 17:07:44 | 20-29    | 0:10:00  |
| 60 second intervals         | All ASUs  | ASU1     | ASU2     | ASU3     |
| <b>0</b>                    | 12,116.15 | 7,233.07 | 1,483.03 | 3,400.05 |
| <b>1</b>                    | 12,099.40 | 7,197.43 | 1,501.07 | 3,400.90 |
| <b>2</b>                    | 12,086.50 | 7,202.42 | 1,481.42 | 3,402.67 |
| <b>3</b>                    | 12,115.68 | 7,218.35 | 1,496.03 | 3,401.30 |
| <b>4</b>                    | 12,090.17 | 7,206.43 | 1,483.58 | 3,400.15 |
| <b>5</b>                    | 12,105.07 | 7,221.55 | 1,495.33 | 3,388.18 |
| <b>6</b>                    | 12,106.50 | 7,203.18 | 1,491.10 | 3,412.22 |
| <b>7</b>                    | 12,091.97 | 7,211.25 | 1,482.52 | 3,398.20 |
| <b>8</b>                    | 12,098.95 | 7,224.30 | 1,480.28 | 3,394.37 |
| <b>9</b>                    | 12,107.65 | 7,223.10 | 1,483.42 | 3,401.13 |
| <b>10</b>                   | 12,122.20 | 7,230.62 | 1,482.55 | 3,409.03 |
| <b>11</b>                   | 12,093.15 | 7,204.87 | 1,481.57 | 3,406.72 |
| <b>12</b>                   | 12,119.25 | 7,229.37 | 1,490.30 | 3,399.58 |
| <b>13</b>                   | 12,079.38 | 7,192.03 | 1,486.23 | 3,401.12 |
| <b>14</b>                   | 12,073.23 | 7,195.97 | 1,489.23 | 3,388.03 |
| <b>15</b>                   | 12,080.78 | 7,200.90 | 1,488.23 | 3,391.65 |
| <b>16</b>                   | 12,094.98 | 7,201.17 | 1,494.63 | 3,399.18 |
| <b>17</b>                   | 12,098.62 | 7,211.87 | 1,488.10 | 3,398.65 |
| <b>18</b>                   | 12,103.82 | 7,222.80 | 1,481.40 | 3,399.62 |
| <b>19</b>                   | 12,098.95 | 7,219.15 | 1,473.88 | 3,405.92 |
| <b>20</b>                   | 12,090.58 | 7,222.95 | 1,479.93 | 3,387.70 |
| <b>21</b>                   | 12,098.18 | 7,221.10 | 1,487.12 | 3,389.97 |
| <b>22</b>                   | 12,096.33 | 7,203.88 | 1,489.62 | 3,402.83 |
| <b>23</b>                   | 12,124.30 | 7,231.28 | 1,497.18 | 3,395.83 |
| <b>24</b>                   | 12,103.58 | 7,211.40 | 1,495.88 | 3,396.30 |
| <b>25</b>                   | 12,106.30 | 7,196.87 | 1,498.33 | 3,411.10 |
| <b>26</b>                   | 12,107.92 | 7,227.35 | 1,491.95 | 3,388.62 |
| <b>27</b>                   | 12,121.12 | 7,219.53 | 1,494.48 | 3,407.10 |
| <b>28</b>                   | 12,120.20 | 7,215.72 | 1,491.80 | 3,412.68 |
| <b>29</b>                   | 12,096.18 | 7,204.35 | 1,492.22 | 3,399.62 |
| <b>Average</b>              | 12,106.47 | 7,215.44 | 1,491.85 | 3,399.18 |

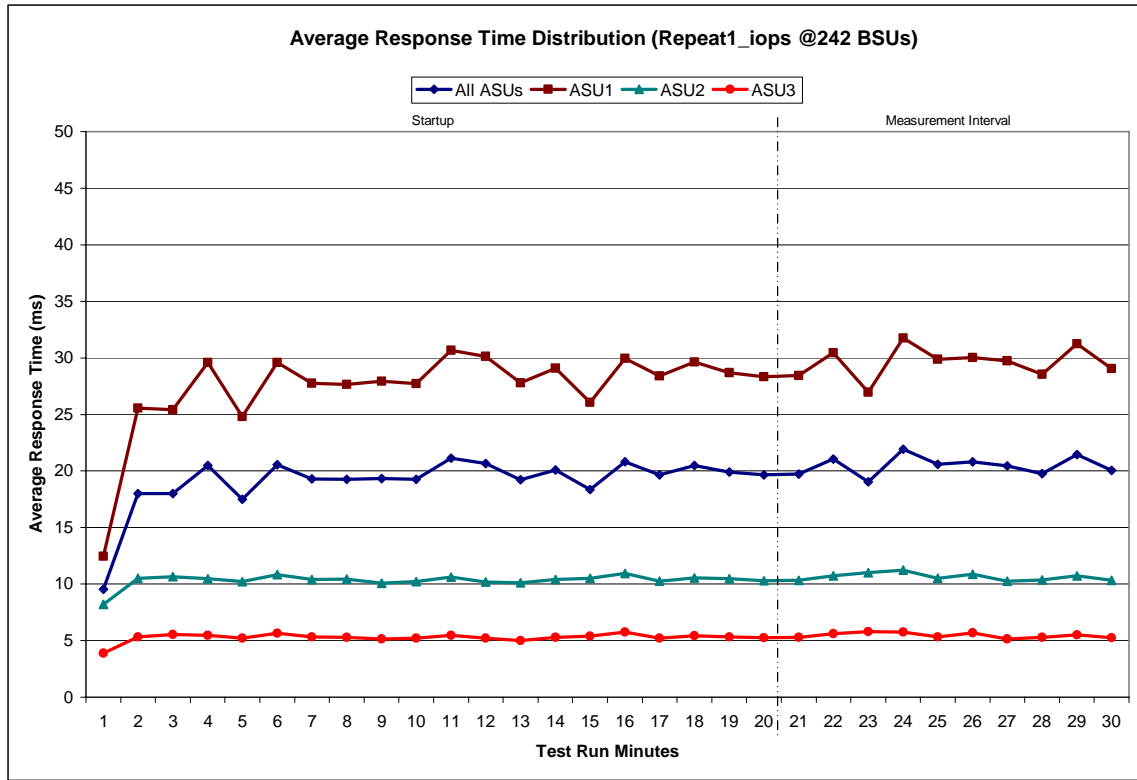
### Repeatability 1 IOPS - I/O Request Throughput Distribution Graph



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

| 242 BSUs                    | Start    | Stop     | Interval | Duration |
|-----------------------------|----------|----------|----------|----------|
| <i>Start-Up/Ramp-Up</i>     | 16:37:43 | 16:57:44 | 0-19     | 0:20:01  |
| <i>Measurement Interval</i> | 16:57:44 | 17:07:44 | 20-29    | 0:10:00  |
| 60 second intervals         | All ASUs | ASU1     | ASU2     | ASU3     |
| 0                           | 9.52     | 12.45    | 8.20     | 3.88     |
| 1                           | 18.01    | 25.57    | 10.50    | 5.34     |
| 2                           | 18.00    | 25.40    | 10.65    | 5.54     |
| 3                           | 20.47    | 29.60    | 10.49    | 5.48     |
| 4                           | 17.51    | 24.82    | 10.22    | 5.20     |
| 5                           | 20.57    | 29.59    | 10.83    | 5.64     |
| 6                           | 19.30    | 27.77    | 10.40    | 5.33     |
| 7                           | 19.25    | 27.63    | 10.44    | 5.31     |
| 8                           | 19.35    | 27.92    | 10.09    | 5.14     |
| 9                           | 19.25    | 27.71    | 10.24    | 5.21     |
| 10                          | 21.14    | 30.67    | 10.63    | 5.49     |
| 11                          | 20.66    | 30.12    | 10.19    | 5.21     |
| 12                          | 19.24    | 27.80    | 10.12    | 5.01     |
| 13                          | 20.09    | 29.09    | 10.42    | 5.30     |
| 14                          | 18.35    | 26.07    | 10.51    | 5.39     |
| 15                          | 20.81    | 29.94    | 10.93    | 5.76     |
| 16                          | 19.64    | 28.39    | 10.26    | 5.23     |
| 17                          | 20.49    | 29.62    | 10.55    | 5.45     |
| 18                          | 19.91    | 28.70    | 10.49    | 5.34     |
| 19                          | 19.64    | 28.33    | 10.29    | 5.27     |
| 20                          | 19.74    | 28.45    | 10.35    | 5.28     |
| 21                          | 21.07    | 30.45    | 10.74    | 5.62     |
| 22                          | 19.05    | 26.98    | 11.00    | 5.80     |
| 23                          | 21.94    | 31.75    | 11.23    | 5.76     |
| 24                          | 20.59    | 29.87    | 10.50    | 5.34     |
| 25                          | 20.79    | 30.02    | 10.87    | 5.68     |
| 26                          | 20.46    | 29.73    | 10.25    | 5.17     |
| 27                          | 19.77    | 28.55    | 10.36    | 5.30     |
| 28                          | 21.47    | 31.24    | 10.72    | 5.52     |
| 29                          | 20.05    | 29.04    | 10.34    | 5.26     |
| <b>Average</b>              | 20.49    | 29.61    | 10.63    | 5.47     |

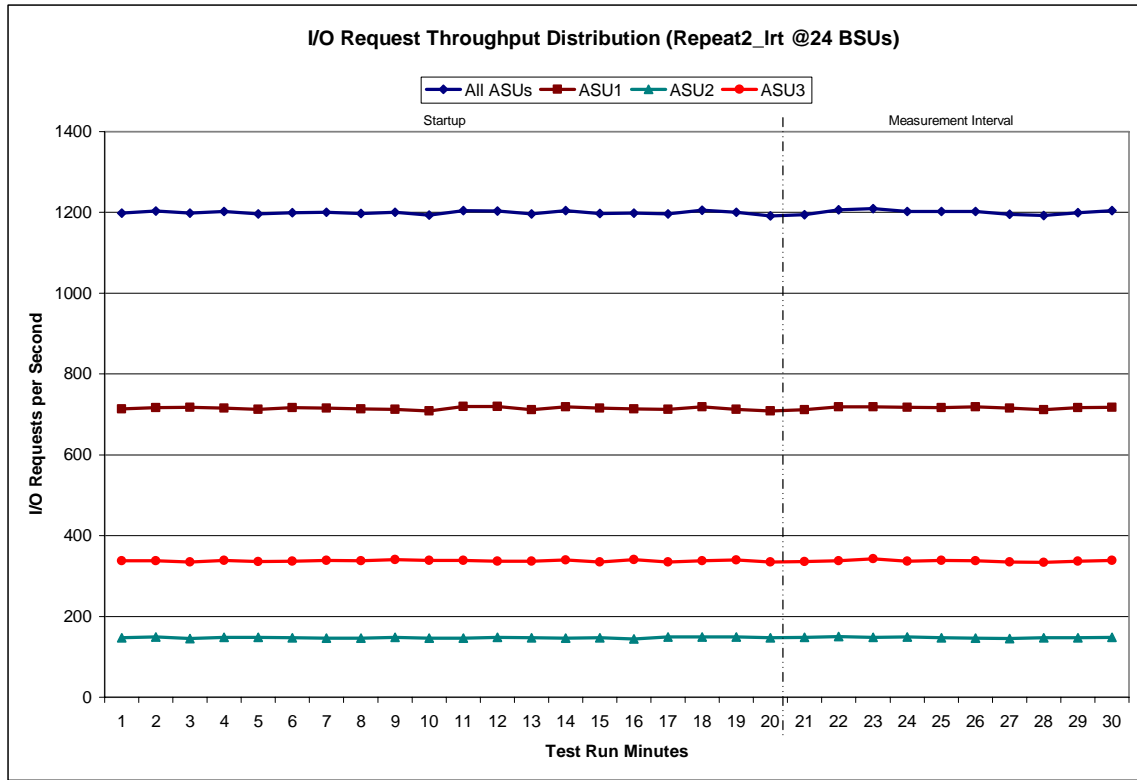
### Repeatability 1 IOPS –Average Response Time (ms) Distribution Graph



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

| 24 BSUs                     | Start    | Stop     | Interval | Duration |
|-----------------------------|----------|----------|----------|----------|
| <i>Start-Up/Ramp-Up</i>     | 17:07:52 | 17:27:52 | 0-19     | 0:20:00  |
| <i>Measurement Interval</i> | 17:27:52 | 17:37:52 | 20-29    | 0:10:00  |
| 60 second intervals         | All ASUs | ASU1     | ASU2     | ASU3     |
| <b>0</b>                    | 1,198.30 | 713.93   | 146.93   | 337.43   |
| <b>1</b>                    | 1,203.03 | 716.92   | 148.93   | 337.18   |
| <b>2</b>                    | 1,198.10 | 718.05   | 145.62   | 334.43   |
| <b>3</b>                    | 1,202.65 | 716.03   | 148.18   | 338.43   |
| <b>4</b>                    | 1,196.07 | 712.42   | 148.22   | 335.43   |
| <b>5</b>                    | 1,199.87 | 716.13   | 147.03   | 336.70   |
| <b>6</b>                    | 1,200.38 | 715.75   | 145.75   | 338.88   |
| <b>7</b>                    | 1,197.12 | 713.72   | 146.23   | 337.17   |
| <b>8</b>                    | 1,200.87 | 712.23   | 148.28   | 340.35   |
| <b>9</b>                    | 1,193.50 | 708.38   | 146.05   | 339.07   |
| <b>10</b>                   | 1,204.48 | 719.32   | 146.65   | 338.52   |
| <b>11</b>                   | 1,203.87 | 719.55   | 148.17   | 336.15   |
| <b>12</b>                   | 1,196.20 | 711.93   | 147.30   | 336.97   |
| <b>13</b>                   | 1,204.62 | 718.65   | 145.97   | 340.00   |
| <b>14</b>                   | 1,197.38 | 715.38   | 147.43   | 334.57   |
| <b>15</b>                   | 1,198.68 | 713.80   | 144.62   | 340.27   |
| <b>16</b>                   | 1,195.92 | 712.33   | 149.25   | 334.33   |
| <b>17</b>                   | 1,205.25 | 718.70   | 149.40   | 337.15   |
| <b>18</b>                   | 1,200.77 | 712.30   | 148.93   | 339.53   |
| <b>19</b>                   | 1,191.42 | 708.75   | 147.62   | 335.05   |
| <b>20</b>                   | 1,194.53 | 711.33   | 148.07   | 335.13   |
| <b>21</b>                   | 1,206.25 | 718.95   | 149.75   | 337.55   |
| <b>22</b>                   | 1,209.30 | 718.50   | 147.92   | 342.88   |
| <b>23</b>                   | 1,202.35 | 717.15   | 148.80   | 336.40   |
| <b>24</b>                   | 1,202.45 | 717.07   | 147.10   | 338.28   |
| <b>25</b>                   | 1,202.10 | 718.27   | 146.33   | 337.50   |
| <b>26</b>                   | 1,195.87 | 715.25   | 145.57   | 335.05   |
| <b>27</b>                   | 1,192.43 | 711.48   | 147.40   | 333.55   |
| <b>28</b>                   | 1,199.37 | 716.25   | 146.95   | 336.17   |
| <b>29</b>                   | 1,204.38 | 717.63   | 148.35   | 338.40   |
| <b>Average</b>              | 1,200.90 | 716.19   | 147.62   | 337.09   |

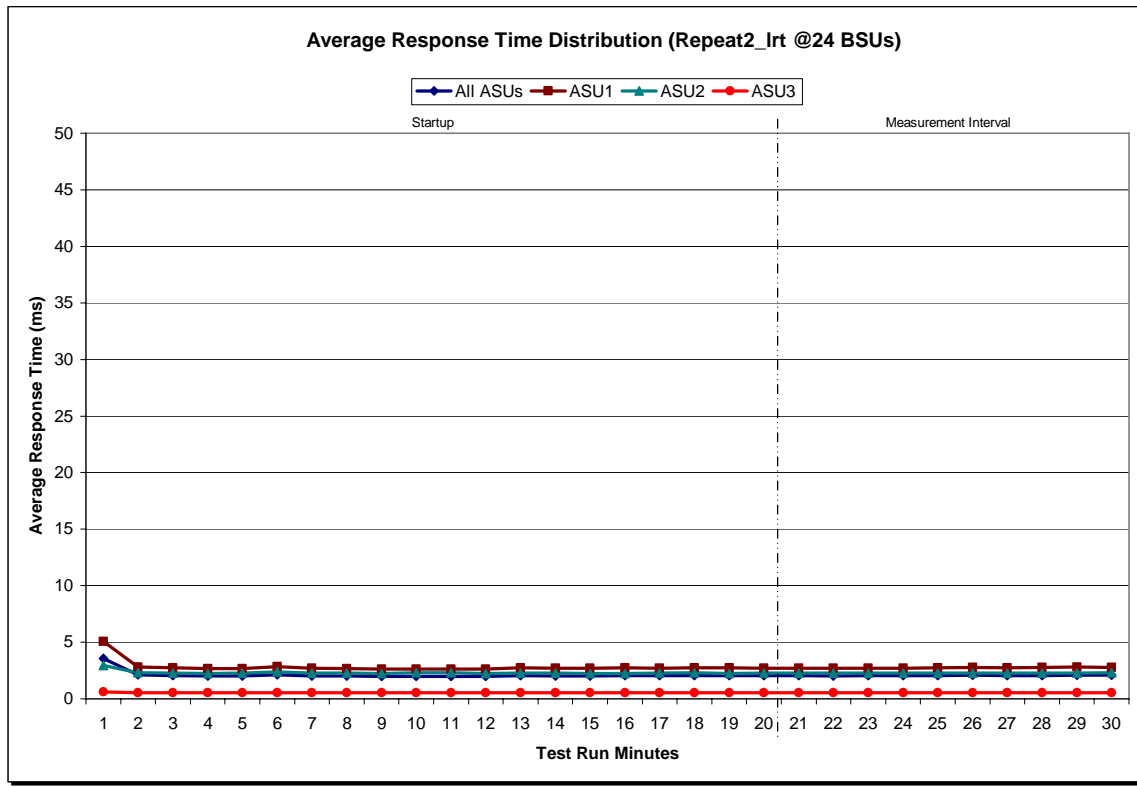
### Repeatability 2 LRT - I/O Request Throughput Distribution Graph



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

| 24 BSUs                     | Start    | Stop     | Interval | Duration |
|-----------------------------|----------|----------|----------|----------|
| <i>Start-Up/Ramp-Up</i>     | 17:07:52 | 17:27:52 | 0-19     | 0:20:00  |
| <i>Measurement Interval</i> | 17:27:52 | 17:37:52 | 20-29    | 0:10:00  |
| 60 second intervals         | All ASUs | ASU1     | ASU2     | ASU3     |
| 0                           | 3.56     | 5.08     | 2.96     | 0.60     |
| 1                           | 2.11     | 2.81     | 2.29     | 0.53     |
| 2                           | 2.06     | 2.73     | 2.28     | 0.53     |
| 3                           | 2.00     | 2.65     | 2.23     | 0.52     |
| 4                           | 2.01     | 2.66     | 2.28     | 0.52     |
| 5                           | 2.13     | 2.83     | 2.37     | 0.53     |
| 6                           | 2.03     | 2.70     | 2.27     | 0.53     |
| 7                           | 2.02     | 2.67     | 2.28     | 0.52     |
| 8                           | 1.99     | 2.63     | 2.24     | 0.53     |
| 9                           | 1.99     | 2.63     | 2.30     | 0.52     |
| 10                          | 2.00     | 2.63     | 2.30     | 0.53     |
| 11                          | 1.99     | 2.63     | 2.24     | 0.52     |
| 12                          | 2.05     | 2.72     | 2.28     | 0.53     |
| 13                          | 2.03     | 2.69     | 2.26     | 0.53     |
| 14                          | 2.03     | 2.70     | 2.24     | 0.53     |
| 15                          | 2.04     | 2.72     | 2.23     | 0.53     |
| 16                          | 2.04     | 2.71     | 2.25     | 0.53     |
| 17                          | 2.06     | 2.74     | 2.31     | 0.53     |
| 18                          | 2.05     | 2.73     | 2.25     | 0.53     |
| 19                          | 2.04     | 2.70     | 2.27     | 0.53     |
| 20                          | 2.05     | 2.72     | 2.27     | 0.53     |
| 21                          | 2.03     | 2.69     | 2.28     | 0.53     |
| 22                          | 2.04     | 2.72     | 2.27     | 0.53     |
| 23                          | 2.04     | 2.71     | 2.28     | 0.53     |
| 24                          | 2.05     | 2.72     | 2.27     | 0.53     |
| 25                          | 2.08     | 2.77     | 2.26     | 0.53     |
| 26                          | 2.06     | 2.75     | 2.26     | 0.52     |
| 27                          | 2.07     | 2.75     | 2.26     | 0.52     |
| 28                          | 2.09     | 2.79     | 2.28     | 0.53     |
| 29                          | 2.09     | 2.78     | 2.30     | 0.53     |
| <b>Average</b>              | 2.06     | 2.74     | 2.27     | 0.53     |

### Repeatability 2 LRT -Average Response Time (ms) Distribution Graph

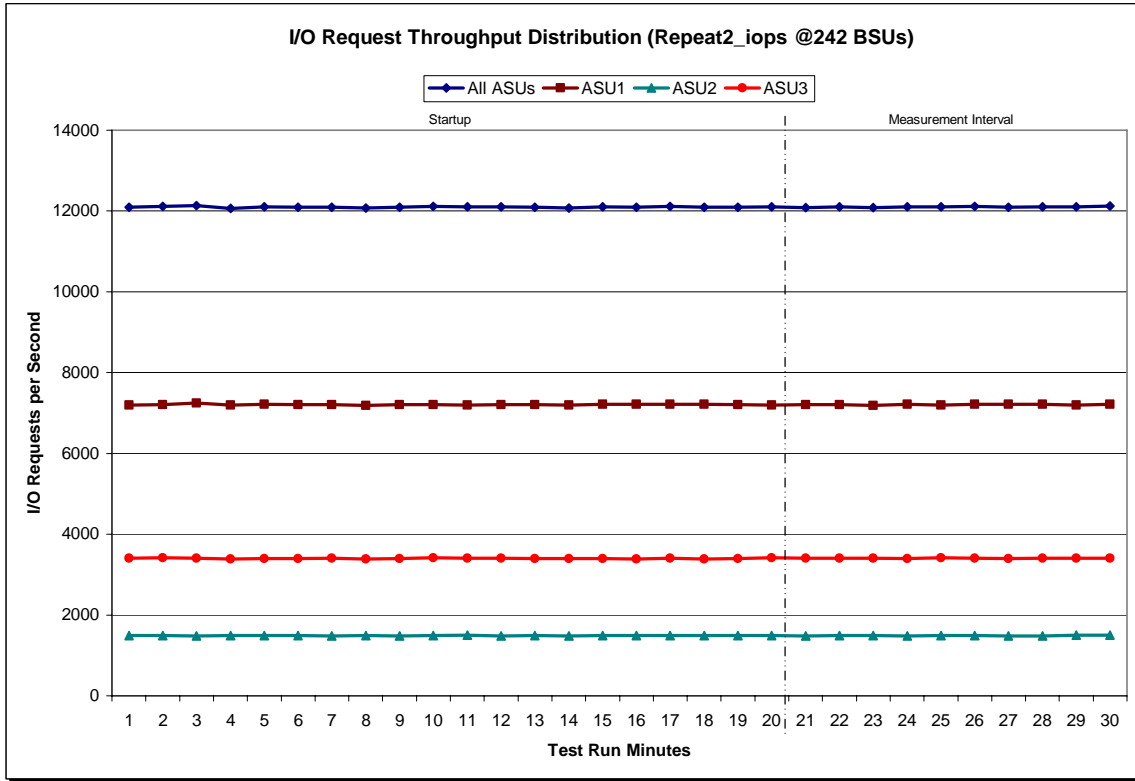




**Repeatability 2 IOPS - I/O Request Throughput Distribution Data**

| 242 BSUs                    | Start     | Stop     | Interval | Duration |
|-----------------------------|-----------|----------|----------|----------|
| <i>Start-Up/Ramp-Up</i>     | 17:37:56  | 17:57:57 | 0-19     | 0:20:01  |
| <i>Measurement Interval</i> | 17:57:57  | 18:07:57 | 20-29    | 0:10:00  |
| 60 second intervals         | All ASUs  | ASU1     | ASU2     | ASU3     |
| <b>0</b>                    | 12,093.73 | 7,196.97 | 1,490.35 | 3,406.42 |
| <b>1</b>                    | 12,113.28 | 7,209.17 | 1,490.55 | 3,413.57 |
| <b>2</b>                    | 12,134.72 | 7,243.17 | 1,486.47 | 3,405.08 |
| <b>3</b>                    | 12,068.25 | 7,193.63 | 1,486.68 | 3,387.93 |
| <b>4</b>                    | 12,107.02 | 7,217.62 | 1,491.10 | 3,398.30 |
| <b>5</b>                    | 12,097.45 | 7,211.05 | 1,487.82 | 3,398.58 |
| <b>6</b>                    | 12,099.72 | 7,210.37 | 1,485.43 | 3,403.92 |
| <b>7</b>                    | 12,070.57 | 7,191.45 | 1,489.15 | 3,389.97 |
| <b>8</b>                    | 12,091.87 | 7,207.35 | 1,485.75 | 3,398.77 |
| <b>9</b>                    | 12,113.88 | 7,209.60 | 1,489.68 | 3,414.60 |
| <b>10</b>                   | 12,106.07 | 7,197.23 | 1,498.03 | 3,410.80 |
| <b>11</b>                   | 12,101.25 | 7,207.85 | 1,483.17 | 3,410.23 |
| <b>12</b>                   | 12,096.93 | 7,211.30 | 1,491.18 | 3,394.45 |
| <b>13</b>                   | 12,079.33 | 7,197.58 | 1,484.70 | 3,397.05 |
| <b>14</b>                   | 12,101.75 | 7,212.25 | 1,488.48 | 3,401.02 |
| <b>15</b>                   | 12,097.20 | 7,215.00 | 1,491.40 | 3,390.80 |
| <b>16</b>                   | 12,111.87 | 7,213.60 | 1,489.43 | 3,408.83 |
| <b>17</b>                   | 12,097.00 | 7,220.08 | 1,492.15 | 3,384.77 |
| <b>18</b>                   | 12,092.90 | 7,202.60 | 1,493.53 | 3,396.77 |
| <b>19</b>                   | 12,107.38 | 7,201.33 | 1,491.78 | 3,414.27 |
| <b>20</b>                   | 12,085.80 | 7,203.07 | 1,480.83 | 3,401.90 |
| <b>21</b>                   | 12,106.37 | 7,203.23 | 1,491.82 | 3,411.32 |
| <b>22</b>                   | 12,084.32 | 7,189.67 | 1,488.28 | 3,406.37 |
| <b>23</b>                   | 12,104.55 | 7,221.53 | 1,483.27 | 3,399.75 |
| <b>24</b>                   | 12,100.98 | 7,199.70 | 1,489.30 | 3,411.98 |
| <b>25</b>                   | 12,111.33 | 7,214.97 | 1,489.07 | 3,407.30 |
| <b>26</b>                   | 12,096.13 | 7,217.42 | 1,485.48 | 3,393.23 |
| <b>27</b>                   | 12,104.20 | 7,219.33 | 1,479.52 | 3,405.35 |
| <b>28</b>                   | 12,105.43 | 7,201.13 | 1,497.65 | 3,406.65 |
| <b>29</b>                   | 12,123.67 | 7,216.38 | 1,499.55 | 3,407.73 |
| <b>Average</b>              | 12,102.28 | 7,208.64 | 1,488.48 | 3,405.16 |

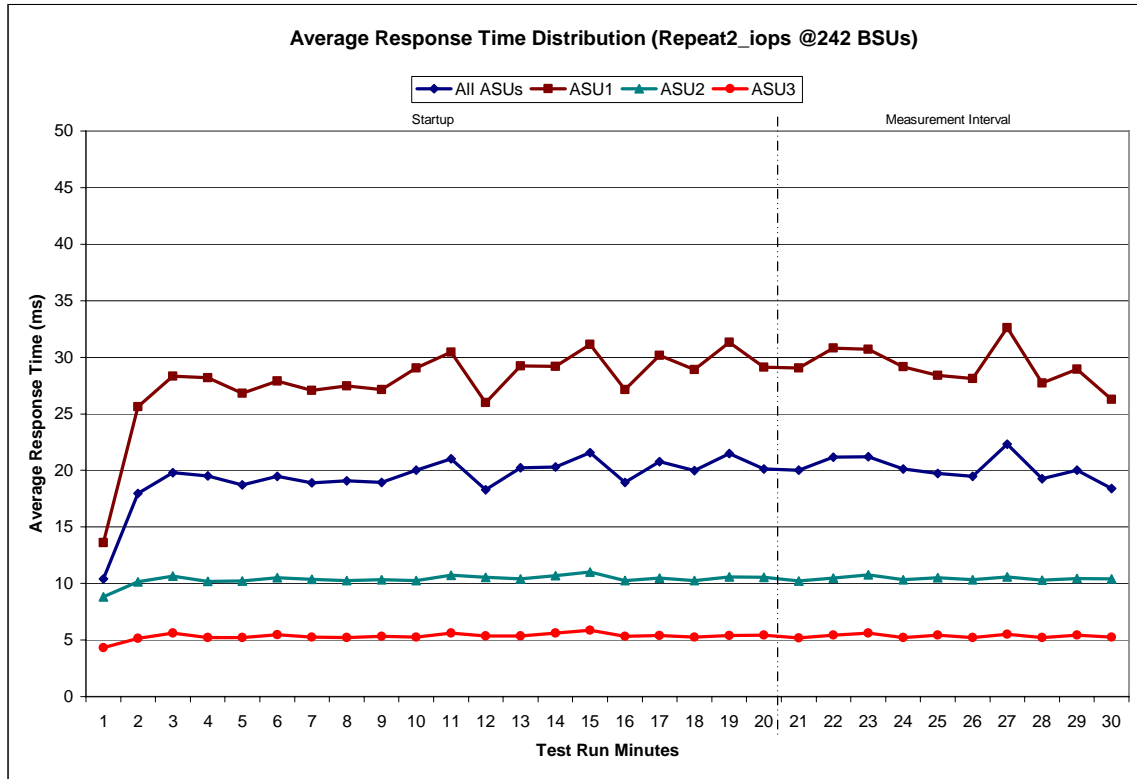
### Repeatability 2 IOPS - I/O Request Throughput Distribution Graph



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

| 242 BSUs                    | Start    | Stop     | Interval | Duration |
|-----------------------------|----------|----------|----------|----------|
| <i>Start-Up/Ramp-Up</i>     | 17:37:56 | 17:57:57 | 0-19     | 0:20:01  |
| <i>Measurement Interval</i> | 17:57:57 | 18:07:57 | 20-29    | 0:10:00  |
| 60 second intervals         | All ASUs | ASU1     | ASU2     | ASU3     |
| <b>0</b>                    | 10.40    | 13.62    | 8.81     | 4.30     |
| <b>1</b>                    | 17.96    | 25.63    | 10.17    | 5.16     |
| <b>2</b>                    | 19.79    | 28.32    | 10.67    | 5.62     |
| <b>3</b>                    | 19.51    | 28.18    | 10.19    | 5.20     |
| <b>4</b>                    | 18.71    | 26.82    | 10.21    | 5.23     |
| <b>5</b>                    | 19.46    | 27.91    | 10.50    | 5.48     |
| <b>6</b>                    | 18.89    | 27.07    | 10.38    | 5.26     |
| <b>7</b>                    | 19.09    | 27.45    | 10.27    | 5.23     |
| <b>8</b>                    | 18.95    | 27.15    | 10.33    | 5.33     |
| <b>9</b>                    | 20.03    | 29.05    | 10.26    | 5.25     |
| <b>10</b>                   | 21.03    | 30.47    | 10.74    | 5.63     |
| <b>11</b>                   | 18.28    | 25.99    | 10.56    | 5.35     |
| <b>12</b>                   | 20.21    | 29.23    | 10.39    | 5.36     |
| <b>13</b>                   | 20.30    | 29.21    | 10.70    | 5.61     |
| <b>14</b>                   | 21.55    | 31.12    | 11.00    | 5.88     |
| <b>15</b>                   | 18.94    | 27.13    | 10.25    | 5.33     |
| <b>16</b>                   | 20.76    | 30.15    | 10.47    | 5.40     |
| <b>17</b>                   | 20.00    | 28.92    | 10.27    | 5.25     |
| <b>18</b>                   | 21.48    | 31.32    | 10.58    | 5.42     |
| <b>19</b>                   | 20.14    | 29.11    | 10.55    | 5.42     |
| <b>20</b>                   | 20.03    | 29.05    | 10.22    | 5.18     |
| <b>21</b>                   | 21.16    | 30.82    | 10.47    | 5.45     |
| <b>22</b>                   | 21.19    | 30.71    | 10.75    | 5.63     |
| <b>23</b>                   | 20.12    | 29.14    | 10.35    | 5.23     |
| <b>24</b>                   | 19.72    | 28.39    | 10.51    | 5.43     |
| <b>25</b>                   | 19.49    | 28.11    | 10.31    | 5.22     |
| <b>26</b>                   | 22.31    | 32.62    | 10.57    | 5.52     |
| <b>27</b>                   | 19.26    | 27.72    | 10.30    | 5.21     |
| <b>28</b>                   | 20.03    | 28.93    | 10.45    | 5.42     |
| <b>29</b>                   | 18.40    | 26.26    | 10.42    | 5.27     |
| <b>Average</b>              | 20.17    | 29.18    | 10.44    | 5.36     |

### Repeatability 2 IOPS - Average Response Time (ms) Distribution Graph



**Repeatability 1 (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 | .0351  | .2823  | .0699  | .2089  | .0180  | .0702  | .0350  | .2807  |
| COV | .0176  | .0063  | .0141  | .0058  | .0389  | .0150  | .0212  | .0065  |

**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.

**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%.

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

**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 | .0350  | .2811  | .0701  | .2099  | .0181  | .0700  | .0351  | .2808  |
| COV | .0079  | .0015  | .0045  | .0036  | .0109  | .0042  | .0067  | .0024  |

**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 | .0349  | .2820  | .0699  | .2096  | .0183  | .0700  | .0346  | .2807  |
| COV | .0186  | .0043  | .0202  | .0088  | .0258  | .0144  | .0184  | .0040  |

**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 | .0350  | .2808  | .0701  | .2098  | .0180  | .0699  | .0351  | .2814  |
| COV | .0062  | .0020  | .0049  | .0016  | .0093  | .0058  | .0048  | .0016  |

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

### Clause 9.2.4.8

*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, able illustrating key results. The content, appearance, and format of this table are specified in Table 9-12. Information displayed in this table shall be obtained from the Test Run Results File referenced below in #3.*
3. *For the successful Data Persistence Test Run, the human readable Test Run Results File produced by the Workload Generator.*

## SPC-1 Workload Generator Input Parameters

The SPC-1 Workload Generator input parameters for the Data Persistence Test are listed below.

```
java -Xmx256m -Xms256m persist1 -b 242  
java -Xmx256m -Xms256m persist2
```

## 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                   | 28,811,248 |
| Total Number of Logical Blocks Verified                  | 22,708,176 |
| 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.

## **TESTED STORAGE CONFIGURATION (TSC) AVAILABILITY DATE**

### **Clause 9.2.4.9**

*The FDR shall state: "The Tested Storage Configuration, as documented in this Full Disclosure Report will be available for shipment to customers on MM DD YY." Where Tested Storage Configuration is the TSC Configuration Name as described in Clause 9.2.4.3.3 and MM is month, DD is the day, and YY is the year of the date that the configuration, as documented, is available for shipment to customers.*

The IBM TotalStorage DS4300 with Turbo Option (*non-mirrored write cache*), as documented in this Full Disclosure Report will become available for customer purchase and shipment on September 12, 2003.

## **PRICING INFORMATION**

### **Clause 9.2.4.11**

*A statement of the respective calculations for pricing must be included.*

Pricing information may found in the Tested Storage Configuration Pricing section on page 13.

## **ANOMALIES OR IRREGULARITIES**

### **Clause 9.2.4.10**

*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 observed during the course of the benchmark measurement of the IBM TotalStorage DS4300 with Turbo Option (*non-mirrored cache*).



## **APPENDIX A: TSC CONFIGURATION SCRIPT**

```

/* SPC-1 configuration script */
/* for the 2882 with 54 drives. */

set controller[a] mode = active;
set controller[b] mode = active;

create volume drives[ 0,1 0,2 0,3 0,4 0,5 0,6 0,7 0,8 0,9 0,10 0,11 0,12 0,13 0,14 1,1
                    1,2 1,3 1,4 1,5 1,6 1,7 1,8 1,9 1,10 1,11 1,12 1,13 1,14 2,1 2,2 ]
RAIDLevel=1
segmentSize=128
userLabel="LUN 0"
capacity=205324mb
owner = A;

create volume drives[ 2,3 2,4 2,5 2,6 2,7 2,8
                    2,9 2,10 2,11 2,12 2,13 2,14 ]
RAIDLevel=1
segmentSize=512
userLabel="LUN 1"
capacity=205324mb
owner = b;

create volume drives[ 3,1 3,2 3,3 3,4 3,5 3,6
                    3,7 3,8 3,9 3,10 3,11 3,12 ]
RAIDLevel=1
segmentSize=64
userLabel="LUN 2"
capacity=45628mb
owner = b;

set volume["LUN 0"] mirrorEnabled = False writeCacheEnabled = True cacheWithoutBatteryEnabled = False readAheadMultiplier = 0;
set volume["LUN 1"] mirrorEnabled = False writeCacheEnabled = True cacheWithoutBatteryEnabled = False readAheadMultiplier = 0;
set volume["LUN 2"] mirrorEnabled = False writeCacheEnabled = True cacheWithoutBatteryEnabled = False readAheadMultiplier = 0;

set storageArray cacheFlushStop = 70 cacheFlushStart = 70;

set storageArray defaultHostType = "Windows 2000/Server 2003 Non-Clustered";

set controller[a] HostNVSARAMByte[0x01, 0x17]=0x01;
set controller[b] HostNVSARAMByte[0x01, 0x17]=0x01;

/* Setup for RDAC failover environment */

set controller[a] HostNVSARAMByte[0x00, 0x24]=0x00;
set controller[a] HostNVSARAMByte[0x01, 0x24]=0x00;
set controller[a] HostNVSARAMByte[0x02, 0x24]=0x00;
set controller[a] HostNVSARAMByte[0x03, 0x24]=0x00;
set controller[a] HostNVSARAMByte[0x04, 0x24]=0x00;
set controller[a] HostNVSARAMByte[0x05, 0x24]=0x00;
set controller[a] HostNVSARAMByte[0x06, 0x24]=0x00;
set controller[a] HostNVSARAMByte[0x07, 0x24]=0x00;
set controller[a] HostNVSARAMByte[0x08, 0x24]=0x00;
set controller[a] HostNVSARAMByte[0x09, 0x24]=0x00;
set controller[a] HostNVSARAMByte[0x0a, 0x24]=0x00;
set controller[a] HostNVSARAMByte[0x0b, 0x24]=0x00;
set controller[a] HostNVSARAMByte[0x0c, 0x24]=0x00;

```

set controller[a] HostNVSRAMByte[0x0d, 0x24]=0x00;  
set controller[a] HostNVSRAMByte[0x0e, 0x24]=0x00;  
set controller[a] HostNVSRAMByte[0x0f, 0x24]=0x00;

set controller[b] HostNVSRAMByte[0x00, 0x24]=0x00;  
set controller[b] HostNVSRAMByte[0x01, 0x24]=0x00;  
set controller[b] HostNVSRAMByte[0x02, 0x24]=0x00;  
set controller[b] HostNVSRAMByte[0x03, 0x24]=0x00;  
set controller[b] HostNVSRAMByte[0x04, 0x24]=0x00;  
set controller[b] HostNVSRAMByte[0x05, 0x24]=0x00;  
set controller[b] HostNVSRAMByte[0x06, 0x24]=0x00;  
set controller[b] HostNVSRAMByte[0x07, 0x24]=0x00;  
set controller[b] HostNVSRAMByte[0x08, 0x24]=0x00;  
set controller[b] HostNVSRAMByte[0x09, 0x24]=0x00;  
set controller[b] HostNVSRAMByte[0x0a, 0x24]=0x00;  
set controller[b] HostNVSRAMByte[0x0b, 0x24]=0x00;  
set controller[b] HostNVSRAMByte[0x0c, 0x24]=0x00;  
set controller[b] HostNVSRAMByte[0x0d, 0x24]=0x00;  
set controller[b] HostNVSRAMByte[0x0e, 0x24]=0x00;  
set controller[b] HostNVSRAMByte[0x0f, 0x24]=0x00;