SPC BENCHMARK 2™
FULL DISCLOSURE REPORT

NETAPP, INC.
NETAPP E-SERIES E5660 STORAGE ARRAY

SPC-2™ V1.5

Submitted for Review: September 10, 2015
Submission Identifier: B00074

First Edition – September 2015

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AUDIT CERTIFICATION

Mark Regester
NetApp, Inc.
3718 North Rock Road
Wichita, KS 67226

September 10, 2015

The SPC Benchmark 2™ Reported Data listed below for the **NetApp E-Series E5660 Storage Array** was produced in compliance with the SPC Benchmark 2™ V1.5 Remote Audit requirements.

SPC Benchmark 2™ V1.5 Reported Data	
Tested Storage Product (TSP) Name: NetApp E-Series E5660 Storage Array	
Metric	**Reported Result**
SPC-2 MBPS™	8,236.16
SPC-2 Price-Performance	$14.74/SPC-2 MBPS™
ASU Capacity	57,045.085 GB
Data Protection Level	Protected 2 *(RAID-6)*
Total Price *(including three-year maintenance)*	$121,409.42
Currency Used	U.S. Dollars
Target Country for availability, sales and support	USA

The following SPC Benchmark 2™ Remote Audit requirements were reviewed and found compliant with V1.5 of the SPC Benchmark 2™ specification:

- A Letter of Good Faith, signed by a senior executive.
- The following Data Repository storage items were verified by documentation supplied by NetApp, Inc.:
  - ✓ Physical Storage Capacity and related requirements.
  - ✓ Configured Storage Capacity and related requirements.
  - ✓ Addressable Storage Capacity and related requirements.
  - ✓ Capacity of each Logical Volume and related requirements.
  - ✓ Capacity of the Application Storage Unit (ASU) and related requirements.
- The total Application Storage Unit (ASU) Capacity was filled with random data prior to the execution of the SPC-2 Tests
- An appropriate diagram of the Benchmark Configuration (BC)/Tested Storage Configuration (TSC).

Storage Performance Council
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Redwood City, CA 94062
AuditService@StoragePerformance.org
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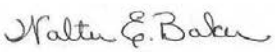
AUDIT CERTIFICATION *(CONT.)*

- Documentation supplied by NetApp, Inc. to verify the components matched the above diagram.
- Listings and commands used to create and configure the Benchmark Configuration/Tested Storage Configuration.
- Documentation that no customer tunable parameter or option was changed from its default value.
- The following Host System items were verified by documentation supplied by NetApp, Inc.:
  - ✓ Required Host System configuration information.
  - ✓ The TSC boundary within the Host System.
- The following SPC-2 Workload Generator information was verified by documentation supplied by NetApp, Inc.:
  - ✓ The presence and version number of the Workload Generator on each Host System.
  - ✓ Commands and parameters used to configure the SPC-2 Workload Generator.
- The Test Results Files and resultant Summary Results Files received from NetApp, Inc. for each of the following were authentic, accurate, and compliant with all of the requirements and constraints of Clauses 6 and 7 of the SPC-2 Benchmark Specification:
  - ✓ Data Persistence Test
  - ✓ Large File Processing Test
  - ✓ Large Database Query Test
  - ✓ Video on Demand Delivery Test
- There were no differences between the Tested Storage Configuration and Priced Storage Configuration.
- The submitted pricing information met all of the requirements and constraints of Clause 9 of the SPC-2 Benchmark Specification.
- The Full Disclosure Report (FDR) met all of the requirements in Clause 10 of the SPC-2 Benchmark Specification.
- This successfully audited SPC measurement is not subject to an SPC Confidential Review.

Audit Notes:

There were no audit notes or exceptions.

Respectfully,



Walter E. Baker
SPC Auditor

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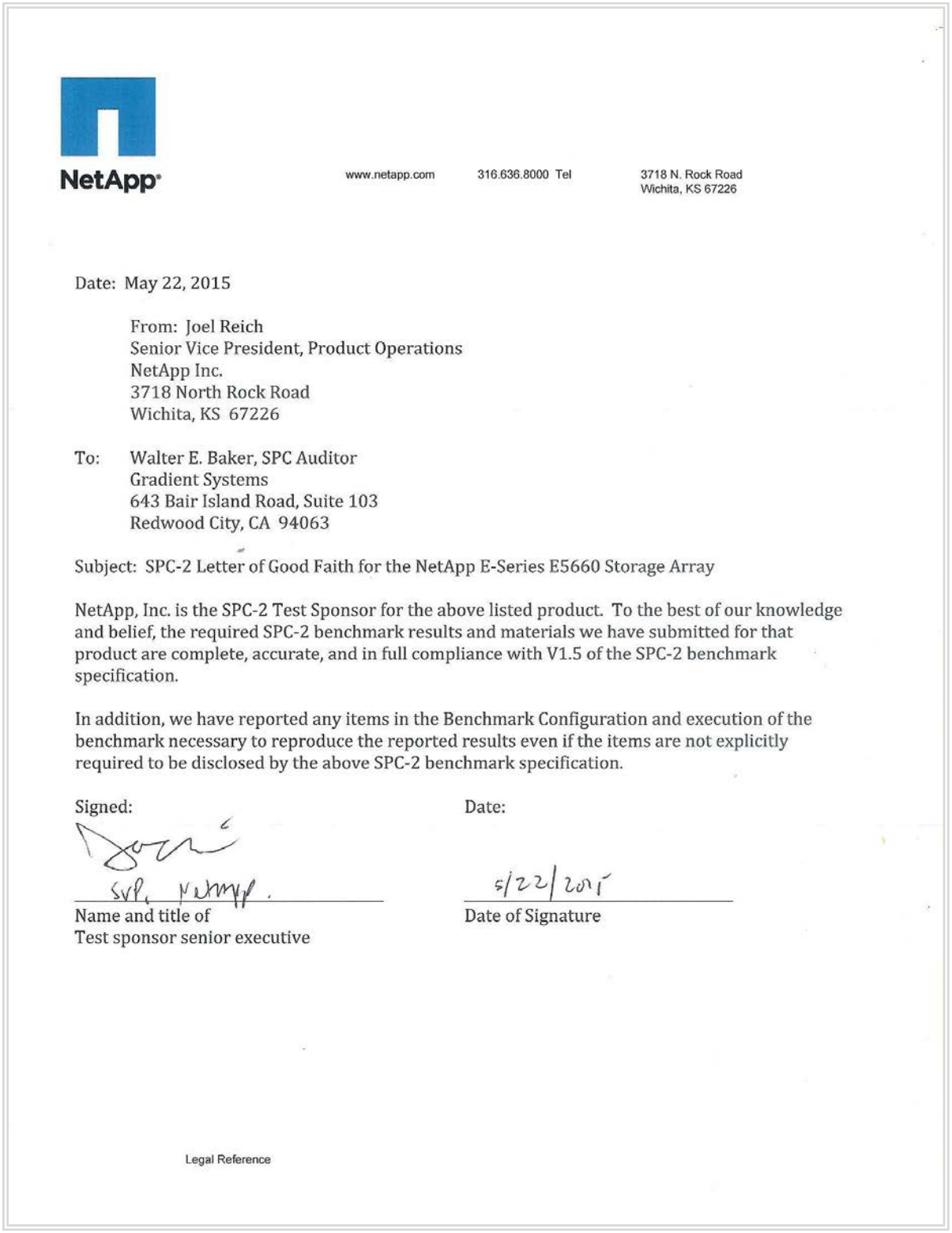
LETTER OF GOOD FAITH



NetApp

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Date: May 22, 2015

From: Joel Reich
Senior Vice President, Product Operations
NetApp Inc.
3718 North Rock Road
Wichita, KS 67226

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

Subject: SPC-2 Letter of Good Faith for the NetApp E-Series E5660 Storage Array

NetApp, Inc. is the SPC-2 Test Sponsor for the above listed product. To the best of our knowledge and belief, the required SPC-2 benchmark results and materials we have submitted for that product are complete, accurate, and in full compliance with V1.5 of the SPC-2 benchmark specification.

In addition, we have reported any items in the Benchmark Configuration and execution of the benchmark necessary to reproduce the reported results even if the items are not explicitly required to be disclosed by the above SPC-2 benchmark specification.

Signed: Date:

SVP, NetApp. 5/22/2015

Name and title of Test sponsor senior executive

Date of Signature

Legal Reference

EXECUTIVE SUMMARY

Test Sponsor and Contact Information

Test Sponsor and Contact Information	
Test Sponsor Primary Contact	NetApp, Inc. – http://www.netapp.com Mark Regester – Mark.Regester@netapp.com 3718 North Rock Road Wichita, KS 67226 Phone: (316) 636-8340
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Auditor	Storage Performance Council – http://www.storageperformance.org Walter E. Baker – AuditService@StoragePerformance.org 643 Bair Island Road, Suite 103 Redwood City, CA 94063 Phone: (650) 556-9384 FAX: (650) 556-9385

Revision Information and Key Dates

Revision Information and Key Dates	
SPC-2 Specification revision number	V1.5
SPC-2 Workload Generator revision number	V1.2
Date Results were first used publicly	September 10, 2015
Date FDR was submitted to the SPC	September 10, 2015
Date the TSC will be available for shipment to customers	currently available
Date the TSC completed audit certification	September 4, 2015

Tested Storage Product (TSP) Description

The NetApp® E5600 SAN storage array brings together extreme performance, enterprise-grade reliability and availability to create a system optimized for variety of workloads. The E5600 storage array is designed for bandwidth-intensive applications, high-performance file systems, high-IOPS databases and mixed workloads, latency-sensitive workloads – supporting them all with equal ease due to its high throughput architecture and adaptive caching algorithms.

The E5600 storage array is modular in architecture and offers flexible integrated storage (E5612, E5624, and E5660) and expansion (DE1600, DE5600, and DE6600) shelf options as per the performance, capacity, and density requirements of supported workloads. The E5600 storage array supports flexible capacity optimized, performance optimized, and latency optimized drives for storage. Additionally, the E5600 storage array can be seamlessly expanded to 384 drives to a maximum raw capacity of 2.3PB. The E5600 storage array provides flexible host interface options for direct-attached and SAN protocols – SAS, Fiber Channel, iSCSI, and Infiniband.

The E5600 storage array's core architecture has been proven in the world's most demanding and complex computing environments. Its field-proven design is the culmination of over 20 years of industry knowledge focused on designing enterprise-class storage. The fully redundant E-Series storage array is architected to provide the highest levels of enterprise-proven reliability, availability, and data protection.

SPC-2 Reported Data

SPC-2 Reported Data consists of three groups of information:

- The following SPC-2 Primary Metrics, which characterize the overall benchmark result:
  - SPC-2 MBPS™
  - SPC-2 Price Performance™
  - Application Storage Unit (ASU) Capacity
- Supplemental data to the SPC-2 Primary Metrics.
  - Total Price
  - Data Protection Level
  - Currency Used
  - Target Country
- Reported Data for each SPC Test: Large File Processing (LFP), Large Database Query (LDQ), and Video on Demand Delivery (VOD) Test.

SPC-2 MBPS™ represents the aggregate data rate, in megabytes per second, of all three SPC-2 workloads: Large File Processing (LFP), Large Database Query (LDQ), and Video on Demand (VOD).

SPC-2 Price-Performance™ is the ratio of **Total Price** to **SPC-2 MBPS™**.

ASU *(Application Storage Unit)* **Capacity** represents the total storage capacity available to be read and written in the course of executing the SPC-2 benchmark.

Total Price includes the cost of the Priced Storage Configuration plus three years of hardware maintenance and software support as detailed on page 18.

Data Protection Level of **Protected 2** using ***RAID-6***, which provides double-party RAID protection again data loss.

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

Currency Used is formal name for the currency used in calculating the **Total Price** and **SPC-2 Price-Performance™**. That currency may be the local currency of the **Target Country** or the currency of a difference country *(non-local currency).*

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

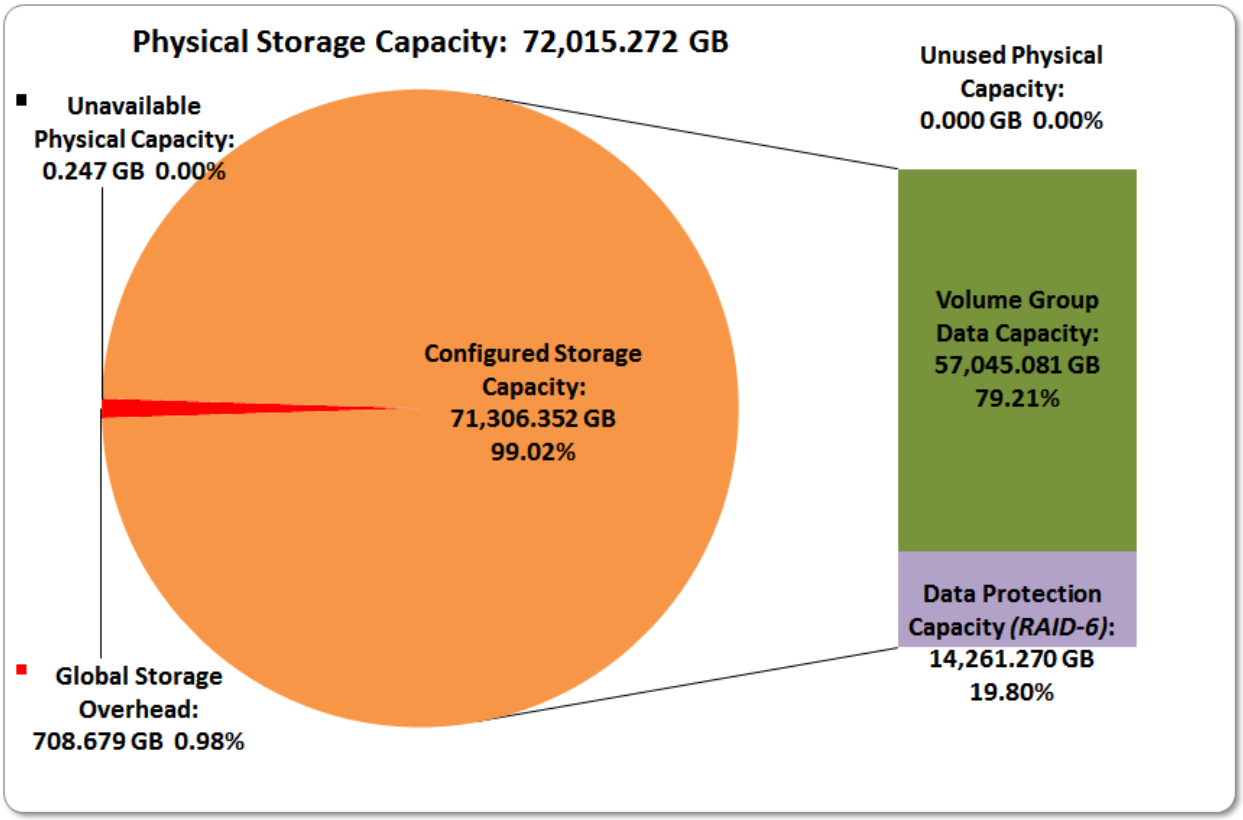
SPC-2 Reported Data *(continued)*

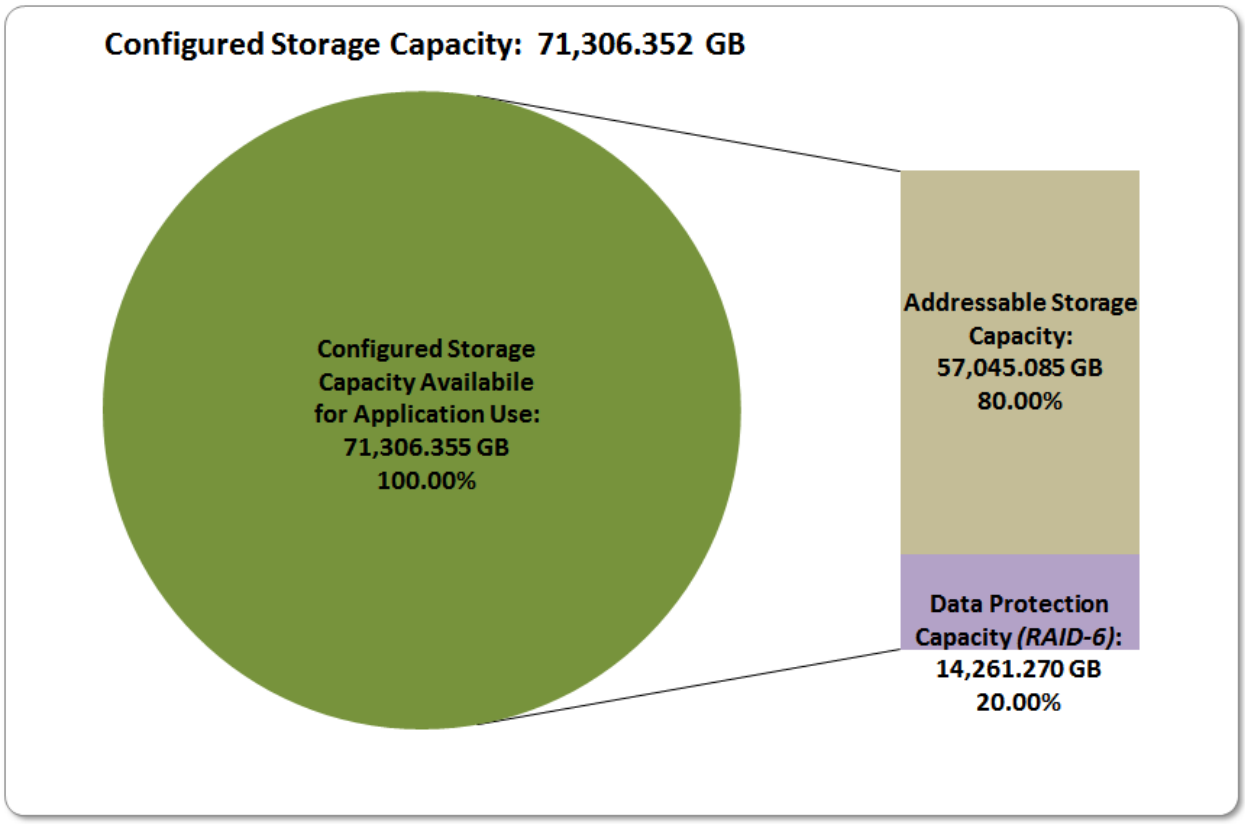
SPC-2 Reported Data				
NetApp E-Series E5660 Storage Array				
SPC-2 MBPS™	**SPC-2 Price-Performance**	**ASU Capacity (GB)**	**Total Price**	**Data Protection Level**
8,236.16	$14.74	57,045.085	$121,409.42	Protected 2 *(RAID-6)*
The above SPC-2 MBPS™ value represents the aggregate data rate of all three SPC-2 workloads: Large File Processing (LFP), Large Database Query (LDQ), and Video On Demand (VOD)				
Currency Used:		**"Target Country":**		
U.S. dollars		USA		
SPC-2 Large File Processing (LFP) Reported Data				
	Data Rate *(MB/second)*	**Number of Streams**	**Data Rate per Stream**	**Price-Performance**
LFP Composite	9,060.42			$13.40
Write Only:				
1024 KiB Transfer	6,974.15	96	72.65	
256 KiB Transfer	6,872.73	96	71.59	
Read-Write:				
1024 KiB Transfer	9,278.57	96	96.65	
256 KiB Transfer	9,225.22	96	96.10	
Read Only:				
1024 KiB Transfer	10,995.86	96	114.54	
256 KiB Transfer	11,015.99	96	114.75	
The above SPC-2 Data Rate value for LFP Composite represents the aggregate performance of all three LFP Test Phases: (Write Only, Read-Write, and Read Only).				
SPC-2 Large Database Query (LDQ) Reported Data				
	Data Rate *(MB/second)*	**Number of Streams**	**Data Rate per Stream**	**Price-Performance**
LDQ Composite	11,086.72			$10.95
1024 KiB Transfer Size				
4 I/Os Outstanding	12,642.47	12	1,053.54	
1 I/O Outstanding	10,947.25	96	114.03	
64 KiB Transfer Size				
4 I/Os Outstanding	11,699.38	12	974.95	
1 I/O Outstanding	9,057.79	96	94.35	
The above SPC-2 Data Rate value for LDQ Composite represents the aggregate performance of the two LDQ Test Phases: (1024 KiB and 64 KiB Transfer Sizes).				
SPC-2 Video On Demand (VOD) Reported Data				
	Data Rate *(MB/second)*	**Number of Streams**	**Data Rate per Stream**	**Price-Performance**
	4,561.32	5,800	0.79	$26.62

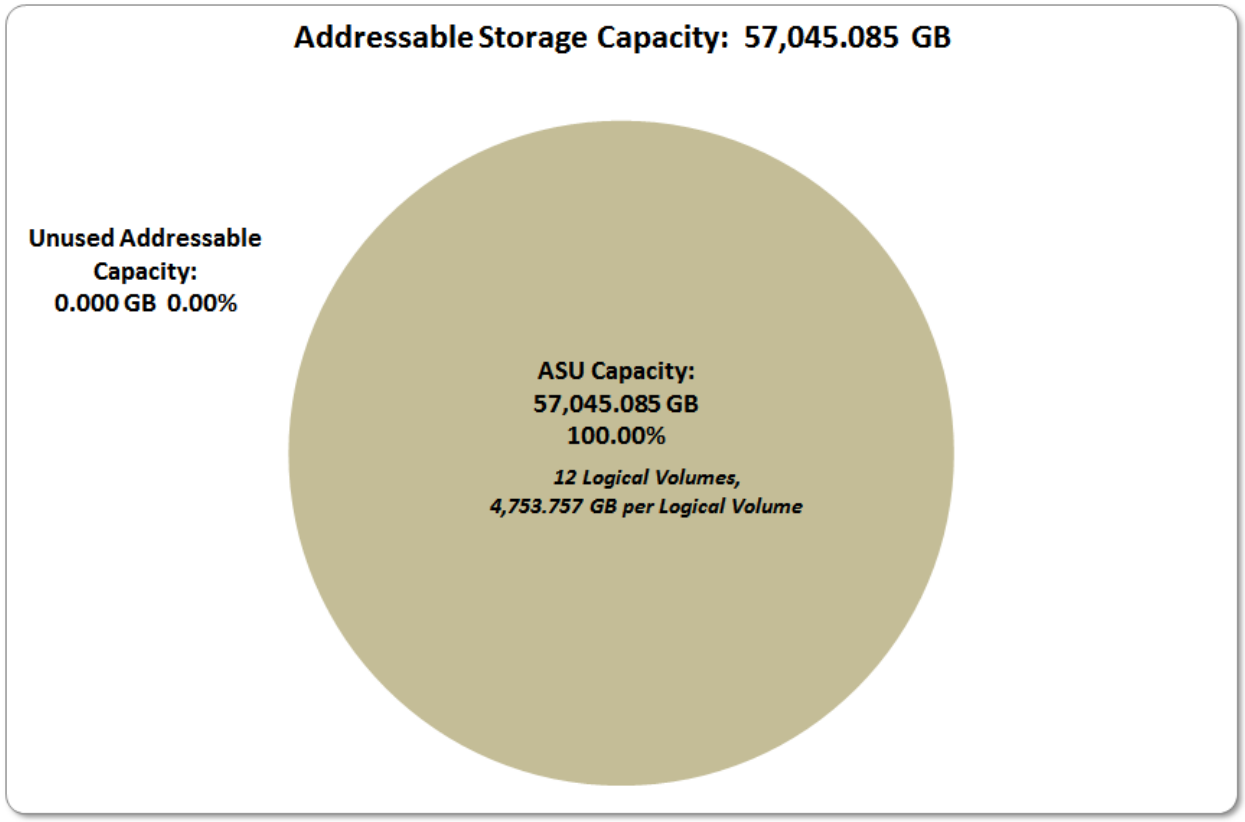
Storage Capacities, Relationships and Utilization

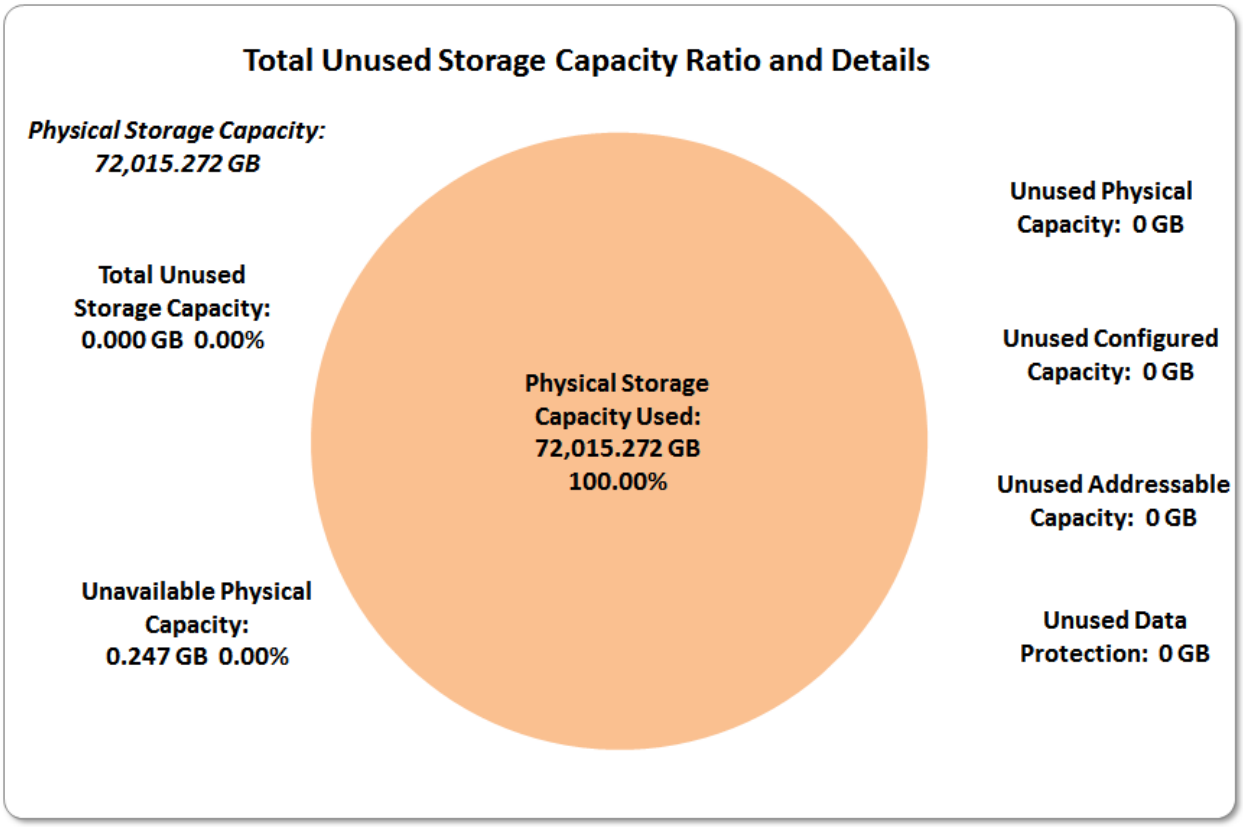
The following four charts and table document the various storage capacities, used in this benchmark, and their relationships, as well as the storage utilization values required to be reported.

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




Configured Storage Capacity: 71,306.352 GB
Configured Storage Capacity Availabile for Application Use: 71,306.355 GB 100.00%
Addressable Storage Capacity: 57,045.085 GB 80.00%
Data Protection Capacity (RAID-6): 14,261.270 GB 20.00%


Addressable Storage Capacity: 57,045.085 GB
Unused Addressable Capacity: 0.000 GB 0.00%
ASU Capacity: 57,045.085 GB 100.00%
12 Logical Volumes, 4,753.757 GB per Logical Volume



SPC-2 Storage Capacity Utilization	
Application Utilization	79.21%
Protected Application Utilization	99.02%
Unused Storage Ratio	0.00%

Application Utilization: Total ASU Capacity *(57,045.085 GB)* divided by Physical Storage Capacity *(72,015.272 GB)*.

Protected Application Utilization: Total ASU Capacity *(57,045.085 GB)* plus total Data Protection Capacity *(14,261.270 GB)* minus unused Data Protection Capacity *(0.000 GB)* divided by Physical Storage Capacity *(72,015.272 GB)*.

Unused Storage Ratio: Total Unused Capacity *(0.000 GB)* divided by Physical Storage Capacity *(72,015.272 GB)* and may not exceed 45%.

Detailed information for the various storage capacities and utilizations is available on pages 26-27 in the Full Disclosure Report.

Priced Storage Configuration Pricing

Part number	Description	Quantity	Unit List Price	Extended LP
E5600A-12GB-R6-C	E5600 Controller, 12GB Cache No Host Interface Card	2	19,500.00	39,000.00
X-56016-00-R6-C	E5600 Host Interface Card, 16Gb FC, 4-ports	2	2,425.00	4,850.00
X-48619-00-R6-C	E5600 Battery	2	460.00	920.00
E-X5680A-R6-C	E5600 4U-60 Storage Enclosure, No drives, 2 PSUs	1	19,060.00	19,060.00
E-X4049A-R6-C	Disk Drive, 600GB, 10k SAS, FDE	120	665.00	79,800.00
E-X5680A-DM-R6-C	DE6600 4U-60 Storage Expansion Enclosure, No drives, 2 PSUs	1	19,060.00	19,060.00
E-X30030A-R6-C	DE6600 ESM, Expansion Service Module	2	2,630.00	5,260.00
X-48895-00-R6-C	SFP, Unified, 10Gb iSCSI/16Gb FC	16	600.00	9,600.00
X-24936-00-R6-C	miniSAS cable, 2 meter	4	125.00	500.00
OS-SANTRICITY-CAP2-0P-C	SANtricity OS Enable, Per 0.1TB, Performance Storage	720	52.00	37,440.00
	NetApp Hardware / Software Subtotal			**215,490.00**
CS-A2-4R-VA	Support, 3-yr 24/7, 4 hour on-site	1		**17,081.00**
ServerSupply QLE2672-CK	QLE2672-CK Qlogic HBA, 16Gb FC, 2-ports	4	1,235.00	4,940.00
CDW 1148024	Tripp Lite, OM3 Optical cable, 2 meter	8	22.99	183.92
	Third-Party Subtotal			**5,123.92**

Description	Extended LP	Discount	Discounted Price
NetApp Hardware/Software Subtotal	215,490.00	50%	107,745.00
Support	17,081.00	50%	8,540.50
Third-Party Subtotal	5,123.92	0%	5,123.92
Totals	**237,694.92**		**121,409.42**

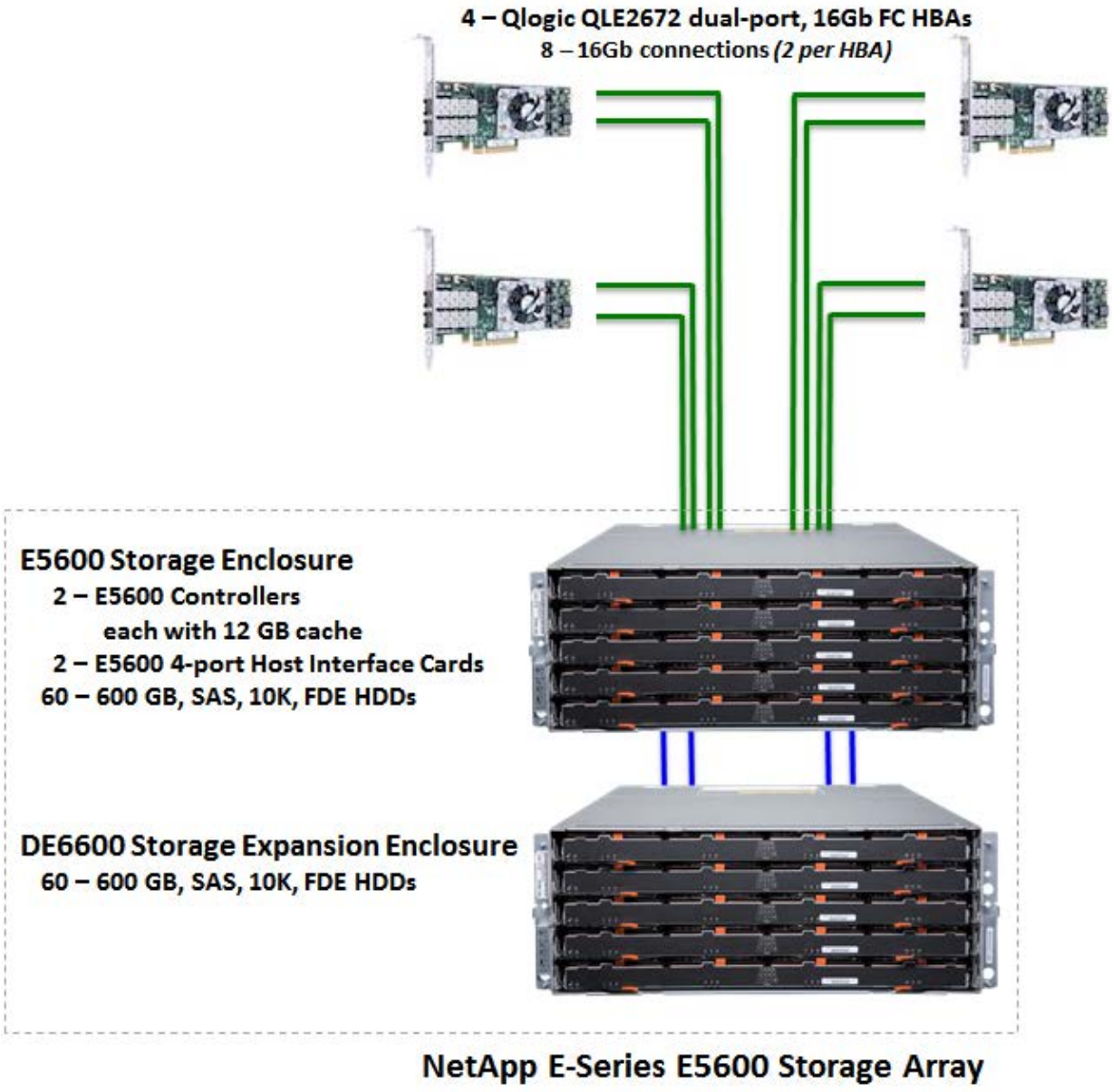
The above pricing includes the following:

- Acknowledgement of new and existing hardware and/or software problems within four hours.
- Onsite presence of a qualified maintenance engineer or provision of a customer replaceable part within four hours of the above acknowledgement for any hardware failure that results in an inoperative Priced Storage Configuration component.

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

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

Priced Storage Configuration Diagram



Priced Storage Configuration Components

Priced Storage Configuration
4 – QLogic QLE2672 dual-port, 16Gb, FC HBAs
NetApp E-Series E5660 Storage Array 1 – E5600 Storage Enclosure with 2 – controllers, each with 12 GB cache *(24 GB total)* 2 – 4-port Host Interface Cards *(1 card/4 ports per controller, 8 ports total and used)* 5 – 6 Gb SAS connections per controller *(10 connections total and used)* 60 – 600 GB, SAS, 10K FDE HDDs
1 – DE6600 Storage Expansion Enclosure with 60 – 600 GB, SAS, 10K FDE HDDs

CONFIGURATION INFORMATION

This portion of the Full Disclosure Report documents and illustrates the detailed information necessary to recreate the Benchmark Configuration (BC), including the Tested Storage Configuration (TSC), so that the SPC-2 benchmark result produced by the BC may be independently reproduced.

In each of the following sections of this document, the appropriate Full Disclosure Report requirement, from the SPC-2 benchmark specification, is stated in italics followed by the information to fulfill the stated requirement.

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

Clause 10.6.6

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

The Benchmark Configuration (BC)/Tested Storage Configuration (TSC) is illustrated on page 22 *(Benchmark Configuration (BC)/Tested Storage Configuration (TSC) Diagram)*.

Storage Network Configuration

Clause 10.6.6.1

If a storage network was configured as a part of the Tested Storage Configuration and the Benchmark Configuration described in Clause 10.6.6 contains a high-level illustration of the network configuration, the Executive Summary will contain a one page topology diagram of the storage network as illustrated in Figure 10.11.

The Tested Storage Configuration (TSC) was configured with direct-attached storage.

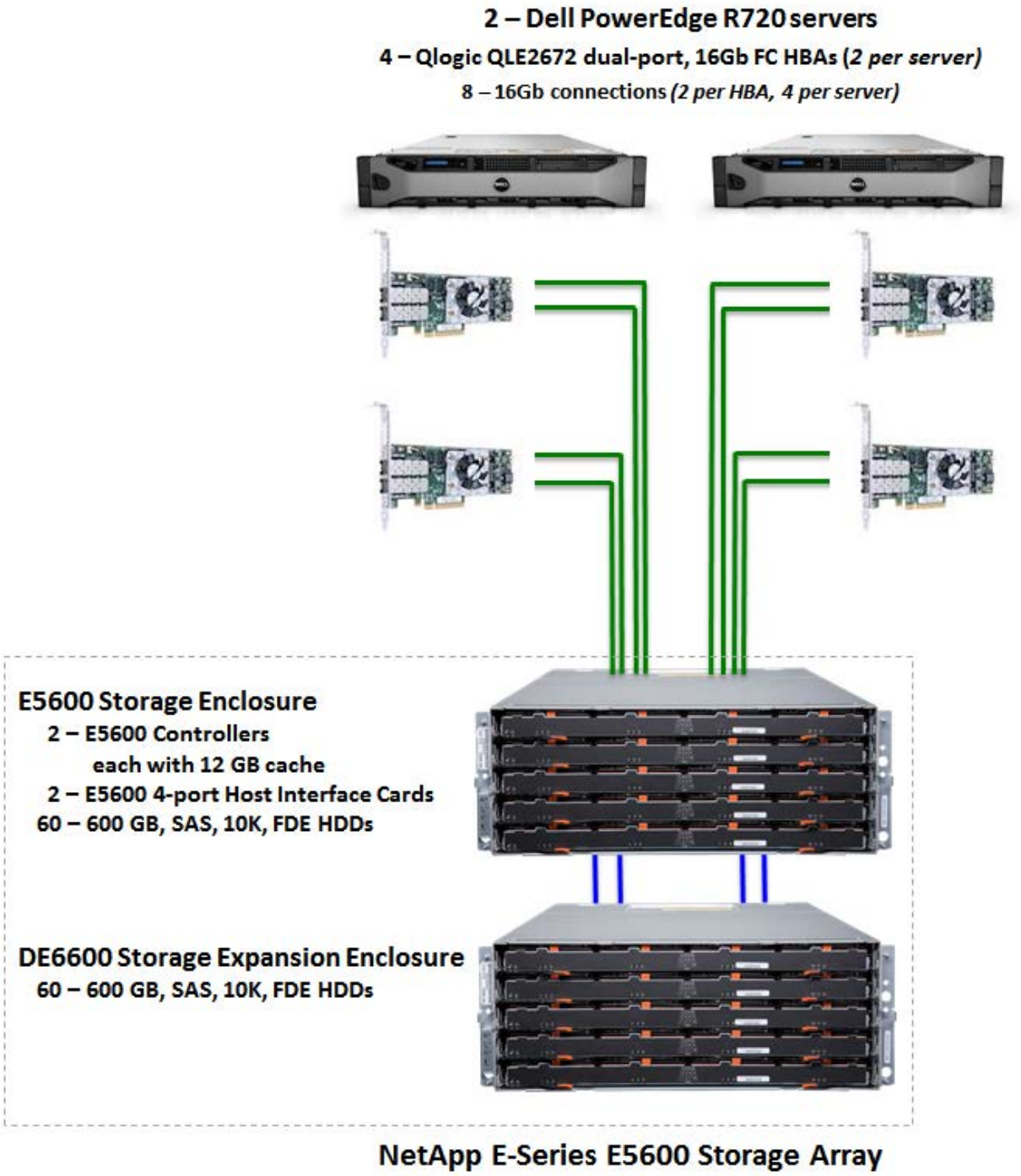
Host System and Tested Storage Configuration Table

Clause 10.6.6.2

The FDR will contain a table that lists the major components of each Host System and the Tested Storage Configuration.

The components that comprise each Host System and the Tested Storage Configuration are listed in the table that appears on page 23 *(Host System and Tested Storage Configuration Components)*.

Benchmark Configuration/Tested Storage Configuration Diagram



Host System and Tested Storage Configuration Components

Host Systems
2 – Dell PowerEdge R720 servers, each with: 2 – Intel® Xeon® E5-2650 processors 2.6 GHz each with 8 cores, 256 KB L1, 2 MB L2, 20 MB L3 64 GB main memory Windows Server 2008 R2 Enterprise version 6.1 *(Build 7601: Service Pack 1)* PCIe
Priced Storage Configuration
4 – QLogic QLE2672 dual-port, 16Gb, FC HBAs
NetApp E-Series E5660 Storage Array 1 – E5600 Storage Enclosure with 2 – controllers, each with 12 GB cache *(24 GB total)* 2 – 4-port Host Interface Cards *(1 card/4 ports per controller, 8 ports total and used)* 5 – 6 Gb SAS connections per controller *(10 connections total and used)* 60 – 600 GB, SAS, 10K FDE HDDs
1 – DE6600 Storage Expansion Enclosure with 60 – 600 GB, SAS, 10K FDE HDDs

Customer Tunable Parameters and Options

Clause 10.6.7.1

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

Appendix B: Customer Tunable Parameters and Options on page 67 contains the customer tunable parameters and options that have been altered from their default values for this benchmark.

Tested Storage Configuration (TSC) Creation and Configuration

Clause 10.6.7.2

The Full Disclosure Report must include sufficient information to recreate the logical representation of the Tested Storage Configuration (TSC). In addition to customer tunable parameters and options (Clause10.6.6.1), that information must include, at a minimum:

- *A diagram and/or description of the following:*
  - *All physical components that comprise the TSC. Those components are also illustrated in the BC Configuration Diagram in Clause 10.6.5.7 and the Storage Network Configuration Diagram in Clause 10.6.5.8.*
  - *The logical representation of the TSC, configured from the above components that will be presented to the SPC-2 Workload Generator.*
- *Listings of scripts used to create the logical representation of the TSC.*
- *If scripts were not used, a description of the process used with sufficient detail to recreate the logical representation of the TSC.*

Appendix C: Tested Storage Configuration (TSC) Creation on page 68 contains the detailed information that describes how to create and configure the logical TSC.

SPC-2 Workload Generator Storage Configuration

Clause 10.6.7.3

The Full Disclosure Report will include all SPC-2 Workload Generator storage configuration commands and parameters used in the SPC-2 benchmark measurement.

The SPC-2 Workload Generator storage configuration commands and parameters for this measurement appear in Appendix D: SPC-2 Workload Generator Storage Commands and Parameter Files on page 71.

ASU Pre-Fill

Clause 6.3.3

The SPC-2 ASU is required to be completely filled with specified content prior to the execution of audited SPC-2 Tests. The content is required to consist of random data pattern such as that produced by an SPC recommended tool.

…

Clause 6.3.3.3

The required ASU pre-fill must be executed as the first step in the uninterrupted benchmark execution sequence described in Clause 6.4.2. That uninterrupted sequence will consist of: ASU Pre-Fill, Large File Processing, Large Database Query, Video on Demand Delivery and Persistence Test Run 1. The only exception to this requirement is described in Clause 6.3.3.4.

Clause 6.3.3.4

If approved by the Auditor, the Test Sponsor may complete the required ASU pre-fill prior to the execution of the audited SPC-2 Tests and not as part of the SPC-2 Test execution sequence.

The Auditor will verify the required random data pattern content in the ASU prior to the execution of the audited SPC-2 Tests. If that verification fails, the Test Sponsor is required to reload the specified content to the ASU.

The configuration file used to complete the required ASU pre-fill appears in Appendix D: SPC-2 Workload Generator Storage Commands and Parameter Files on page 71.

SPC-2 DATA REPOSITORY

This portion of the Full Disclosure Report presents the detailed information that fully documents the various SPC-2 storage capacities and mappings used in the Tested Storage Configuration. SPC-2 Data Repository Definitions on page 62 contains definitions of terms specific to the SPC-2 Data Repository.

In each of the following sections of this document, the appropriate Full Disclosure Report requirement, from the SPC-2 benchmark specification, is stated in italics followed by the information to fulfill the stated requirement.

SPC-2 Storage Capacities and Relationships

Clause 10.6.8.1

Two tables and four charts documenting the storage capacities and relationships of the SPC-2 Storage Hierarchy (Clause 2.1) shall be included in the FDR. … The capacity value in each chart may be listed as an integer value, for readability, rather than the decimal value listed in the table below.

SPC-2 Storage Capacities

The Physical Storage Capacity consisted of 72,015.272 GB distributed over 120 disk drives (HDDs) each with a formatted capacity of 600.127 GB. There was 0.000 GB (0.00%) of Unused Storage within the Physical Storage Capacity. Global Storage Overhead consisted of 708.679 GB (0.98%) of the Physical Storage Capacity. There was 0.000 GB (0.00%) of Unused Storage within the Configured Storage Capacity. The Total ASU Capacity utilized 100.00% of the Addressable Storage Capacity resulting in 0.000 GB (0.00%) of Unused Storage within the Addressable Storage Capacity. The Data Protection *(RAID-6)* capacity was 14,261.270 GB of which 14,261.270 GB was utilized. The total Unused Storage was 0.000 GB.

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

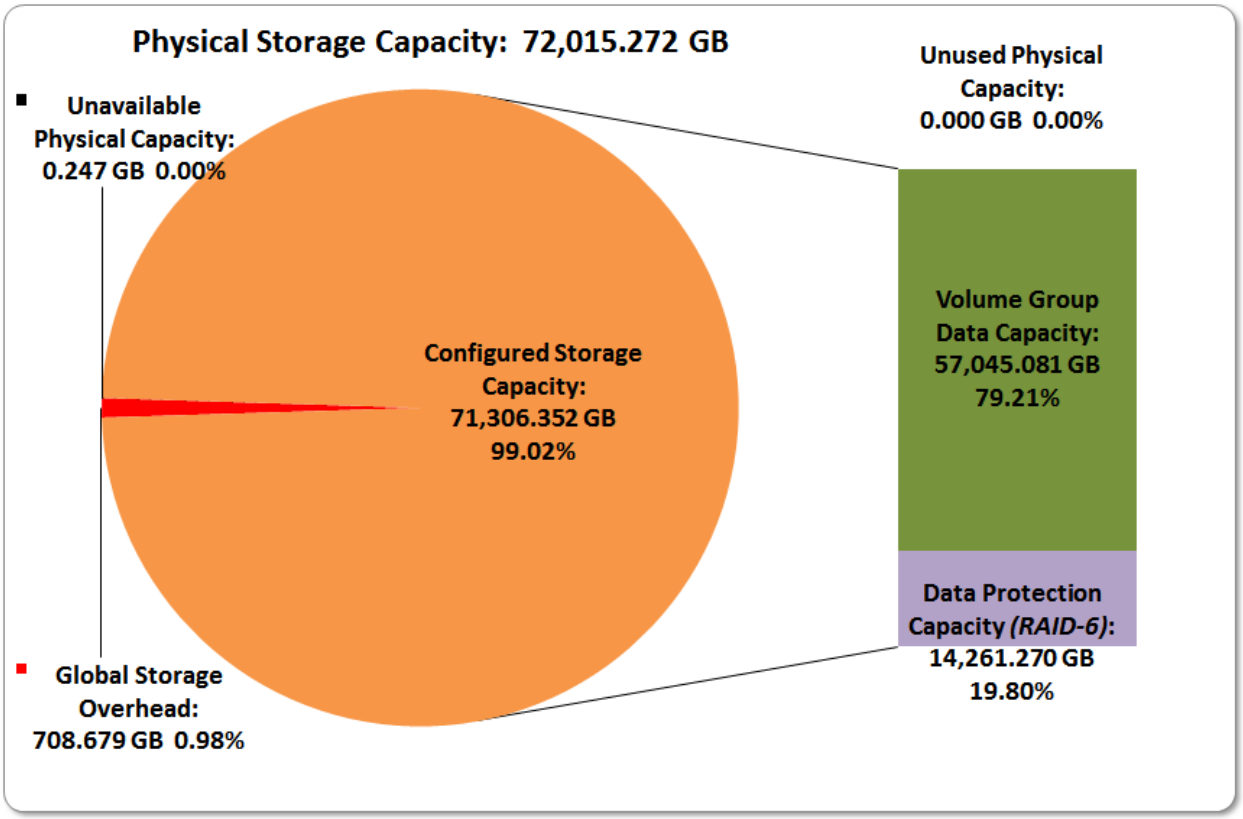
SPC-2 Storage Capacities

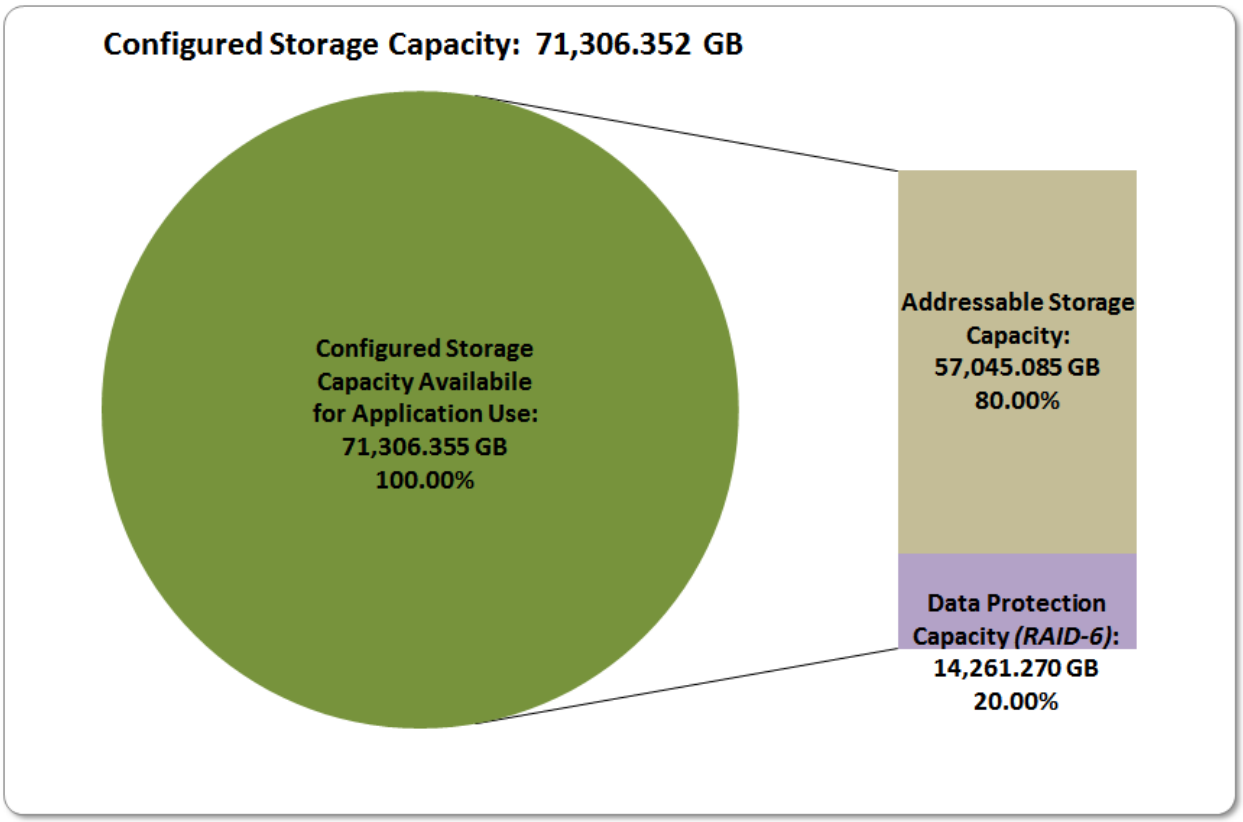
Storage Hierarchy Component	Units	Capacity
Total ASU Capacity	Gigabytes (GB)	57,045.085
Addressable Storage Capacity	Gigabytes (GB)	56,045.085
Configured Storage Capacity	Gigabytes (GB)	71,306.352
Physical Storage Capacity	Gigabytes (GB)	72,015.272
Data Protection *(RAID-6)*	Gigabytes (GB)	14,261.270
Required Storage	Gigabytes (GB)	0.000
Global Storage Overhead	Gigabytes (GB)	708.679
Total Unused Storage	Gigabytes (GB)	0.000

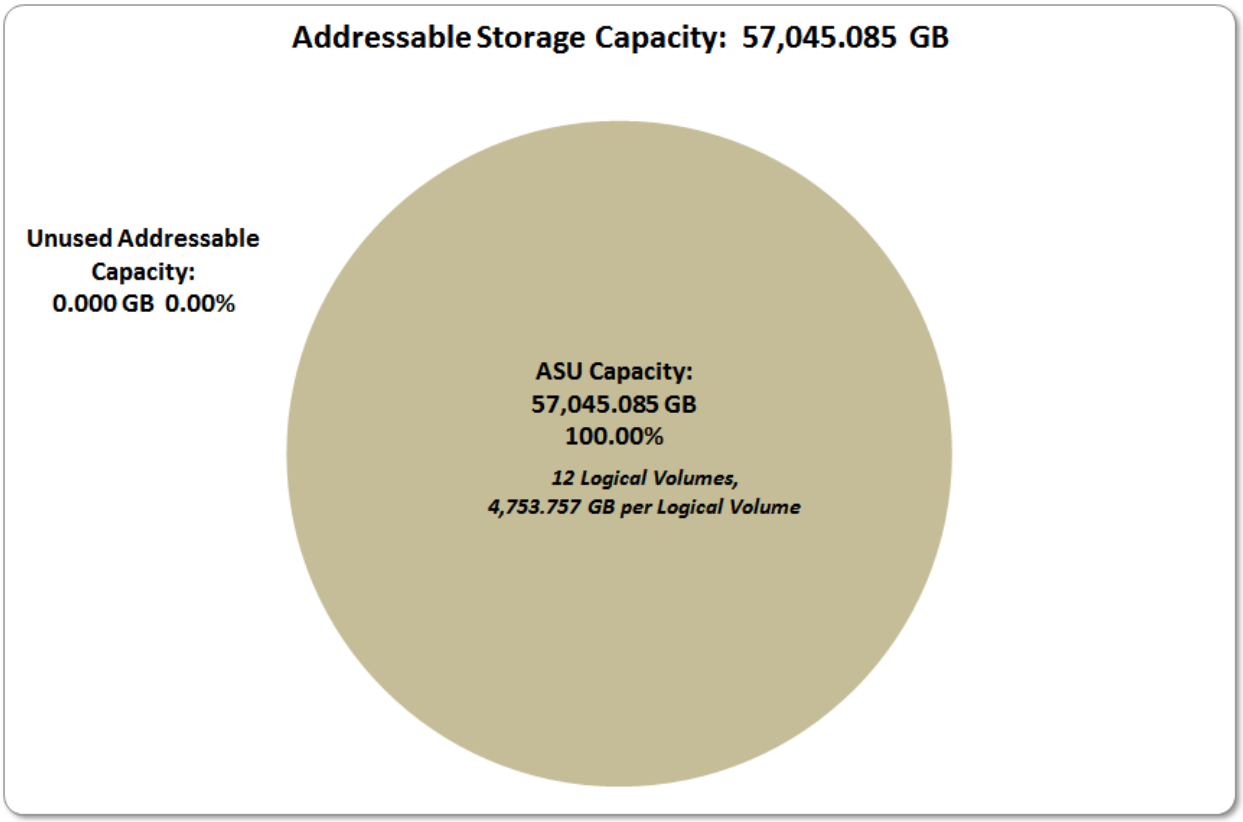
SPC-2 Storage Hierarchy Ratios

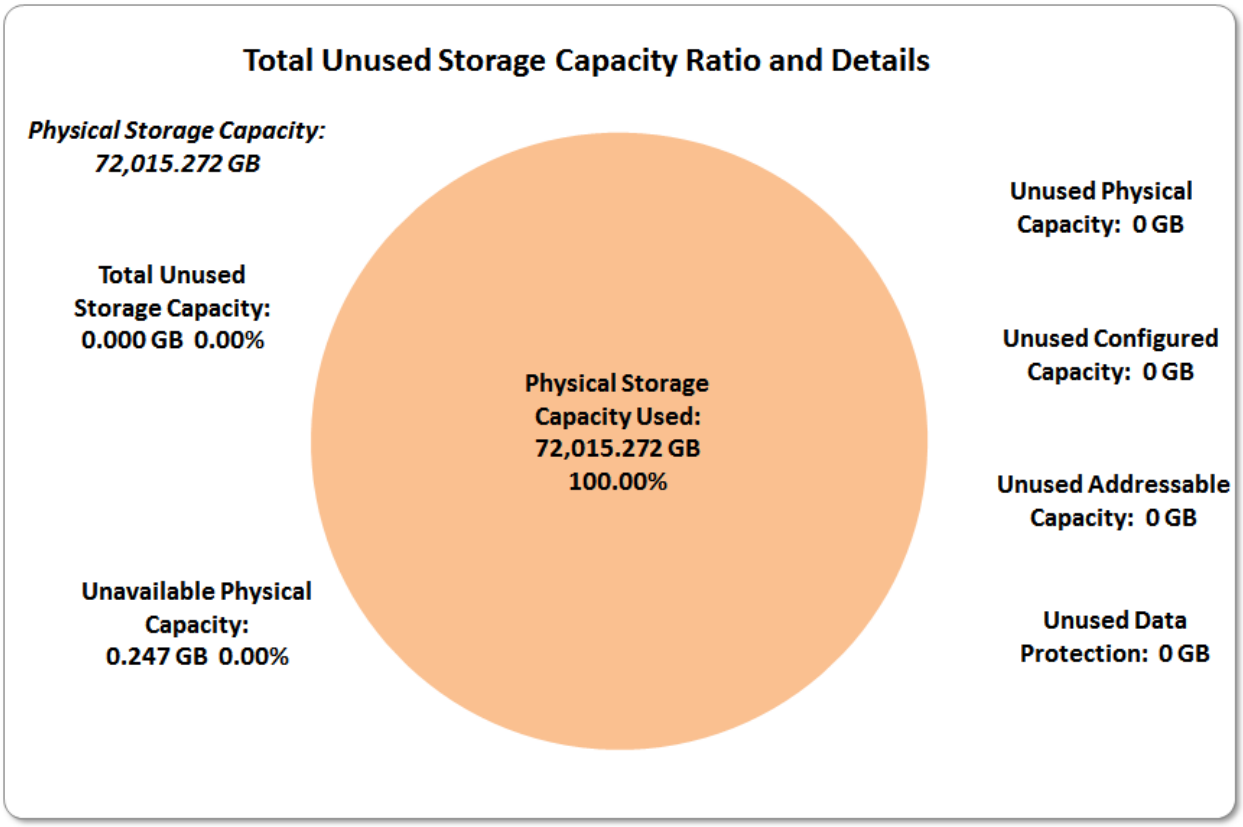
	Addressable Storage Capacity	Configured Storage Capacity	Physical Storage Capacity
Total ASU Capacity	100.00%	80.00%	79.21%
Data Protection *(RAID-6)*		20.00%	19.80%
Addressable Storage Capacity		80.00%	79.21%
Required Storage		0.00%	0.00%
Configured Storage Capacity			99.02%
Global Storage Overhead			0.98%
Unused Storage:			
Addressable	0.00%		
Configured		0.00%	
Physical			0.00%

SPC-2 Storage Capacity Charts




Configured Storage Capacity: 71,306.352 GB
Configured Storage Capacity Availabile for Application Use: 71,306.355 GB 100.00%
Addressable Storage Capacity: 57,045.085 GB 80.00%
Data Protection Capacity (RAID-6): 14,261.270 GB 20.00%


Addressable Storage Capacity: 57,045.085 GB
Unused Addressable Capacity: 0.000 GB 0.00%
ASU Capacity: 57,045.085 GB 100.00%
12 Logical Volumes, 4,753.757 GB per Logical Volume



Storage Capacity Utilization

Clause 10.6.8.2

The FDR will include a table illustrating the storage capacity utilization values defined for Application Utilization (Clause 2.8.1), Protected Application Utilization (Clause 2.8.2), and Unused Storage Ratio (Clause 2.8.3).

Clause 2,8.1

Application Utilization *is defined as Total ASU Capacity divided by Physical Storage Capacity.*

Clause 2,8.2

Protected Application Utilization *is defined as (Total ASU Capacity plus total Data Protection Capacity minus unused Data Protection Capacity) divided by Physical Storage Capacity.*

Clause 2,8.3

Unused Storage Ratio *is defined as Total Unused Capacity divided by Physical Storage Capacity and may not exceed 45%.*

SPC-2 Storage Capacity Utilization	
Application Utilization	79.21%
Protected Application Utilization	99.02%
Unused Storage Ratio	0.00%

Logical Volume Capacity and ASU Mapping

Clause 10.6.8.3

A table illustrating the capacity of the Application Storage Unit (ASU) and the mapping of Logical Volumes to ASU will be provided in the FDR. Capacity must be stated in gigabytes (GB) as a value with a minimum of two digits to the right of the decimal point. Each Logical Volume will be sequenced in the table from top to bottom per its position in the contiguous address space of the ASU. Each Logical Volume entry will list its total capacity, the portion of that capacity used for the ASU, and any unused capacity.

Logical Volume (LV) Capacity and Mapping			
ASU (56,045.085 GB)			
	Total Capacity *(GB)*	Capacity Used *(GB)*	Capacity Unused *(GB)*
12 Logical Volumes	4,753.757 per LV	4,753.757 per LV	0.000 per LV

See the Storage Definition (sd) entries in Appendix D: SPC-2 Workload Generator Storage Commands and Parameter Files on page 71 for more detailed configuration information.

SPC-2 BENCHMARK EXECUTION RESULTS

This portion of the Full Disclosure Report documents the results of the various SPC-2 Tests, Test Phases, Test Run Sequences, and Test Runs. An SPC-2 glossary on page 62 contains definitions of terms specific to the SPC-2 Data Repository.

In each of the following sections of this document, the appropriate Full Disclosure Report requirement, from the SPC-2 benchmark specification, is stated in italics followed by the information to fulfill the stated requirement.

SPC-2 Tests, Test Phases, Test Run Sequences, and Test Runs

The SPC-2 benchmark consists of the following Tests, Test Phases, Test Run Sequences, and Test Runs:

- **Data Persistence Test**
  - Data Persistence Test Run 1
  - Data Persistence Test Run 2
- **Large File Processing Test**
  - WRITE ONLY Test Phase
    - Test Run Sequence 1
      - ✓ Test Run 1 – 1024 KiB Transfer – maximum number of Streams
      - ✓ Test Run 2 – 1024 KiB Transfer – 50% of Test Run 1's Streams value
      - ✓ Test Run 3 – 1024 KiB Transfer – 25% of Test Run 1's Streams value
      - ✓ Test Run 4 – 1024 KiB Transfer – 12.5% of Test Run 1's Streams value
      - ✓ Test Run 5 – 1024 KiB Transfer – single (1) Stream
    - Test Run Sequence 2
      - ✓ Test Run 6 – 256 KiB Transfer – maximum number of Streams
      - ✓ Test Run 7 – 256 KiB Transfer – 50% of Test Run 6's Streams value
      - ✓ Test Run 8 – 256 KiB Transfer – 25% of Test Run 6's Streams value
      - ✓ Test Run 9 – 256 KiB Transfer – 12.5% of Test Run 6's Streams value
      - ✓ Test Run 10 – 256 KiB Transfer – single (1) Stream
  - READ-WRITE Test Phase
    - Test Run Sequence 3
      - ✓ Test Run 11 – 1024 KiB Transfer – maximum number of Streams
      - ✓ Test Run 12 – 1024 KiB Transfer – 50% of Test Run 11's Streams value
      - ✓ Test Run 13 – 1024 KiB Transfer – 25% of Test Run 11's Streams value
      - ✓ Test Run 14 – 1024 KiB Transfer – 12.5% of Test Run 11's Streams value
      - ✓ Test Run 15 – 1024 KiB Transfer – single (1) Stream
    - Test Run Sequence 4
      - ✓ Test Run 16 – 256 KiB Transfer – maximum number of Streams
      - ✓ Test Run 17 – 256 KiB Transfer – 50% of Test Run 16's Streams value
      - ✓ Test Run 18 – 256 KiB Transfer – 25% of Test Run 16's Streams value
      - ✓ Test Run 19 – 256 KiB Transfer – 12.5% of Test Run 16's Streams value
      - ✓ Test Run 20 – 256 KiB Transfer – single (1) Stream
  - READ ONLY Test Phase
    - Test Run Sequence 5
      - ✓ Test Run 21 – 1024 KiB Transfer – maximum number of Streams

- ✓ Test Run 22 – 1024 KiB Transfer – 50% of Test Run 21's Streams value
- ✓ Test Run 23 – 1024 KiB Transfer – 25% of Test Run 21's Streams value
- ✓ Test Run 24 – 1024 KiB Transfer – 12.5% of Test Run 21's Streams value
- ✓ Test Run 25 – 1024 KiB Transfer – single (1) Stream

- Test Run Sequence 6
  - ✓ Test Run 26 – 256 KiB Transfer – maximum number of Streams
  - ✓ Test Run 27 – 256 KiB Transfer – 50% of Test Run 26's Streams value
  - ✓ Test Run 28 – 256 KiB Transfer – 25% of Test Run 26's Streams value
  - ✓ Test Run 29 – 256 KiB Transfer – 12.5% of Test Run 26's Streams value
  - ✓ Test Run 30 – 256 KiB Transfer – single (1) Stream

- **Large Database Query Test**
  - 1024 KIB TRANSFER SIZE Test Phase
    - Test Run Sequence 1
      - ✓ Test Run 1 – 4 I/O Requests Outstanding – maximum number of Streams
      - ✓ Test Run 2 – 4 I/O Requests Outstanding – 50% of Test Run 1's Streams value
      - ✓ Test Run 3 – 4 I/O Requests Outstanding – 25% of Test Run 1's Streams value
      - ✓ Test Run 4 – 4 I/O Requests Outstanding – 12.5% of Test Run 1's Streams value
      - ✓ Test Run 5 – 4 I/O Requests Outstanding – single (1) Stream
    - Test Run Sequence 2
      - ✓ Test Run 6 – 1 I/O Request Outstanding – maximum number of Streams
      - ✓ Test Run 7 – 1 I/O Request Outstanding – 50% of Test Run 6's Streams value
      - ✓ Test Run 8 – 1 I/O Request Outstanding – 25% of Test Run 6's Streams value
      - ✓ Test Run 9 – 1 I/O Request Outstanding – 12.5% of Test Run 6's Streams value
      - ✓ Test Run 10 – 1 I/O Request Outstanding – single (1) Stream
  - 64 KIB TRANSFER SIZE Test Phase
    - Test Run Sequence 3
      - ✓ Test Run 11 – 4 I/O Requests Outstanding – maximum number of Streams
      - ✓ Test Run 12 – 4 I/O Requests Outstanding – 50% of Test Run 11's Streams value
      - ✓ Test Run 13 – 4 I/O Requests Outstanding – 25% of Test Run 11's Streams value
      - ✓ Test Run 14 – 4 I/O Requests Outstanding – 12.5% of Test Run 11's Streams value
      - ✓ Test Run 15 – 4 I/O Requests Outstanding – single (1) Stream
    - Test Run Sequence 4
      - ✓ Test Run 16 – 1 I/O Request Outstanding – maximum number of Streams
      - ✓ Test Run 17 – 1 I/O Request Outstanding – 50% of Test Run 16's Streams value
      - ✓ Test Run 18 – 1 I/O Request Outstanding – 25% of Test Run 16's Streams value
      - ✓ Test Run 19 – 1 I/O Request Outstanding – 12.5% of Test Run 16's Streams value
      - ✓ Test Run 20 – 1 I/O Request Outstanding – single (1) Stream

- **Video on Demand Delivery Test**
  - Video on Demand Delivery Test Run

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

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

Large File Processing Test

Clause 6.4.3.1

The Large File Processing Test consists of the I/O operations associated with the type of applications, in a wide range of fields, which require simple sequential processing of one or more large files. Specific examples of those types of applications include scientific computing and large-scale financial processing

Clause 6.4.3.2

The Large File Processing Test has three Test Phases, which shall be executed in the following uninterrupted sequence:

1. *WRITE ONLY*
2. *READ-WRITE*
3. *READ ONLY*

The BC shall not be restarted or manually disturbed, altered, or adjusted during the execution of the Large File Processing Test. If power is lost to the BC during this Test all results shall be rendered invalid and the Test re-run in its entirety.

Clause 10.6.9.1

The Full Disclosure Report will contain the following content for the Large File Processing Test:

1. *A listing of the SPC-2 Workload Generator commands and parameters used to execute each of the Test Runs in the Large File Processing Test.*
2. *The human readable SPC-2 Test Results File for each of the Test Runs in the Large File Processing Test.*
3. *The following three tables:*
    - *Average Data Rate: The average Data Rate, in MB per second for the Measurement Interval of each Test Run in the Large File Processing Test.*
    - *Average Data Rate per Stream: The average Data Rate per Stream, in MB per second, for the Measurement Interval of each Test Run in the Large File Processing Test.*
    - *Average Response Time: The average response time, in milliseconds (ms), for the Measurement Interval of each Test Run in the Large File Processing Test.*
4. *Average Data Rate, Average Data Rate per Stream and Average Response Time graphs as defined in Clauses 10.1.1, 10.1.2 and 10.1.3.*

SPC-2 Workload Generator Commands and Parameters

The SPC-2 Workload Generator commands and parameters for the Large File Processing Test Runs are documented in Appendix E: SPC-2 Workload Generator Execution Commands and Parameters on Page 76.

SPC-2 Test Results File

A link to the SPC-2 Test Results file generated from the Large File Processing Test Runs is listed below.

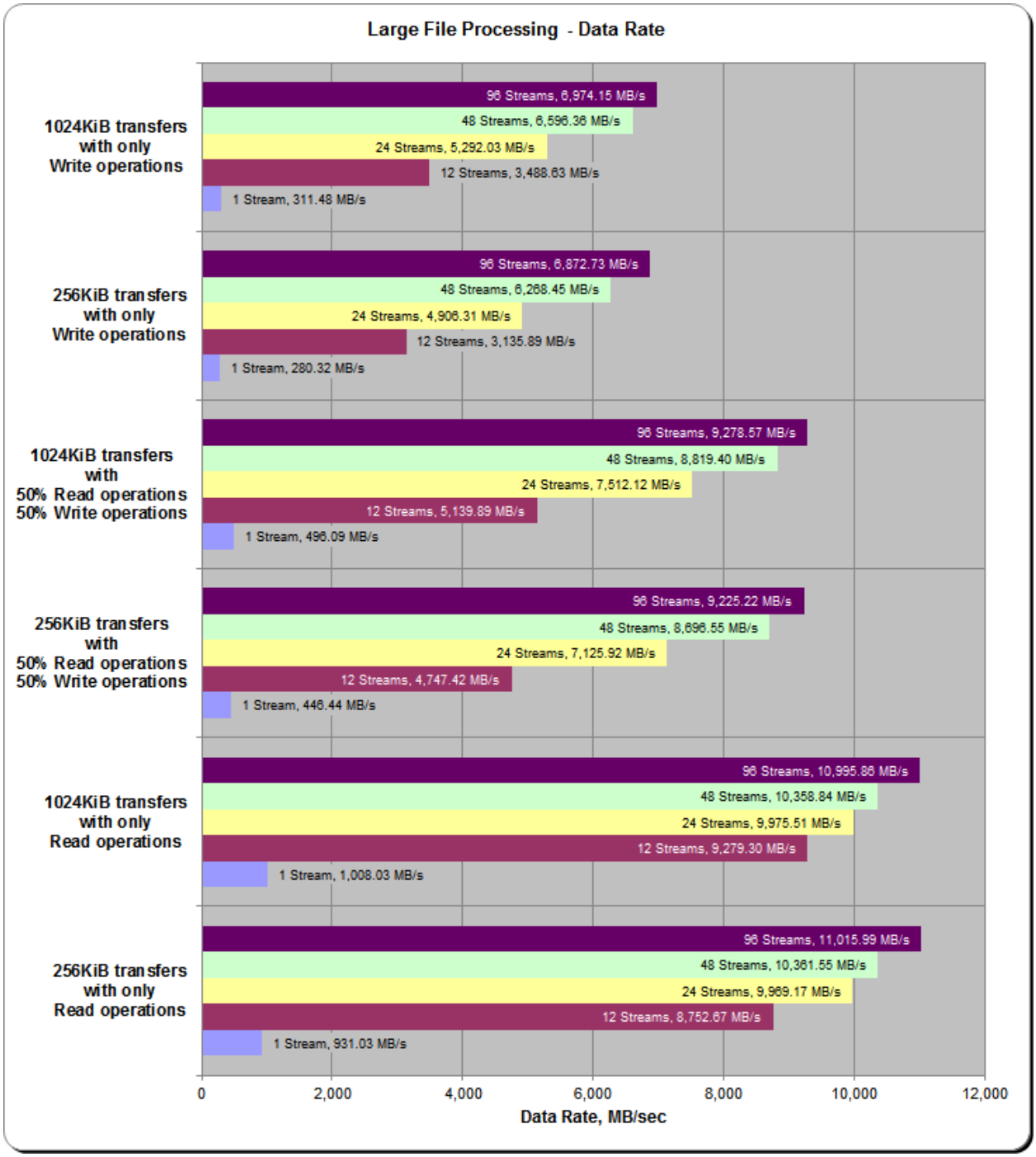
SPC-2 Large File Processing Test Results File

SPC-2 Large File Processing Average Data Rates (MB/s)

The average Data Rate (MB/s) for each Test Run in the three Test Phases of the SPC-2 Large File Processing Test is listed in the table below as well as illustrated in the following graph.

Test Run Sequence	1 Stream	12 Streams	24 Streams	48 Streams	96 Streams
Write 1024KiB	311.48	3,488.63	5,292.03	6,596.36	6,974.15
Write 256KiB	280.32	3,135.89	4,906.31	6,268.45	6,872.73
Read/Write 1024KiB	496.09	5,139.89	7,512.12	8,819.40	9,278.57
Read/Write 256KiB	446.44	4,747.42	7,125.92	8,696.55	9,225.22
Read 1024KiB	1,008.03	9,279.30	9,975.51	10,358.84	10,995.86
Read 256KiB	931.03	8,752.67	9,969.17	10,361.55	11,015.99

SPC-2 Large File Processing Average Data Rates Graph

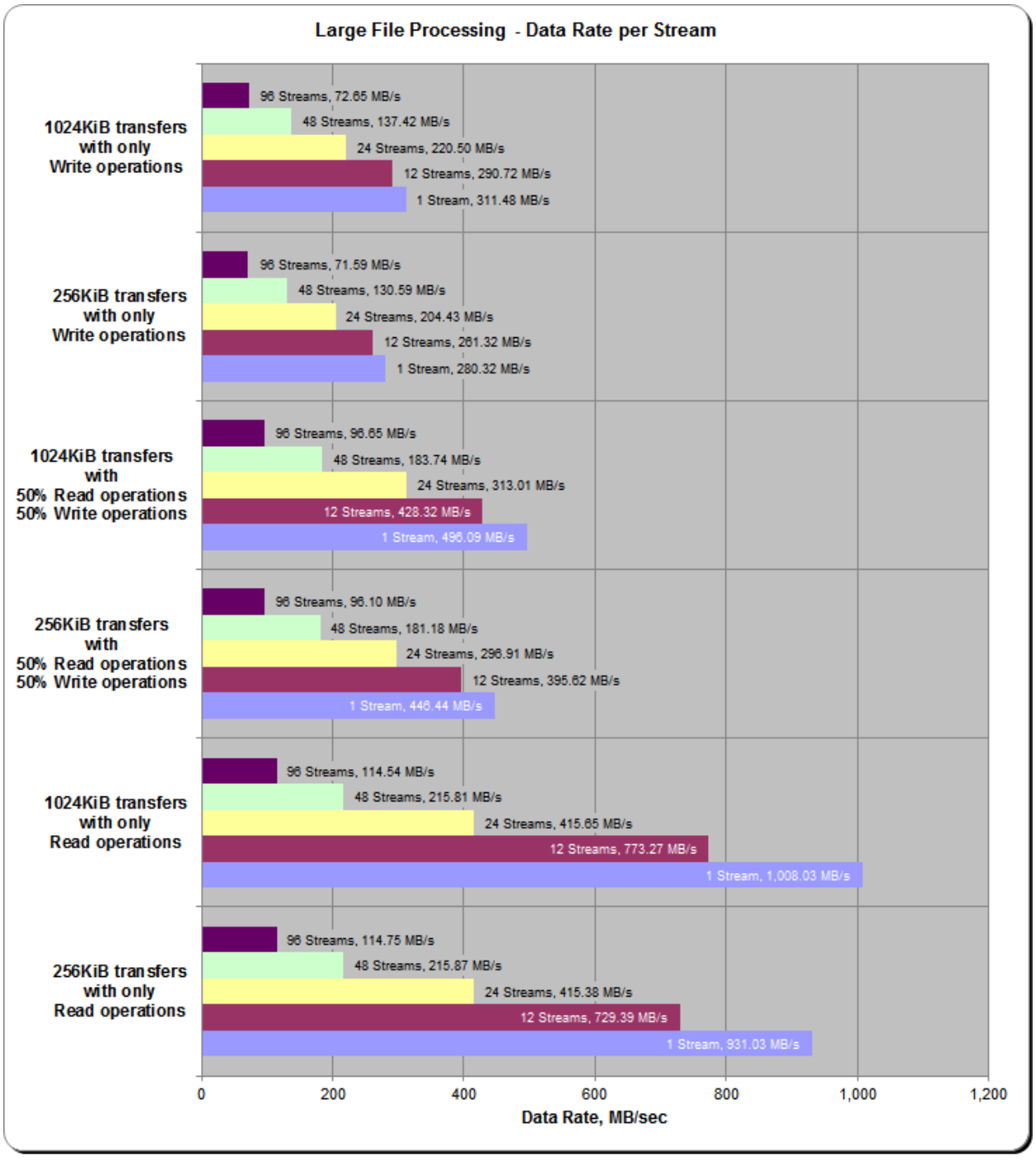


SPC-2 Large File Processing Average Data Rate per Stream

The average Data Rate per Stream for each Test Run in the three Test Phases of the SPC-2 Large File Processing Test is listed in the table below as well as illustrated in the following graph.

Test Run Sequence	1 Stream	12 Streams	24 Streams	48 Streams	96 Streams
Write 1024KiB	311.48	290.72	220.50	137.42	72.65
Write 256KiB	280.32	261.32	204.43	130.59	71.59
Read/Write 1024KiB	496.09	428.32	313.01	183.74	96.65
Read/Write 256KiB	446.44	395.62	296.91	181.18	96.10
Read 1024KiB	1,008.03	773.27	415.65	215.81	114.54
Read 256KiB	931.03	729.39	415.38	215.87	114.75

SPC-2 Large File Processing Average Data Rate per Stream Graph

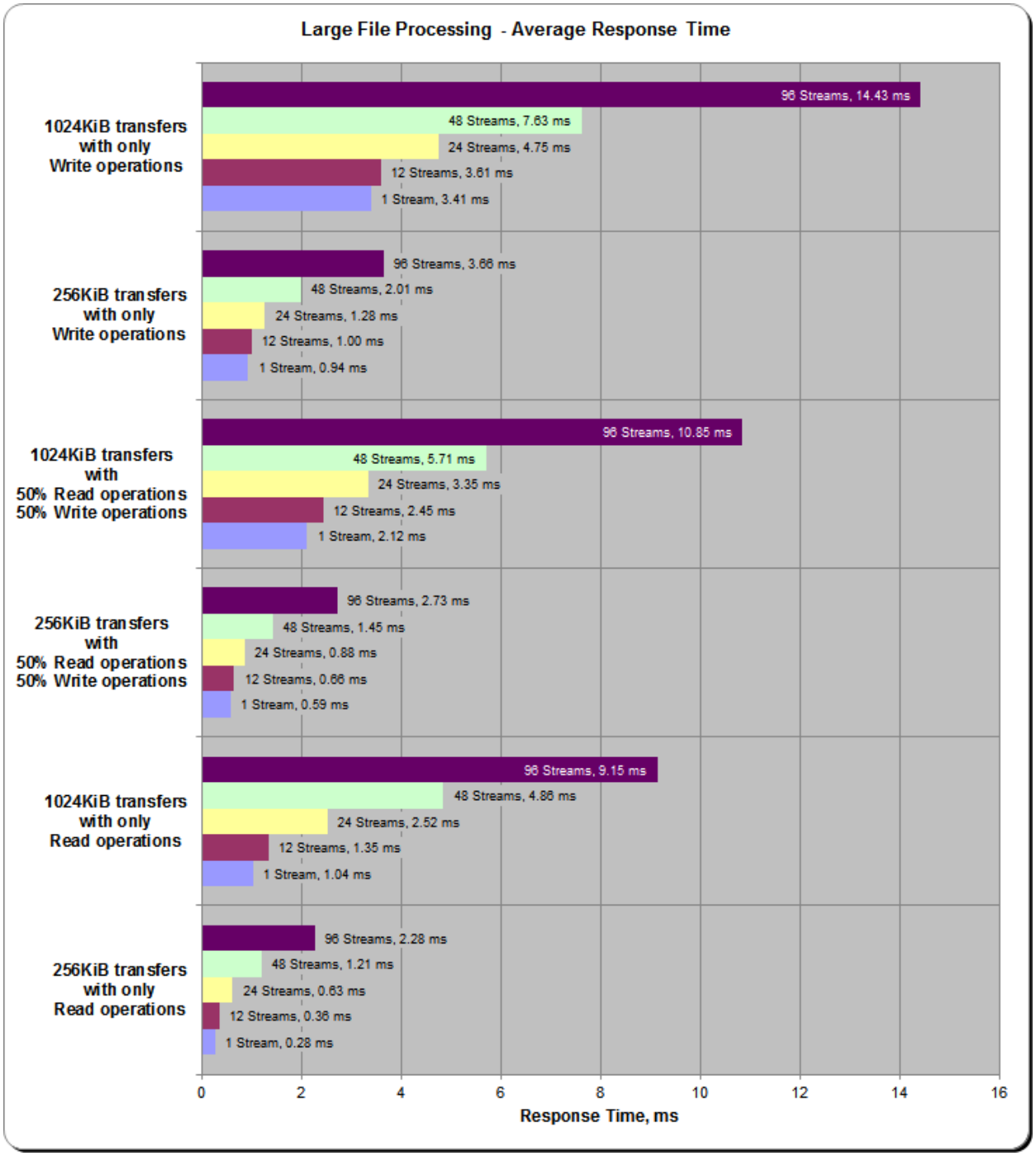


SPC-2 Large File Processing Average Response Time

The average Response Time, milliseconds (ms), for each Test Run in the three Test Phases of the SPC-2 Large File Processing Test is listed in the table below as well as illustrated in the following graph.

Test Run Sequence	1 Stream	12 Streams	24 Streams	48 Streams	96 Streams
Write 1024KiB	3.41	3.61	4.75	7.63	14.43
Write 256KiB	0.94	1.00	1.28	2.01	3.66
Read/Write 1024KiB	2.12	2.45	3.35	5.71	10.85
Read/Write 256KiB	0.59	0.66	0.88	1.45	2.73
Read 1024KiB	1.04	1.35	2.52	4.86	9.15
Read 256KiB	0.28	0.36	0.63	1.21	2.28

SPC-2 Large File Processing Average Response Time Graph



Large File Processing Test – WRITE ONLY Test Phase

Clause 10.6.9.1.1

1. *A table that will contain the following information for each "WRITE ONLY, 1024 KiB Transfer Size" Test Run:*
   - *The number of Streams specified.*
   - *The Average Data Rate, Average Data Rate per Stream, and Average Response Time reported at five second intervals.*
2. *Average Data Rate by Intervals, Average Data Rate per Stream by Intervals, and Average Response Time by Intervals graphs for the "WRITE ONLY, 1024 KiB Transfer Size" Test Runs as specified in Clauses 10.1.4 – 10.1.6.*
3. *A table that will contain the following information for each "WRITE ONLY, 256 KiB Transfer Size" Test Run:*
   - *The number of Streams specified.*
   - *The Average Data Rate, Average Data Rate per Stream, and Average Response Time reported at five second intervals.*
4. *Average Data Rate by Intervals, Average Data Rate per Stream by Intervals, and Average Response Time by Intervals graphs for the "WRITE ONLY, 256 KiB Transfer Size" Test Runs as specified in Clauses 10.1.4 – 10.1.6.*

A hyperlink for each of the above tables and graphs may appear in the FDR to provide access to the table or graph.

A hyperlink to a table with the SPC-2 "Large File Processing/WRITE ONLY/1024 KiB Transfer Size" Test Run data appears on the next page. That entry is followed by hyperlinks to graphs illustrating the average Data Rate, average Data Rate per Stream, and average Response Time produced by the same Test Runs. The table and graphs present the data at five-second intervals.

Immediately following the above SPC-2 "Large File Processing/WRITE ONLY/1024 KiB Transfer Size" entries will be hyperlinks for SPC-2 "Large File Processing/WRITE ONLY/256 KiB Transfer Size" table and graphs. The table contains the Test Run data and the graphs illustrate the average Data Rate, average Data Rate per Stream, and average Response Time produced by the Test Runs.

SPC-2 "Large File Processing/WRITE ONLY/1024 KiB Transfer Size" Test Run Data

SPC-2 "Large File Processing/WRITE ONLY/1024 KiB Transfer Size" Test Run Data Tables: Ramp-Up, Measurement Interval, Run-Out, and Ramp-Down Periods
(3 pages)

SPC-2 "Large File Processing/WRITE ONLY/1024 KiB Transfer Size" Graphs

Average Data Rate – Complete Test Run

Average Data Rate – Measurement Interval (MI) Only

Average Data Rate per Stream

Average Response Time

SPC-2 "Large File Processing/WRITE ONLY/1024 KiB Transfer Size" graphs
(four pages, 1 graph per page)

SPC-2 "Large File Processing/WRITE ONLY/256 KiB Transfer Size" Test Run Data

SPC-2 "Large File Processing/WRITE ONLY/256 KiB Transfer Size" Test Run Data Tables: Ramp-Up, Measurement Interval, Run-Out, and Ramp-Down Periods
(3 pages)

SPC-2 "Large File Processing/WRITE ONLY/256 KiB Transfer Size" Graphs

Average Data Rate – Complete Test Run

Average Data Rate – Measurement Interval (MI) Only

Average Data Rate per Stream

Average Response Time

SPC-2 "Large File Processing/WRITE ONLY/256 KiB Transfer Size" graphs
(four pages, 1 graph per page)

Large File Processing Test – READ-WRITE Test Phase

Clause 10.6.9.1.2

1. *A table that will contain the following information for each "READ-WRITE, 1024 KiB Transfer Size" Test Run:*
   - *The number of Streams specified.*
   - *The Average Data Rate, Average Data Rate per Stream, and Average Response Time reported at five second intervals.*
2. *Average Data Rate by Intervals, Average Data Rate per Stream by Intervals, and Average Response Time by Intervals graphs for the "READ-WRITE, 1024 KiB Transfer Size" Test Runs as specified in Clauses 10.1.4 – 10.1.6.*
3. *A table that will contain the following information for each " READ-WRITE, 256 KiB Transfer Size" Test Run:*
   - *The number of Streams specified.*
   - *The Average Data Rate, Average Data Rate per Stream, and Average Response Time reported at five second intervals.*
4. *Average Data Rate by Intervals, Average Data Rate per Stream by Intervals, and Average Response Time by Intervals graphs for the "READ-WRITE, 256 KiB Transfer Size" Test Runs as specified in Clauses 10.1.4 – 10.1.6.*

A hyperlink for each of the above tables and graphs may appear in the FDR to provide access to the table or graph.

A hyperlink to a table with the SPC-2 "Large File Processing/READ-WRITE/1024 KiB Transfer Size" Test Run data appears on the next page. That entry is followed by hyperlinks to graphs illustrating the average Data Rate, average Data Rate per Stream, and average Response Time produced by the same Test Runs. The table and graphs present the data at five-second intervals.

Immediately following the above SPC-2 "Large File Processing/READ-WRITE/1024 KiB Transfer Size" entries will be hyperlinks for SPC-2 "Large File Processing/READ-WRITE/256 KiB Transfer Size" table and graphs. The table contains the Test Run data and the graphs illustrate the average Data Rate, average Data Rate per Stream, and average Response Time produced by the Test Runs.

SPC-2 "Large File Processing/READ-WRITE/1024 KiB Transfer Size" Test Run Data

SPC-2 "Large File Processing/READ-WRITE/1024 KiB Transfer Size" Test Run Data Tables: Ramp-Up, Measurement Interval, Run-Out, and Ramp-Down Periods
(3 pages)

SPC-2 "Large File Processing/READ-WRITE/1024 KiB Transfer Size" Graphs

Average Data Rate – Complete Test Run

Average Data Rate – Measurement Interval (MI) Only

Average Data Rate per Stream

Average Response Time

SPC-2 "Large File Processing/READ-WRITE/1024 KiB Transfer Size" graphs
(four pages, 1 graph per page)

SPC-2 "Large File Processing/READ-WRITE/256 KiB Transfer Size" Test Run Data

SPC-2 "Large File Processing/READ-WRITE/256 KiB Transfer Size" Test Run Data Tables: Ramp-Up, Measurement Interval, Run-Out, and Ramp-Down Periods
(3 pages)

SPC-2 "Large File Processing/READ-WRITE/256 KiB Transfer Size" Graphs

Average Data Rate – Complete Test Run

Average Data Rate – Measurement Interval (MI) Only

Average Data Rate per Stream

Average Response Time

SPC-2 "Large File Processing/READ-WRITE/256 KiB Transfer Size" graphs
(four pages, 1 graph per page)

Large File Processing Test – READ ONLY Test Phase

Clause 10.6.9.1.3

1. *A table that will contain the following information for each "READ ONLY, 1024 KiB Transfer Size" Test Run:*
   - *The number of Streams specified.*
   - *The Average Data Rate, Average Data Rate per Stream, and Average Response Time reported at five second intervals.*
2. *Average Data Rate by Intervals, Average Data Rate per Stream by Intervals, and Average Response Time by Intervals graphs for the "READ ONLY, 1024 KiB Transfer Size" Test Runs as specified in Clauses 10.1.4 – 10.1.6.*
3. *A table that will contain the following information for each "READ ONLY, 256 KiB Transfer Size" Test Run:*
   - *The number of Streams specified.*
   - *The Average Data Rate, Average Data Rate per Stream, and Average Response Time reported at five second intervals.*
4. *Average Data Rate by Intervals, Average Data Rate per Stream by Intervals, and Average Response Time by Intervals graphs for the "READ ONLY, 256 KiB Transfer Size" Test Runs as specified in Clauses 10.1.4 – 10.1.6.*

A hyperlink for each of the above tables and graphs may appear in the FDR to provide access to the table or graph.

A hyperlink to a table with the SPC-2 "Large File Processing/READ ONLY/1024 KiB Transfer Size" Test Run data appears on the next page. That entry is followed by hyperlinks to graphs illustrating the average Data Rate, average Data Rate per Stream, and average Response Time produced by the same Test Runs. The table and graphs present the data at five-second intervals.

Immediately following the above SPC-2 "Large File Processing/READ ONLY/1024 KiB Transfer Size" entries will be hyperlinks for SPC-2 "Large File Processing/READ ONLY/256 KiB Transfer Size" table and graphs. The table contains the Test Run data and the graphs illustrate the average Data Rate, average Data Rate per Stream, and average Response Time produced by the Test Runs.

SPC-2 "Large File Processing/READ ONLY/1024 KiB Transfer Size" Test Run Data

SPC-2 "Large File Processing/READ ONLY/1024 KiB Transfer Size" Test Run Data Tables: Ramp-Up, Measurement Interval, Run-Out, and Ramp-Down Periods
(3 pages)

SPC-2 "Large File Processing/READ ONLY/1024 KiB Transfer Size" Graphs

Average Data Rate – Complete Test Run

Average Data Rate – Measurement Interval (MI) Only

Average Data Rate per Stream

Average Response Time

SPC-2 "Large File Processing/READ ONLY/1024 KiB Transfer Size" graphs
(four pages, 1 graph per page)

SPC-2 "Large File Processing/READ ONLY/256 KiB Transfer Size" Test Run Data

SPC-2 "Large File Processing/READ ONLY/256 KiB Transfer Size" Test Run Data Tables: Ramp-Up, Measurement Interval, Run-Out, and Ramp-Down Periods
(3 pages)

SPC-2 "Large File Processing/READ ONLY/256 KiB Transfer Size" Graphs

Average Data Rate – Complete Test Run

Average Data Rate – Measurement Interval (MI) Only

Average Data Rate per Stream

Average Response Time

SPC-2 "Large File Processing/READ ONLY/256 KiB Transfer Size" graphs
(four pages, 1 graph per page)

Large Database Query Test

Clause 6.4.4.1

The Large Database Query Test is comprised of a set of I/O operations representative of scans or joins of large relational tables such as those performed for data mining or business intelligence.

Clause 6.4.4.2

The Large Database Query Test has two Test Phases, which shall be executed in the following uninterrupted sequence:

1. *1024 KIB TRANSFER SIZE*
2. *64 KIB TRANSFER SIZE*

The BC shall not be restarted or manually disturbed, altered, or adjusted during the execution of the Large File Processing Test. If power is lost to the BC during this Test all results shall be rendered invalid and the Test re-run in its entirety.

Clause 10.6.9.2

The Full Disclosure Report will contain the following content for the Large Database Query Test:

1. *A listing of the SPC-2 Workload Generator commands and parameters used to execute each of the Test Runs in the Large Database Query Test.*
2. *The human readable SPC-2 Test Results File for each of the Test Runs in the Large Database Query Test.*
3. *A table that contains the following information for each Test Run in the two Test Phases of the Large Database Query Test:*
    - *Average Data Rate: The average Data Rate, in MB per second for the Measurement Interval of each Test Run in the Large Database Query Test.*
    - *Average Data Rate per Stream: The average Data Rate per Stream, in MB per second, for the Measurement Interval of each Test Run in the Large Database Query Test.*
    - *Average Response Time: The average response time, in milliseconds (ms), for the Measurement Interval of each Test Run in the Large Database Query Test.*
4. *Average Data Rate, Average Data Rate per Stream and Average Response time graphs as defined in Clauses 10.1.1, 10.1.2 and 10.1.3.*

SPC-2 Workload Generator Commands and Parameters

The SPC-2 Workload Generator commands and parameters for the Large Database Query Test Runs are documented in Appendix E: SPC-2 Workload Generator Execution Commands and Parameters on Page 76.

SPC-2 Test Results File

A link to the SPC-2 Test Results file generated from the Large Database Query Test Runs is listed below.

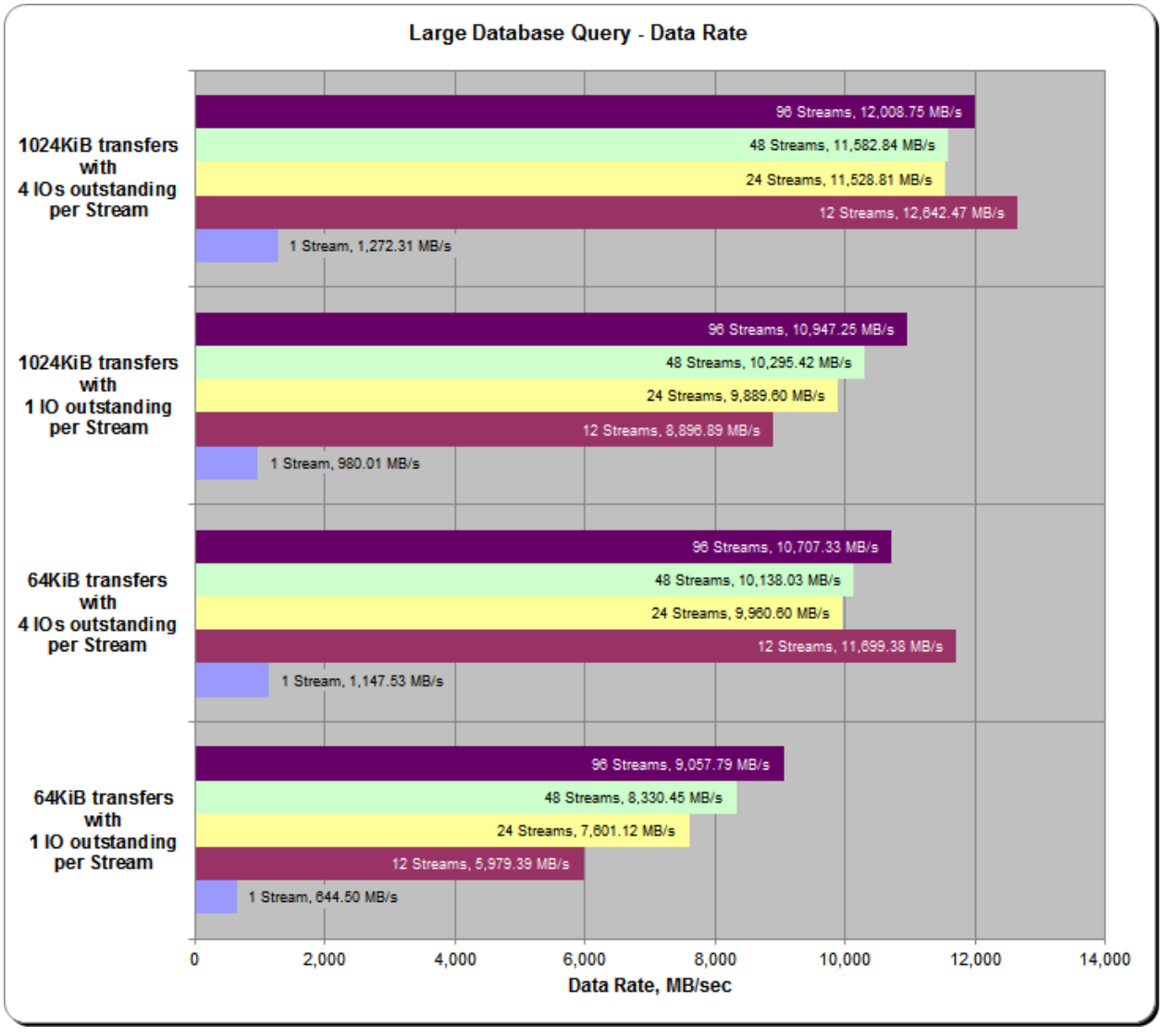
SPC-2 Large Database Query Test Results File

SPC-2 Large Database Query Average Data Rates (MB/s)

The average Data Rate (MB/s) for each Test Run in the two Test Phases of the SPC-2 Large Database Query Test is listed in the table below as well as illustrated in the following graph.

Test Run Sequence	1 Stream	12 Streams	24 Streams	48 Streams	96 Streams
1024KiB w/ 4 IOs/Stream	1,272.31	12,642.47	11,528.81	11,582.84	12,008.75
1024KiB w/ 1 IO/Stream	980.01	8,896.89	9,889.60	10,295.42	10,947.25
64KiB w/ 4 IOs/Stream	1,147.53	11,699.38	9,960.60	10,138.03	10,707.33
64KiB w/ 1 IO/Stream	644.50	5,979.39	7,601.12	8,330.45	9,057.79

SPC-2 Large Database Query Average Data Rates Graph

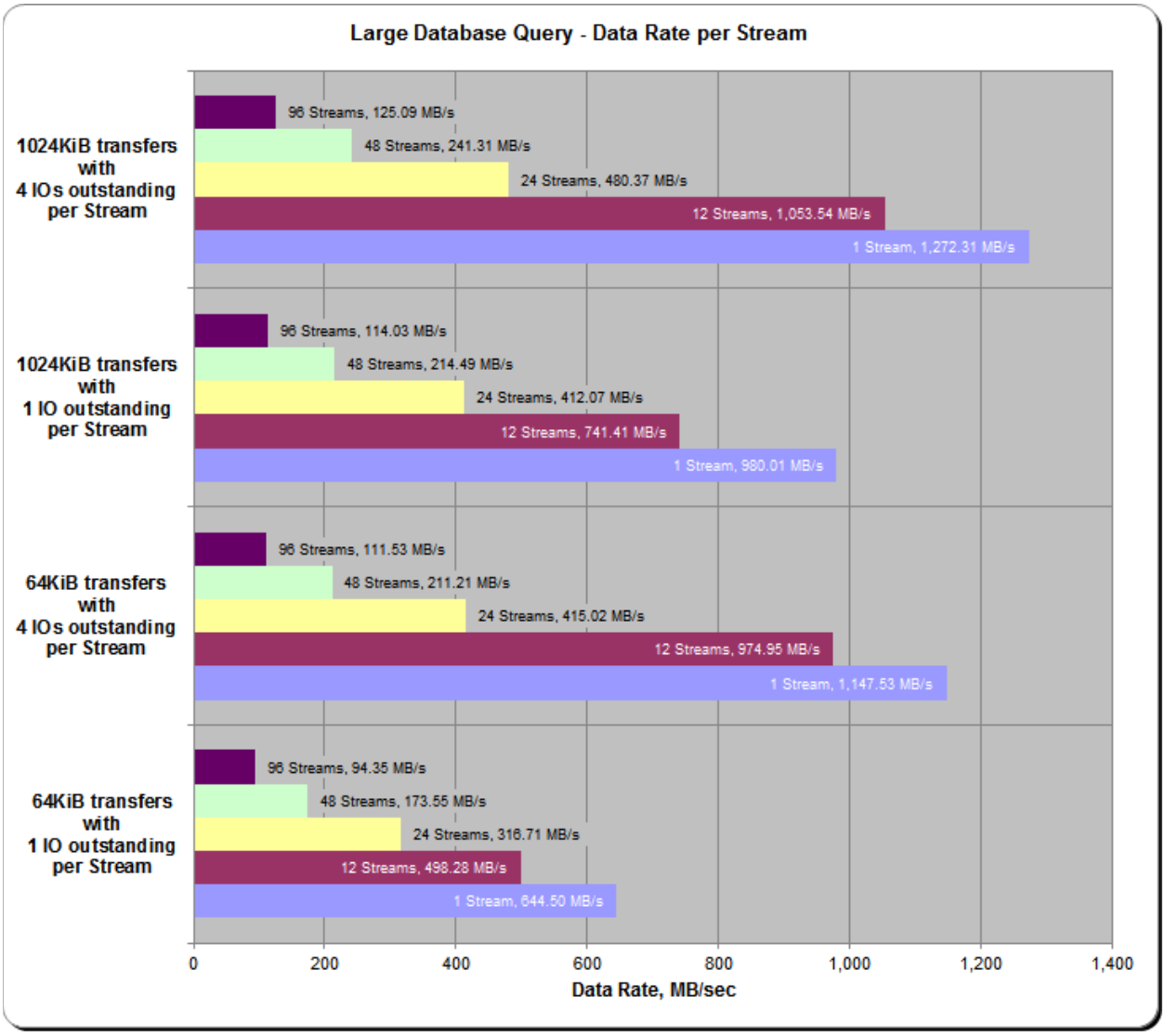


SPC-2 Large Database Query Average Data Rate per Stream

The average Data Rate per Stream for each Test Run in the two Test Phases of the SPC-2 Large Database Query Test is listed in the table below as well as illustrated in the following graph.

Test Run Sequence	1 Stream	12 Streams	24 Streams	48 Streams	96 Streams
1024KiB w/ 4 IOs/Stream	1,272.31	1,053.54	480.37	241.31	125.09
1024KiB w/ 1 IO/Stream	980.01	741.41	412.07	214.49	114.03
64KiB w/ 4 IOs/Stream	1,147.53	974.95	415.02	211.21	111.53
64KiB w/ 1 IO/Stream	644.50	498.28	316.71	173.55	94.35

SPC-2 Large Database Query Average Data Rate per Stream Graph

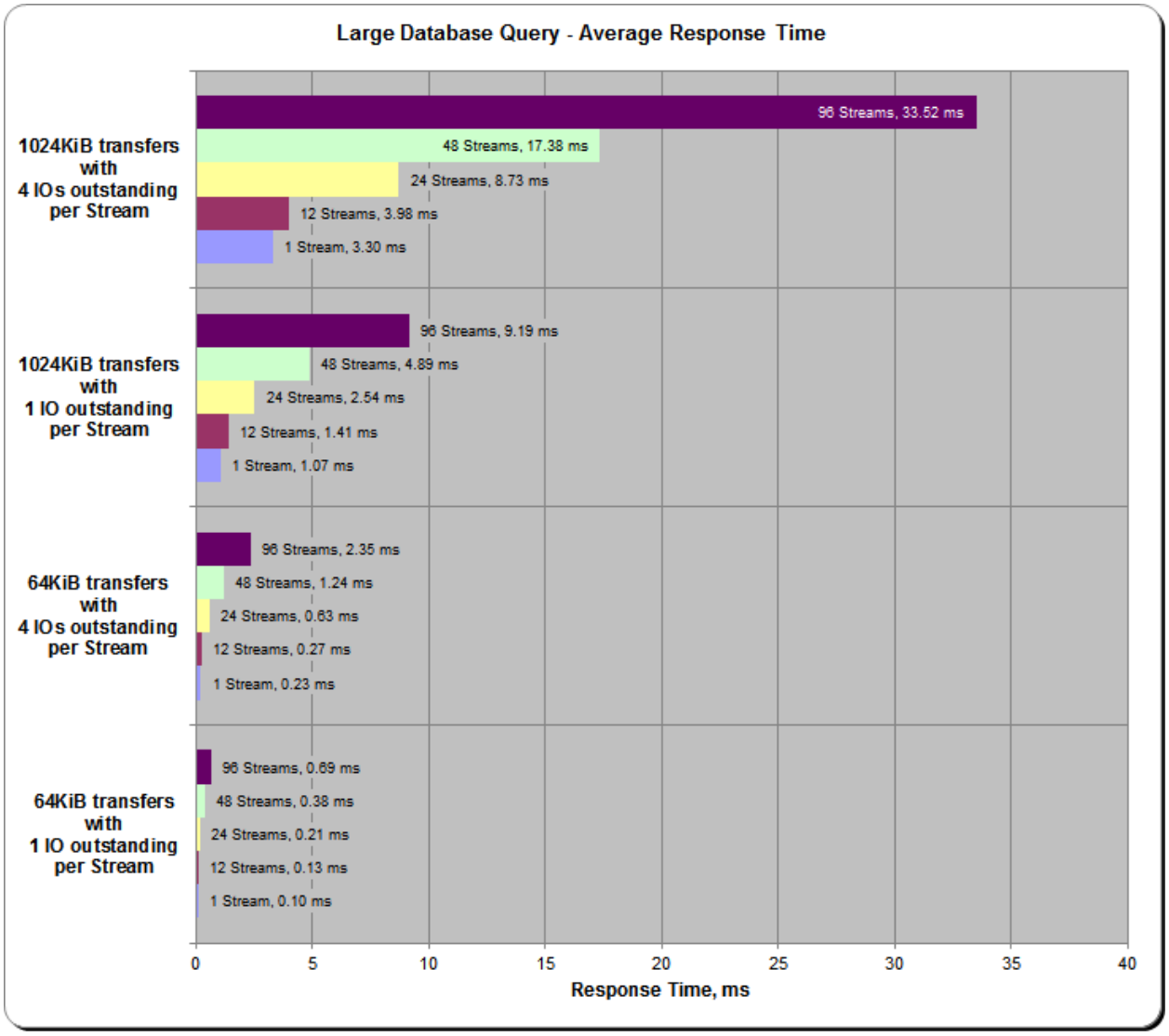


SPC-2 Large Database Query Average Response Time

The average Response Time, in milliseconds, for each Test Run in the two Test Phases of the SPC-2 Large Database Query Test is listed in the table below as well as illustrated in the following graph.

Test Run Sequence	1 Stream	12 Streams	24 Streams	48 Streams	96 Streams
1024KiB w/ 4 IOs/Stream	3.30	3.98	8.73	17.38	33.52
1024KiB w/ 1 IO/Stream	1.07	1.41	2.54	4.89	9.19
64KiB w/ 4 IOs/Stream	0.23	0.27	0.63	1.24	2.35
64KiB w/ 1 IO/Stream	0.10	0.13	0.21	0.38	0.69

SPC-2 Large Database Query Average Response Time Graph



Large Database Query Test – 1024 KIB TRANSFER SIZE Test Phase

Clause 10.6.9.2.1

1. *A table that will contain the following information for each "1024 KiB Transfer Size, 4 Outstanding I/Os" Test Run:*
   - *The number of Streams specified.*
   - *The Average Data Rate, Average Data Rate per Stream, and Average Response Time reported at five second intervals.*
2. *Average Data Rate by Intervals, Average Data Rate per Stream by Intervals, and Average Response Time by Intervals graphs for the "1024 KiB Transfer Size, 4 Outstanding I/Os" Test Runs as specified in Clauses 10.1.4 – 10.1.6.*
3. *A table that will contain the following information for each "1024 KiB Transfer Size, 1 Outstanding I/O" Test Run:*
   - *The number of Streams specified.*
   - *The Average Data Rate, Average Data Rate per Stream, and Average Response Time reported at five second intervals.*
4. *Average Data Rate by Intervals, Average Data Rate per Stream by Intervals, and Average Response Time by Intervals graphs for the "1024 KiB Transfer Size, 1 Outstanding I/O" Test Runs as specified in Clauses 10.1.4 – 10.1.6.*

A hyperlink for each of the above tables and graphs may appear in the FDR to provide access to the table or graph.

A hyperlink to a table with the SPC-2 "Large Database Query/1024 KIB TRANSFER SIZE/4 Outstanding I/Os" Test Run data appears on the next page. That entry is followed by hyperlinks to graphs illustrating the average Data Rate, average Data Rate per Stream, and average Response Time produced by the same Test Runs. The table and graphs present the data at five-second intervals.

Immediately following the above SPC-2 "Large Database Query/1024 KIB TRANSFER SIZE/4 Outstanding I/Os" entries will be hyperlinks for SPC-2 "Large Database Query/1024 KIB TRANSFER SIZE/1 Outstanding I/O" table and graphs. The table contains the Test Run data and the graphs illustrate the average Data Rate, average Data Rate per Stream, and average Response Time produced by the Test Runs.

SPC-2 "Large Database Query/1024 KIB TRANSFER SIZE/4 Outstanding I/Os" Test Run Data

SPC-2 "Large Database Query/1024 KIB TRANSFER SIZE/4 Outstanding I/Os" Test Run Data Tables: Ramp-Up, Measurement Interval, Run-Out, and Ramp-Down Periods
(3 pages)

SPC-2 "Large Database Query/1024 KIB TRANSFER SIZE/4 Outstanding I/Os" Graphs

Average Data Rate – Complete Test Run

Average Data Rate – Measurement Interval (MI) Only

Average Data Rate per Stream

Average Response Time

SPC-2 "Large Database Query/1024 KIB TRANSFER SIZE/4 Outstanding I/Os" graphs
(four pages, 1 graph per page)

SPC-2 "Large Database Query/1024 KIB TRANSFER SIZE/1 Outstanding I/O" Test Run Data

SPC-2 "Large Database Query/1024 KIB TRANSFER SIZE/1 Outstanding I/O" Test Run Data Tables: Ramp-Up, Measurement Interval, Run-Out, and Ramp-Down Periods
(3 pages)

SPC-2 "Large Database Query/1024 KIB TRANSFER SIZE/1 Outstanding I/O" Graphs

Average Data Rate – Complete Test Run

Average Data Rate – Measurement Interval (MI) Only

Average Data Rate per Stream

Average Response Time

SPC-2 "Large Database Query/1024 KIB TRANSFER SIZE/1 Outstanding I/O" graphs
(four pages, 1 graph per page)

Large Database Query Test – 64 KiB TRANSFER SIZE Test Phase

Clause 10.6.9.2.2

1. *A table that will contain the following information for each "64 KiB Transfer Size, 4 Outstanding I/Os" Test Run:*
   - *The number of Streams specified.*
   - *The Average Data Rate, Average Data Rate per Stream, and Average Response Time reported at five second intervals.*
2. *Average Data Rate by Intervals, Average Data Rate per Stream by Intervals, and Average Response Time by Intervals graphs for the "64 KiB Transfer Size, 4 Outstanding I/Os" Test Runs as specified in Clauses 10.1.4 – 10.1.6.*
3. *A table that will contain the following information for each "64 KiB Transfer Size, 1 Outstanding I/O" Test Run:*
   - *The number of Streams specified.*
   - *The Average Data Rate, Average Data Rate per Stream, and Average Response Time reported at five second intervals.*
4. *Average Data Rate by Intervals, Average Data Rate per Stream by Intervals, and Average Response Time by Intervals graphs for the "64 KiB Transfer Size, 1 Outstanding I/O" Test Runs as specified in Clauses 10.1.4 – 10.1.6.*

A hyperlink for each of the above tables and graphs may appear in the FDR to provide access to the table or graph.

A hyperlink to a table with the SPC-2 "Large Database Query/64 KIB TRANSFER SIZE/4 Outstanding I/Os" Test Run data appears on the next page. That entry is followed by hyperlinks to graphs illustrating the average Data Rate, average Data Rate per Stream, and average Response Time produced by the same Test Runs. The table and graphs present the data at five-second intervals.

Immediately following the above SPC-2 "Large Database Query/64 KIB TRANSFER SIZE/4 Outstanding I/Os" entries will be hyperlinks for SPC-2 "Large Database Query/64 KIB TRANSFER SIZE/1 Outstanding I/O" table and graphs. The table contains the Test Run data and the graphs illustrate the average Data Rate, average Data Rate per Stream, and average Response Time produced by the Test Runs.

SPC-2 "Large Database Query/64 KIB TRANSFER SIZE/4 Outstanding I/Os" Test Run Data

SPC-2 "Large Database Query/64 KIB TRANSFER SIZE/4 Outstanding I/Os" Test Run Data Tables: Ramp-Up, Measurement Interval, Run-Out, and Ramp-Down Periods
(3 pages)

SPC-2 "Large Database Query/64 KIB TRANSFER SIZE/4 Outstanding I/Os" Graphs

Average Data Rate – Complete Test Run

Average Data Rate – Measurement Interval (MI) Only

Average Data Rate per Stream

Average Response Time

SPC-2 "Large Database Query/64 KIB TRANSFER SIZE/4 Outstanding I/Os" graphs
(four pages, 1 graph per page)

SPC-2 "Large Database Query/64 KIB TRANSFER SIZE/1 Outstanding I/O" Test Run Data

SPC-2 "Large Database Query/64 KIB TRANSFER SIZE/1 Outstanding I/O" Test Run Data Tables: Ramp-Up, Measurement Interval, Run-Out, and Ramp-Down Periods
(3 pages)

SPC-2 "Large Database Query/64 KIB TRANSFER SIZE/1 Outstanding I/O" Graphs

Average Data Rate – Complete Test Run

Average Data Rate – Measurement Interval (MI) Only

Average Data Rate per Stream

Average Response Time

SPC-2 "Large Database Query/64 KIB TRANSFER SIZE/1 Outstanding I/O" graphs
(four pages, 1 graph per page)

Video on Demand Delivery Test

Clause 6.4.5.1

The Video on Demand Delivery Test represents the I/O operations required to enable individualized video entertainment for a community of subscribers, which draw from a digital film library.

Clause 6.4.5.2

The Video on Demand Delivery Test consists of one (1) Test Run.

The BC shall not be restarted or manually disturbed, altered, or adjusted during the execution of the Video on Demand Delivery Test. If power is lost to the BC during this Test all results shall be rendered invalid and the Test re-run in its entirety.

Clause 10.6.9.3

The Full Disclosure Report will contain the following content for the Video on Demand Delivery Test:

1. *A listing of the SPC-2 Workload Generator commands and parameters used to execute the Test Run in the Video on Demand Delivery Test.*
2. *The human readable SPC-2 Test Results File for the Test Run in the Video on Demand Delivery Test.*
3. *A table that contains the following information for the Test Run in the Video on Demand Delivery Test:*
    - *The number Streams specified.*
    - *The Ramp-Up duration in seconds.*
    - *The Measurement Interval duration in seconds.*
    - *The average data rate, in MB per second, for the Measurement Interval.*
    - *The average data rate, in MB per second, per Stream for the Measurement Interval.*
4. *A table that contains the following information for the single Video on Demand Delivery Test Run:*
    - *The number Streams specified.*
    - *The average data rate, average data rate per stream, average Response Time, and Maximum Response Time reported at 60 second intervals.*
5. *Average Data Rate by Intervals, Average Data Rate per Stream by Intervals, and Average Response Time by Intervals graphs for the single Video on Demand Delivery Test Run as specified in Clause 10.1.8.*
6. *A Maximum Response Time (intervals) graph as specified in Clause 10.1.8.*

SPC-2 Workload Generator Commands and Parameters

The SPC-2 Workload Generator commands and parameters for the Video on Demand Delivery Test Run are documented in Appendix E: SPC-2 Workload Generator Execution Commands and Parameters on Page 76..

SPC-2 Test Results File

A link to the SPC-2 Test Results file generated from the Video on Demand Delivery Test Run is listed below.

SPC-2 Video on Demand Delivery Test Results File

SPC-2 Video on Demand Delivery Test Run Data

The number of Streams specified, Ramp-Up duration in seconds, Measurement Interval duration in seconds, average Data Rate for the Measurement Interval, and average Data Rate per Stream for the Measurement Interval are listed in the following table.

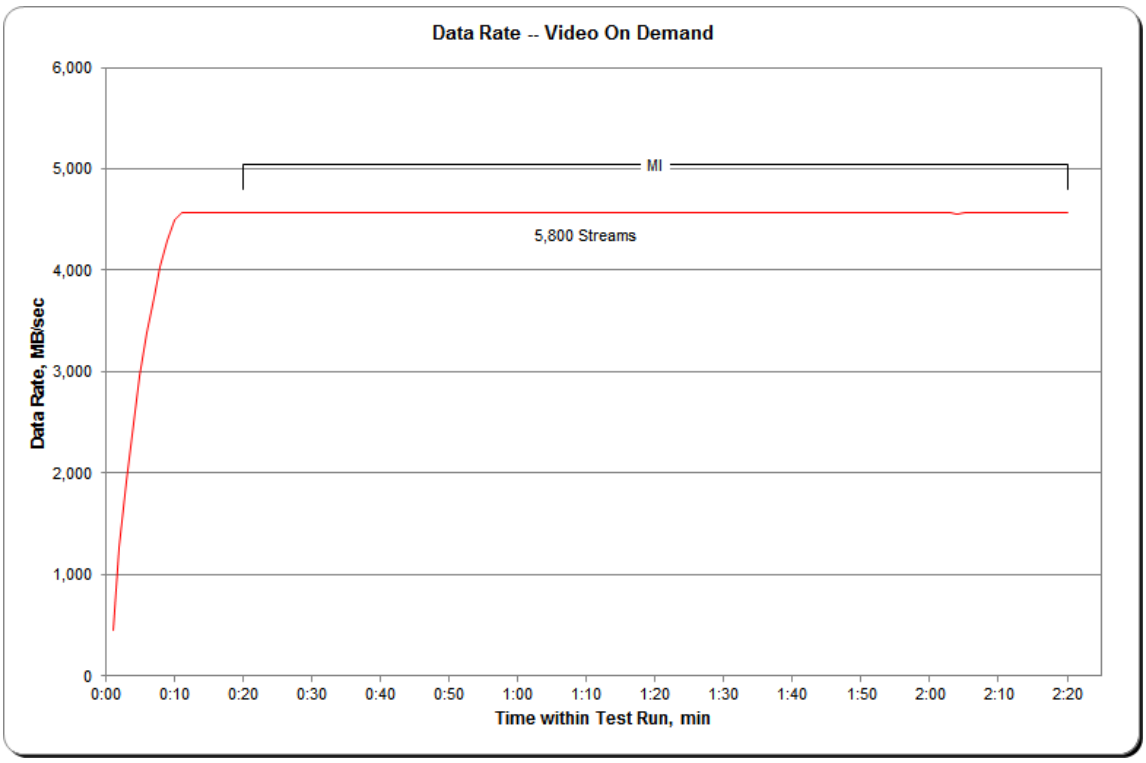
SPC-2-VOD	TR1
Number of Streams	5,800
Ramp-up Time, sec	1,200
Measurement Interval, sec	7,200
Average Data Rate, MB/sec	4,561.32
Per Stream Data Rate, MB/sec	0.79
Average Response Time, ms	27.36
Average Max Response Time, ms	567.25

Video on Demand Delivery Test – TEST RUN DATA BY INTERVAL

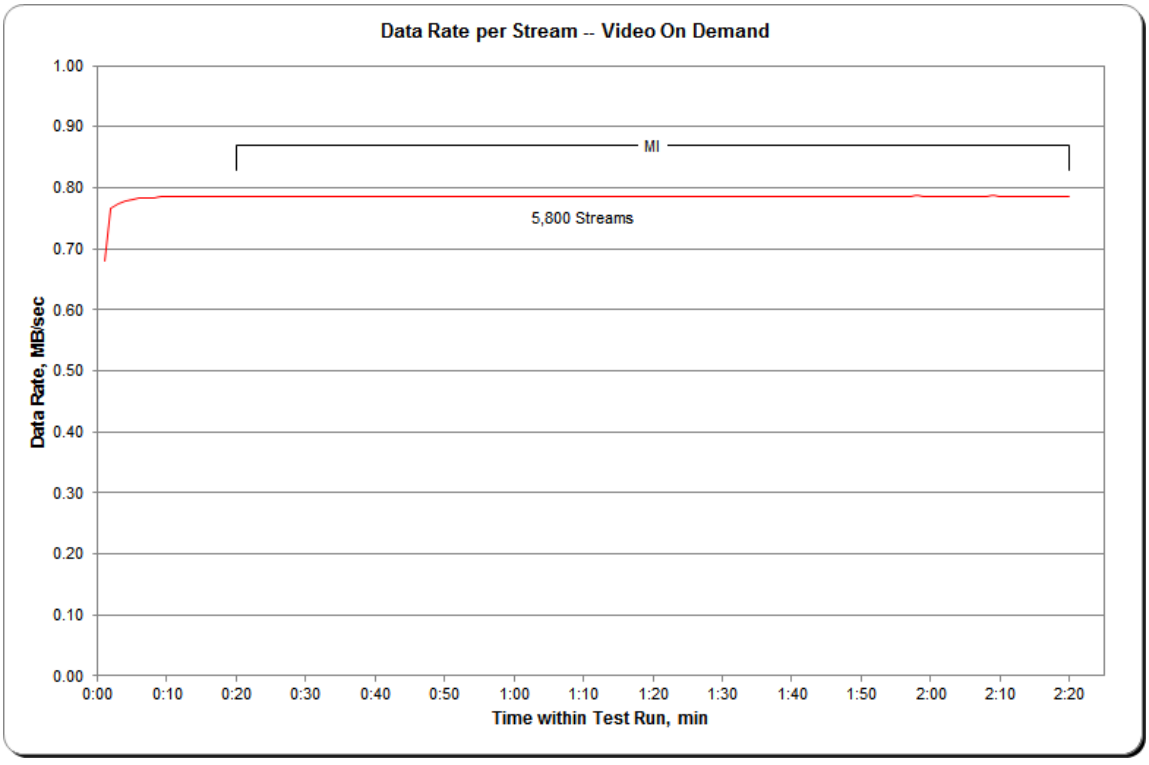
The SPC-2 Video on Demand Delivery Test Run data is contained in the table that appears below. That table is followed by graphs illustrating the average Data Rate and average Data Rate per Stream produced by the same Test Runs. The table and graphs present the data at sixty second intervals.

TR1	5,800 Streams				TR1	5,800 Streams				TR1	5,800 Streams			
Test Run Sequence Time	Data Rate, MB/sec	Data Rate / Stream, MB/sec	Response Time, ms	Maximum Response Time, ms	Test Run Sequence Time	Data Rate, MB/sec	Data Rate / Stream, MB/sec	Response Time, ms	Maximum Response Time, ms	Test Run Sequence Time	Data Rate, MB/sec	Data Rate / Stream, MB/sec	Response Time, ms	Maximum Response Time, ms
0:01:00	447.83	0.68	3.54	47.42	0:48:00	4,561.33	0.79	27.33	546.87	1:35:00	4,561.30	0.79	27.12	576.40
0:02:00	1,266.40	0.77	5.66	97.09	0:49:00	4,561.30	0.79	26.99	579.84	1:36:00	4,561.38	0.79	27.02	606.64
0:03:00	1,926.16	0.77	7.31	120.40	0:50:00	4,561.22	0.79	27.02	521.95	1:37:00	4,561.33	0.79	26.97	610.58
0:04:00	2,500.00	0.78	9.13	177.48	0:51:00	4,561.29	0.79	27.10	539.36	1:38:00	4,561.22	0.79	26.98	536.06
0:05:00	2,954.67	0.78	10.95	192.81	0:52:00	4,561.33	0.79	27.11	518.59	1:39:00	4,561.23	0.79	27.16	595.88
0:06:00	3,383.71	0.78	13.39	315.82	0:53:00	4,561.42	0.79	27.10	620.27	1:40:00	4,561.29	0.79	27.05	630.33
0:07:00	3,727.85	0.78	15.60	255.33	0:54:00	4,561.41	0.79	27.14	520.59	1:41:00	4,561.35	0.79	26.85	551.32
0:08:00	4,034.85	0.78	18.70	387.70	0:55:00	4,561.28	0.79	27.10	486.65	1:42:00	4,561.35	0.79	27.22	534.16
0:09:00	4,289.77	0.78	21.43	389.56	0:56:00	4,561.50	0.79	27.76	640.53	1:43:00	4,561.28	0.79	27.46	548.16
0:10:00	4,489.71	0.78	24.75	594.53	0:57:00	4,561.36	0.79	27.16	460.83	1:44:00	4,561.31	0.79	27.45	599.15
0:11:00	4,561.57	0.79	26.01	499.00	0:58:00	4,561.22	0.79	27.07	545.90	1:45:00	4,561.40	0.79	27.60	573.26
0:12:00	4,561.40	0.79	26.26	599.63	0:59:00	4,561.19	0.79	27.12	530.04	1:46:00	4,561.26	0.79	27.32	617.55
0:13:00	4,561.52	0.79	25.99	491.24	1:00:00	4,561.16	0.79	27.14	461.86	1:47:00	4,561.21	0.79	27.25	568.90
0:14:00	4,561.21	0.79	26.42	675.89	1:01:00	4,561.47	0.79	27.60	565.40	1:48:00	4,561.16	0.79	27.37	550.98
0:15:00	4,561.18	0.79	26.00	476.67	1:02:00	4,561.31	0.79	27.14	435.79	1:49:00	4,561.53	0.79	26.93	558.70
0:16:00	4,561.37	0.79	26.47	616.39	1:03:00	4,561.22	0.79	26.78	498.38	1:50:00	4,561.32	0.79	26.88	626.03
0:17:00	4,561.14	0.79	26.07	449.25	1:04:00	4,561.37	0.79	26.71	512.48	1:51:00	4,560.97	0.79	26.96	492.37
0:18:00	4,561.11	0.79	26.38	571.15	1:05:00	4,561.69	0.79	27.31	602.34	1:52:00	4,561.39	0.79	26.83	462.02
0:19:00	4,561.40	0.79	26.15	461.25	1:06:00	4,561.26	0.79	27.50	526.10	1:53:00	4,561.08	0.79	26.61	417.38
0:20:00	4,561.25	0.79	26.24	570.36	1:07:00	4,561.68	0.79	28.07	676.29	1:54:00	4,561.22	0.79	26.95	484.62
0:21:00	4,561.25	0.79	26.76	466.31	1:08:00	4,561.21	0.79	27.92	561.71	1:55:00	4,561.35	0.79	26.66	424.51
0:22:00	4,561.36	0.79	26.44	530.66	1:09:00	4,560.86	0.79	28.22	622.17	1:56:00	4,561.28	0.79	27.35	557.07
0:23:00	4,561.42	0.79	26.87	499.82	1:10:00	4,561.36	0.79	27.90	512.95	1:57:00	4,561.41	0.79	26.80	439.53
0:24:00	4,561.02	0.79	26.99	567.95	1:11:00	4,561.42	0.79	27.99	659.86	1:58:00	4,561.92	0.79	27.04	579.20
0:25:00	4,561.42	0.79	26.99	544.50	1:12:00	4,561.45	0.79	27.77	517.84	1:59:00	4,561.35	0.79	26.73	437.60
0:26:00	4,561.18	0.79	27.05	511.93	1:13:00	4,561.67	0.79	28.18	682.35	2:00:00	4,561.34	0.79	27.24	657.98
0:27:00	4,561.30	0.79	27.32	548.71	1:14:00	4,561.69	0.79	28.17	665.85	2:01:00	4,561.26	0.79	26.63	430.75
0:28:00	4,561.45	0.79	27.84	571.85	1:15:00	4,561.27	0.79	28.13	647.87	2:02:00	4,561.38	0.79	26.74	686.42
0:29:00	4,561.39	0.79	28.12	561.99	1:16:00	4,561.28	0.79	28.07	608.75	2:03:00	4,561.26	0.79	26.61	415.90
0:30:00	4,561.22	0.79	28.04	604.96	1:17:00	4,561.39	0.79	28.05	613.09	2:04:00	4,560.52	0.79	27.19	561.52
0:31:00	4,561.27	0.79	27.99	607.70	1:18:00	4,561.37	0.79	28.18	642.75	2:05:00	4,561.15	0.79	27.06	461.62
0:32:00	4,561.61	0.79	27.84	595.88	1:19:00	4,561.47	0.79	28.11	629.59	2:06:00	4,561.40	0.79	27.37	630.76
0:33:00	4,561.41	0.79	27.95	543.22	1:20:00	4,561.49	0.79	28.14	624.35	2:07:00	4,561.35	0.79	27.36	486.65
0:34:00	4,561.26	0.79	27.96	660.59	1:21:00	4,561.39	0.79	27.57	618.39	2:08:00	4,561.32	0.79	27.44	587.08
0:35:00	4,561.28	0.79	27.94	567.27	1:22:00	4,561.12	0.79	27.36	599.13	2:09:00	4,562.03	0.79	27.70	585.79
0:36:00	4,561.40	0.79	27.91	534.48	1:23:00	4,561.42	0.79	26.88	508.20	2:10:00	4,561.37	0.79	27.79	636.56
0:37:00	4,561.46	0.79	27.96	562.79	1:24:00	4,561.21	0.79	26.53	500.02	2:11:00	4,561.38	0.79	27.73	619.19
0:38:00	4,561.24	0.79	27.97	641.98	1:25:00	4,561.40	0.79	26.93	519.04	2:12:00	4,561.47	0.79	27.69	594.76
0:39:00	4,561.24	0.79	27.98	579.28	1:26:00	4,561.41	0.79	27.27	580.10	2:13:00	4,561.55	0.79	27.74	672.16
0:40:00	4,561.55	0.79	28.13	559.02	1:27:00	4,561.27	0.79	27.18	626.98	2:14:00	4,561.21	0.79	27.60	597.76
0:41:00	4,560.99	0.79	27.26	511.19	1:28:00	4,561.37	0.79	27.08	598.53	2:15:00	4,561.16	0.79	27.67	610.78
0:42:00	4,561.05	0.79	27.63	603.12	1:29:00	4,561.44	0.79	26.84	598.05	2:16:00	4,561.40	0.79	27.65	622.99
0:43:00	4,561.09	0.79	27.04	593.60	1:30:00	4,561.35	0.79	26.97	604.21	2:17:00	4,561.32	0.79	27.73	603.42
0:44:00	4,561.23	0.79	27.24	626.75	1:31:00	4,561.42	0.79	27.08	561.38	2:18:00	4,561.21	0.79	27.73	645.11
0:45:00	4,561.43	0.79	26.95	617.27	1:32:00	4,561.35	0.79	27.10	611.39	2:19:00	4,561.25	0.79	27.68	599.79
0:46:00	4,561.29	0.79	27.52	586.60	1:33:00	4,561.11	0.79	27.07	622.35	2:20:00	4,561.52	0.79	27.73	562.44
0:47:00	4,561.12	0.79	27.44	586.83	1:34:00	4,561.31	0.79	27.05	542.79	0:00:00	0.00	0.00	0.00	0.00

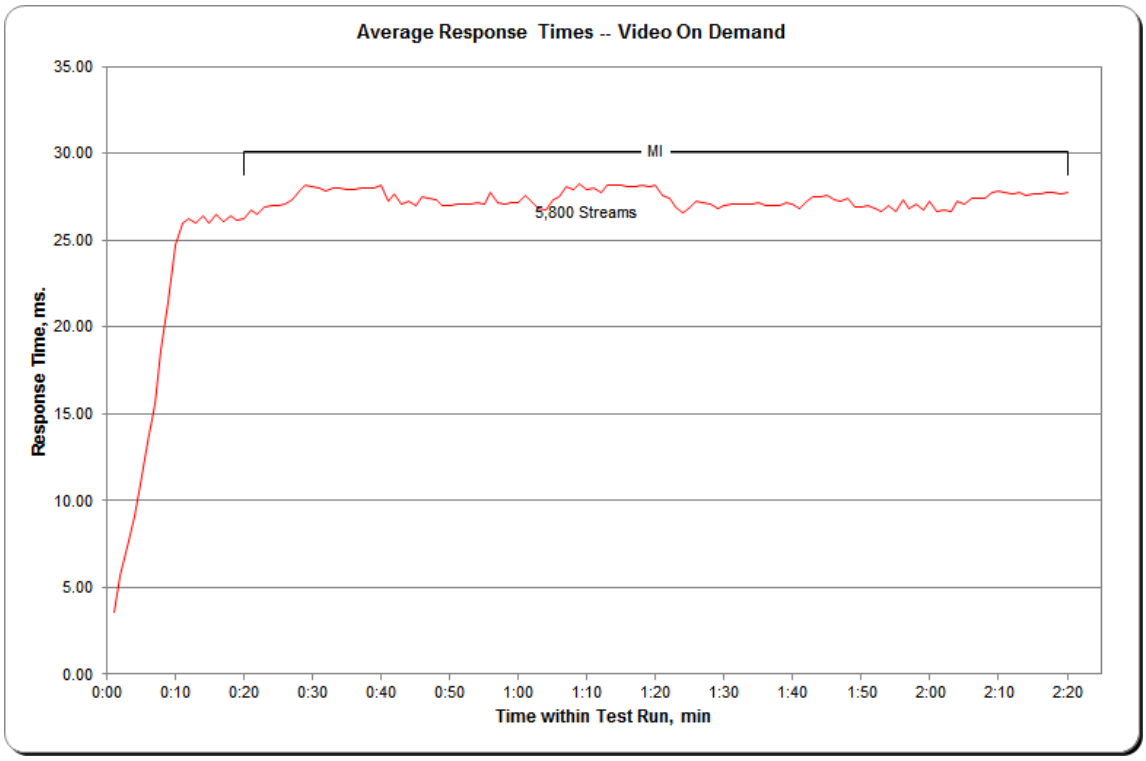
SPC-2 Video on Demand Delivery Average Data Rate Graph



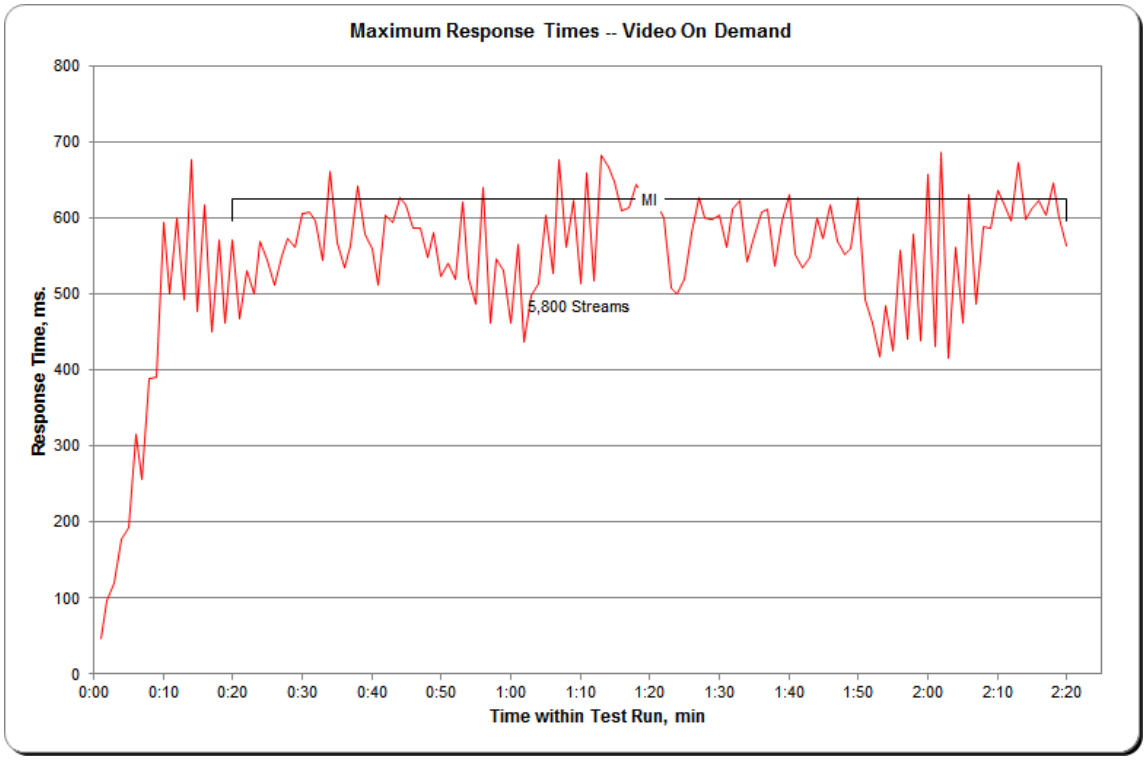
SPC-2 Video on Demand Delivery Average Data Rate per Stream Graph



SPC-2 Video on Demand Delivery Average Response Time Graph



SPC-2 Video on Demand Delivery Maximum Response Time Graph



Data Persistence Test

Clause 7

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

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

The SPC-2 Workload Generator will write a specific pattern at randomly selected locations throughout the Total ASU Capacity (Persistence Test Run 1). The SPC-2 Workload Generator will retain the information necessary to later validate the pattern written at each location.

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

Restart the TSC, and if the Host System(s) were shutdown and powered off, restart the Host System(s).

The SPC-2 Workload Generator will utilize the retained data from Persistence Test Run 1 to verify (Persistence Run 2) the bit patterns written in Persistence Test Run 1 and their corresponding location.

Clause 10.6.9.4

The Full Disclosure Report will contain the following content for the Data Persistence Test:

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

SPC-2 Workload Generator Commands and Parameters

The SPC-2 Workload Generator commands and parameters for the Persistence Test Runs are documented in Appendix E: SPC-2 Workload Generator Execution Commands and Parameters on Page 76.

Data Persistence Test Results File

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

Persistence 1 Test Run *(write phase)* Results File

Persistence 2 Test Run *(read phase)* Results File

Data Persistence Test Results

Data Persistence Test Results	
Data Persistence Test Number: 1	
Total Number of Logical Blocks Written	758,690
Total Number of Logical Blocks Re-referenced	5,306
Total Number of Logical Blocks Verified	753,384
Total Number of Logical Blocks that Failed Verification	0
Number of Failed I/O Requests in the process of the Test	0

PRICED STORAGE CONFIGURATION AVAILABILITY DATE

Clause 10.6.9

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

The Availability Data shall be stated in either a combination of specific alphanumeric month, numeric day and numeric year or as "Currently Available".

The NetApp E-Series E5660 Storage Array, as documented in this SPC-2 Full Disclosure Report, is currently available for customer purchase and shipment.

ANOMALIES OR IRREGULARITIES

Clause 10.6.12

The FDR shall include a clear and complete description of any anomalies or irregularities encountered in the course of executing the SPC-2 benchmark that may in any way call into question the accuracy, verifiability, or authenticity of information published in this FDR.

There were no anomalies or irregularities encountered during the SPC-2 Remote Audit of the NetApp E-Series E5660 Storage Array.

APPENDIX A: SPC-2 GLOSSARY

"Decimal" *(powers of ten)* Measurement Units

In the storage industry, the terms "kilo", "mega", "giga", "tera", "peta", and "exa" are commonly used prefixes for computing performance and capacity. For the purposes of the SPC workload definitions, all of the following terms are defined in "powers of ten" measurement units.

- A kilobyte (KB) is equal to 1,000 (10^3) bytes.
- A megabyte (MB) is equal to 1,000,000 (10^6) bytes.
- A gigabyte (GB) is equal to 1,000,000,000 (10^9) bytes.
- A terabyte (TB) is equal to 1,000,000,000,000 (10^{12}) bytes.
- A petabyte (PB) is equal to 1,000,000,000,000,000 (10^{15}) bytes
- An exabyte (EB) is equal to 1,000,000,000,000,000,000 (10^{18}) bytes

"Binary" *(powers of two)* Measurement Units

The sizes reported by many operating system components use "powers of two" measurement units rather than "power of ten" units. The following standardized definitions and terms are also valid and may be used in this document.

- A kibibyte (KiB) is equal to 1,024 (2^{10}) bytes.
- A mebibyte (MiB) is equal to 1,048,576 (2^{20}) bytes.
- A gigibyte (GiB) is equal to 1,073,741,824 (2^{30}) bytes.
- A tebibyte (TiB) is equal to 1,099,511,627,776 (2^{40}) bytes.
- A pebibyte (PiB) is equal to 1,125,899,906,842,624 (2^{50}) bytes.
- An exbibyte (EiB) is equal to 1,152,921,504,606,846,967 (2^{60}) bytes.

SPC-2 Data Repository Definitions

Total ASU Capacity: The total storage capacity read and written in the course of executing the SPC-2 benchmark.

Application Storage Unit (ASU): The logical interface between the storage and SPC-2 Workload Generator. The ASU is 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-2 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-2 Workload Generator.

Configured Storage Capacity: This capacity includes the Addressable Storage Capacity and any other storage (parity disks, hot spares, etc.) necessary to implement the Addressable Storage Capacity.

Physical Storage Capacity: The formatted capacity of all storage devices physically present in the Tested Storage Configuration (TSC).

Data Protection Overhead: The storage capacity required to implement the selected level of data protection.

Required Storage: The amount of Configured Storage Capacity required to implement the Addressable Storage Configuration, excluding the storage required for the ASU.

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 sum of unused storage capacity within the Physical Storage Capacity, Configured Storage Capacity, and Addressable Storage Capacity.

SPC-2 Data Protection Levels

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

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

SPC-2 Test Execution Definitions

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

Completion Time: The time recorded by the Workload Generator when an I/O Request is completed by the Tested Storage Configuration (TSC) as signaled by System Software.

Data Rate: The data volume, in MB, transferred by all Measured I/O Requests in an SPC-2 Test Run divided by the length of the Test Run in seconds.

Failed I/O Request: Any I/O Request issued by the SPC-2 Workload Generator that meets one of the following conditions *(see "I/O Completion Types" illustrated below)*:

- The I/O Request was signaled as failed by System Software.
- The I/O Request started within the Measurement Interval, but did not complete prior to the end of the appropriate Run-Out period..
- The I/O Request started within the Run-Out period, but did not complete prior to the end of the appropriate Ramp-Down period.

I/O Request Throughput: The total number of Measured I/O Requests in an SPC-2 Test Run divided by the duration of the Measurement Interval in seconds.

Measured I/O Request: A Completed I/O Request that begins (Start Time) within a Measurement Interval and completes (Completion Time) prior to the end of the appropriate Ramp Down *(see "I/O Completion Types" illustrated below).*

Measurement Interval: A specified, contiguous period of time, after the TSC has reached Steady State, when data is collected by the Workload Generator to produce the test results for a SPC-2 Test Run *(see "SPC-2 Test Run Components" illustrated below, Test Run 1: T_2-T_3 and Test Run 2: T_7-T_8).*

Outstanding I/O Requests: The Outstanding I/O Requests parameter specifies the maximum number of concurrent I/O Requests, associated with a give Stream, which have been issued but not yet completed. *(Clause 3.4.4 of the SPC-2 Benchmark Specification).*

Ramp-Down: A specified, contiguous period of time in which the TSC is required to complete I/O Requests started but not completed during the preceding Run-Out period. Ramp-Down begins at the end of the preceding Run-Out period *(see "SPC-2 Test Run Components" illustrated below, Test Run 1: T_4-T_5 and Test Run 2: T_9-T_{10}).* The Workload Generator will not submit any I/O Requests during the Ramp-Down.

Ramp-Up: A specified, contiguous period of time required for the Benchmark Configuration (BC) to produce Steady State throughput after the Workload Generator begins submitting I/O Requests to the TSC for execution. The Ramp-Up period ends at the beginning of the Measurement Interval *(see "SPC-2 Test Run Components" illustrated below, Test Run 1: T_0-T_2 and Test Run 2: T_5-T_7).*

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

Run-Out: A specified, contiguous period of time in which the TSC is required to complete I/O Requests started but not completed during the preceding Measurement Interval. The Run-Out period begins at the end of the preceding Measurement Interval and is a component of the Steady State period *(see "SPC-2 Test Run Components" illustrated below, Test Run 1: T_3-T_4 and Test Run 2: T_9-T_{10}).* The Workload Generator will continue to submit I/O Requests at the Test Run's specified rate during the Run-Out period.

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

Steady State: The period during which the workload presented to the TSC by the SPC-2 Workload Generator is constant and the resulting TSC I/O Request Throughput is both consistent and sustainable. The Steady State period includes both the Measurement Interval and Run-Out periods *(see "SPC-2 Test Run Components" illustrated below, Test Run 1: T_1-T_4 and Test Run 2: T_6-T_9).*

Steady State is achieved only after caches in the TSC have filled and as a result the I/O Request Throughput of the TSC has stabilized.

Stream: A collection of Stream Segments that started within a Test Run.

Stream Segment: A sequentially organized pattern of I/O requests, which transfers a contiguous range of data.

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

Test Phase: A collection of one or more SPC-2 Test Runs sharing a common objective and intended to be run in a specific sequence.

Test Run: The execution of SPC-2 that produces specific SPC-2 test results. SPC-2 Test Runs have specified, measured Ramp-Up, Measurement Interval, Run-Out and Ramp-Down periods. "SPC-2 Test Run Components" *(see below)* illustrates the Ramp-Up, Steady State, Measurement Interval, Run-Out, and Ramp-Down components contained in two uninterrupted SPC-2 Test Runs *(Test Run 1: T_0-T_5 and Test Run 2: T_5-T_{10})*.

Test Run Sequence: A related sequence of Large File Processing (LFP) or Large Database Query (LDQ) Test Runs. Each Test Run Sequence will consist of five Test Runs, which vary the number of Streams as follows:

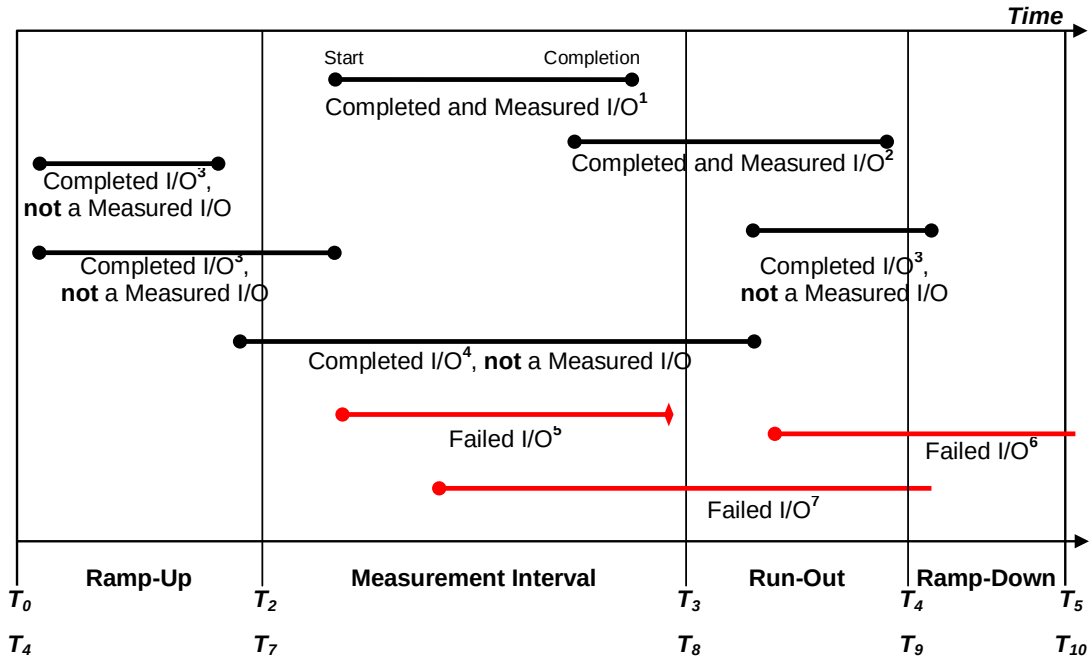
- Test Run 1: Maximum number of Streams, which is selected by the Test Sponsor
- Test Run 2: 50% of the maximum number of Streams used in Test Run 1.
- Test Run 3: 25% of the maximum number of Streams used in Test Run 1.
- Test Run 4: 12.5% of the maximum number of Streams used in Test Run 1.
- Test Run 5: 1 Stream.

Each of the five Test Runs in a Test Run Sequence will share the same attributes with the exception of the number of Streams. For example:

- Large File Processing, Read, 1024 KiB Transfer Size: Maximum Streams
- Large File Processing, Read, 1024 KiB Transfer Size: 50% of Maximum Streams
- Large File Processing, Read, 1024 KiB Transfer Size: 25% of Maximum Streams
- Large File Processing, Read, 1024 KiB Transfer Size: 12.5% of Maximum Streams
- Large File Processing, Read, 1024 KiB Transfer Size: 1 Stream

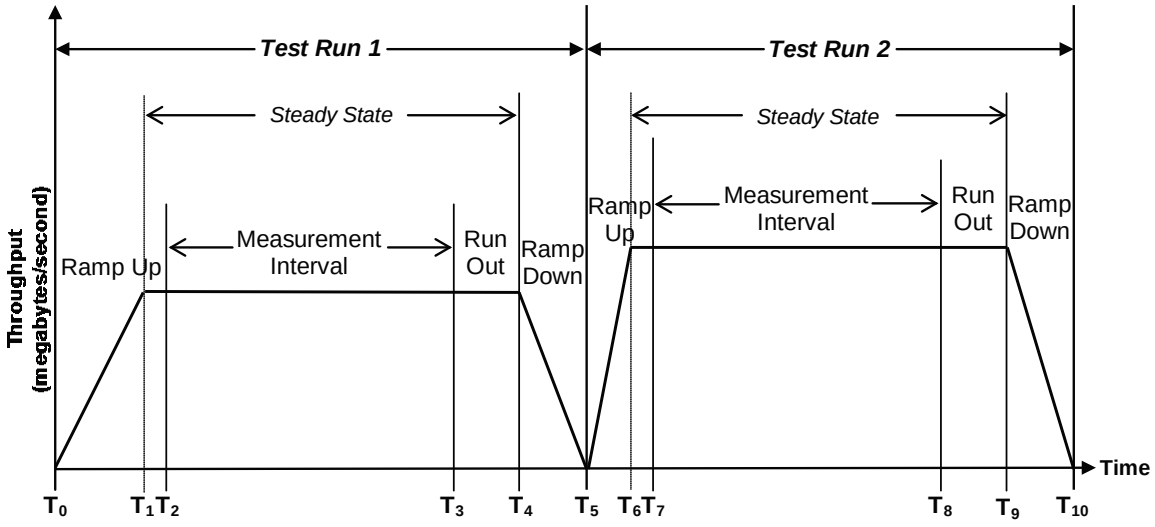
Transfer Size: The Transfer Size parameter specifies the number of bytes in KiB to transfer. *(Clause 3.4.7 of the SPC-2 Benchmark Specification)*

I/O Completion Types



Completed and Measured I/O[1]: *I/O started and completed within the Measurement Interval.*
Completed and Measured I/O[2]: *I/O started within the Measurement Interval and completed within Ramp Down.*
Completed I/O[3]: *I/O started before or after the Measurement Interval – not measured.*
Completed I/O[4]: *I/O started before and completed after the Measurement Interval – not measured.*
Failed I/O[5]: *Signaled as failed by System Software.*
Failed I/O[6]: *I/O did not complete prior to the end of Ramp-Down.*
Failed I/O[7]: *I/O did not complete prior to the end of Run-Out.*

SPC-2 Test Run Components



APPENDIX B: CUSTOMER TUNABLE PARAMETERS AND OPTIONS

QLogic HBA Parameters

The following QLogic Fibre Channel HBA parameters/options were changed from their default values using the **QConvergeConsole CLI** utility:

	Default Value	New Value
Operation Mode	***Interrupt when Interrupt Delay Timer expires or no active IO***	***Interrupt for every IO Completion***
LUNs Per Target	***8***	***128***
Port Down Retry Count	**30**	***70***

Operation Mode: Disable HBA interrupt coalescing.

LUNs Per Target: Specifies the number of LUNs per target.

Port Down Retry Count: Specifies the number of times the driver retries a command to a port returning port down status.

Windows Registry Settings

Set maximum queue depth in QLogic driver to 254. Default = 32.

HKEY_LOCAL_MACHINE\SYSTEM\CurrentControlSet\services\ql2300\Parameters\Device\DriverParameter\qd=254

HBA Transfer Size *(set to support 1MB)*

C:\>qlfc –tsize /fc /set 2048

Usage: The user can open a DOS prompt in administrator mode typing in the Run/Search line CMD then press the CTRL+SHIFT+ENTER key, or right click on the CMD icon and select Run as Administrator. Default is "512". A reboot is required for the change to take effect.

Storage Array Parameters

The following storage array parameter was changed from its default value by the TSC creation script, **SPC2_RAID_Config.script** documented in *"Appendix C: Tested Storage Configuration (TSC) Creation".*

	Default Value	New Value
cacheBlockSize	***8***	***32***

cacheBlockSize – disk array controller cache allocation unit size in KiB (1024).

APPENDIX C: TESTED STORAGE CONFIGURATION (TSC) CREATION

The customer tunable options/parameters, listed in Appendix B: Customer Tunable Parameters and Options, are modified prior to the creation/configuration operations listed below.

Storage Array Volume Creation

The storage management utility software, **E-Series SANtricity Storage Manager**, is downloaded from the NetApp support site and installed on both Host Systems. It is a required software package that provides configuration, monitoring, and failover path management. The software is installed as a Windows installable package. After installation, it can be found in **\Program Files (x86)\StorageManager\client** and is typically started with ***Start→All Programs→SANtricity Storage Manager →SANtricity Storage Manager client***.

The **E-Series SANtricity Storage Manager** was used to create 12 volume groups on the storage subsystem. Each volume group contains one RAID-6 volume. All 12 RAID-6 volumes are visible by each Host System.

The physical storage volumes are created on the storage array using the **E-Series SANtricity Storage Manager** script editor.

- Launch the **E-Series SANtricity Storage Manager** from one of the Host Systems.
- From the Enterprise Management window, right-click the name of the storage array that you will be creating volumes on and select ***Execute Script*** from the pop-up menu.
- In the Script Editor window load the **SPC2_RAID_Config.script** script *(listed below).*
- Once the script is loaded, select ***Execute*** from the Tools menu.

SPC-2 Logical Volume Creation

The steps that follow are executed on each Host System to discover array volumes.

- Reboot each Host System.
- Start Windows Disk Administrator and it will discover the 12 RAID volumes.
- Exit Disk Administrator.

SPC2_RAID_Config.script

```
/* SPC-2 RAID Volume Configuration Script */

create volume drives[ 0,1,1  0,1,2  0,2,1  0,2,2  0,3,1  0,3,2  0,4,1  0,4,2  0,5,1
0,5,2 ]
RAIDLevel=6
segmentSize=512
userLabel="LUN_0"
owner = A;
create volume drives[ 0,1,3  0,1,4  0,2,3  0,2,4  0,3,3  0,3,4  0,4,3  0,4,4  0,5,3
0,5,4 ]
RAIDLevel=6
segmentSize=512
userLabel="LUN_1"
owner = A;
create volume drives[ 0,1,5  0,1,6  0,2,5  0,2,6  0,3,5  0,3,6  0,4,5  0,4,6  0,5,5
0,5,6 ]
RAIDLevel=6
segmentSize=512
userLabel="LUN_2"
owner = A;
create volume drives[ 1,1,1  1,1,2  1,2,1  1,2,2  1,3,1  1,3,2  1,4,1  1,4,2  1,5,1
1,5,2 ]
RAIDLevel=6
segmentSize=512
userLabel="LUN_3"
owner = A;
create volume drives[ 1,1,3  1,1,4  1,2,3  1,2,4  1,3,3  1,3,4  1,4,3  1,4,4  1,5,3
1,5,4 ]
RAIDLevel=6
segmentSize=512
userLabel="LUN_4"
owner = A;
create volume drives[ 1,1,5  1,1,6  1,2,5  1,2,6  1,3,5  1,3,6  1,4,5  1,4,6  1,5,5
1,5,6 ]
RAIDLevel=6
segmentSize=512
userLabel="LUN_5"
owner = A;

create volume drives[ 0,1,7  0,1,8  0,2,7  0,2,8  0,3,7  0,3,8  0,4,7  0,4,8  0,5,7
0,5,8 ]
RAIDLevel=6
segmentSize=512
userLabel="LUN_6"
owner = b;
create volume drives[ 0,1,9  0,1,10  0,2,9  0,2,10  0,3,9  0,3,10  0,4,9  0,4,10
0,5,9  0,5,10 ]
RAIDLevel=6
segmentSize=512
userLabel="LUN_7"
owner = b;
create volume drives[ 0,1,11  0,1,12  0,2,11  0,2,12  0,3,11  0,3,12  0,4,11  0,4,12
0,5,11  0,5,12 ]
RAIDLevel=6
segmentSize=512
userLabel="LUN_8"
owner = b;
create volume drives[ 1,1,7  1,1,8  1,2,7  1,2,8  1,3,7  1,3,8  1,4,7  1,4,8  1,5,7
1,5,8 ]
```

```
RAIDLevel=6
segmentSize=512
userLabel="LUN_9"
owner = b;
create volume drives[ 1,1,9  1,1,10  1,2,9  1,2,10  1,3,9  1,3,10  1,4,9  1,4,10
1,5,9  1,5,10 ]
RAIDLevel=6
segmentSize=512
userLabel="LUN_10"
owner = b;
create volume drives[ 1,1,11  1,1,12  1,2,11  1,2,12  1,3,11  1,3,12  1,4,11  1,4,12
1,5,11  1,5,12 ]
RAIDLevel=6
segmentSize=512
userLabel="LUN_11"
owner = b;

/* define host mappings */
set volume["LUN_0"]  logicalUnitNumber=0  hostGroup=defaultGroup;
set volume["LUN_1"]  logicalUnitNumber=1  hostGroup=defaultGroup;
set volume["LUN_2"]  logicalUnitNumber=2  hostGroup=defaultGroup;
set volume["LUN_3"]  logicalUnitNumber=3  hostGroup=defaultGroup;
set volume["LUN_4"]  logicalUnitNumber=4  hostGroup=defaultGroup;
set volume["LUN_5"]  logicalUnitNumber=5  hostGroup=defaultGroup;
set volume["LUN_6"]  logicalUnitNumber=6  hostGroup=defaultGroup;
set volume["LUN_7"]  logicalUnitNumber=7  hostGroup=defaultGroup;
set volume["LUN_8"]  logicalUnitNumber=8  hostGroup=defaultGroup;
set volume["LUN_9"]  logicalUnitNumber=9  hostGroup=defaultGroup;
set volume["LUN_10"] logicalUnitNumber=10 hostGroup=defaultGroup;
set volume["LUN_11"] logicalUnitNumber=11 hostGroup=defaultGroup;

set allVolumes  mirrorEnabled = True writeCacheEnabled = True
cacheWithoutBatteryEnabled = False cacheReadPrefetch = True;

set storageArray cacheBlockSize  = 32;
```

APPENDIX D: SPC-2 WORKLOAD GENERATOR STORAGE COMMANDS AND PARAMETER FILES

ASU Pre-Fill

```
* SPC-2 Pre-Fill
* 512K sequential writes

*pattern=random
*compression=100        * vdBench version 5.02
compratio=1.0          * vdBench version 5.03

sd=sd1,lun=\\.\PhysicalDrive1,threads=4
sd=sd2,lun=\\.\PhysicalDrive2,threads=4
sd=sd3,lun=\\.\PhysicalDrive3,threads=4
sd=sd4,lun=\\.\PhysicalDrive4,threads=4
sd=sd5,lun=\\.\PhysicalDrive5,threads=4
sd=sd6,lun=\\.\PhysicalDrive6,threads=4
sd=sd7,lun=\\.\PhysicalDrive7,threads=4
sd=sd8,lun=\\.\PhysicalDrive8,threads=4
sd=sd9,lun=\\.\PhysicalDrive9,threads=4
sd=sd10,lun=\\.\PhysicalDrive10,threads=4
sd=sd11,lun=\\.\PhysicalDrive11,threads=4
sd=sd12,lun=\\.\PhysicalDrive12,threads=4

wd=wd1,sd=sd*,xfersize=524288,readpct=0,seekpct=-1

rd=rd1,wd=wd*,elapsed=36000,interval=10,iorate=max
```

Common Commands/Parameters – LFP, LDQ and VOD Tests

The following command/parameter lines appear in each of the command and parameter files for the Large File Processing (LFP), Large Database Query (LDQ) and Video on Demand (VOD) Tests. The command lines are only listed below to eliminate redundancy.

```
*Raid 6
**Master Host
sd=default,host=localhost,size=4753757044736
sd=sd1,lun=\\.\PhysicalDrive1
sd=sd2,lun=\\.\PhysicalDrive2
sd=sd3,lun=\\.\PhysicalDrive3
sd=sd4,lun=\\.\PhysicalDrive4
sd=sd5,lun=\\.\PhysicalDrive5
sd=sd6,lun=\\.\PhysicalDrive6
sd=sd7,lun=\\.\PhysicalDrive7
sd=sd8,lun=\\.\PhysicalDrive8
sd=sd9,lun=\\.\PhysicalDrive9
sd=sd10,lun=\\.\PhysicalDrive10
sd=sd11,lun=\\.\PhysicalDrive11
sd=sd12,lun=\\.\PhysicalDrive12

**Slave Host
sd=default,host=bmr720bx,size=4753757044736
sd=sd1,lun=\\.\PhysicalDrive1
sd=sd2,lun=\\.\PhysicalDrive2
sd=sd3,lun=\\.\PhysicalDrive3
sd=sd4,lun=\\.\PhysicalDrive4
sd=sd5,lun=\\.\PhysicalDrive5
sd=sd6,lun=\\.\PhysicalDrive6
```

```
sd=sd7,lun=\\.\PhysicalDrive7
sd=sd8,lun=\\.\PhysicalDrive8
sd=sd9,lun=\\.\PhysicalDrive9
sd=sd10,lun=\\.\PhysicalDrive10
sd=sd11,lun=\\.\PhysicalDrive11
sd=sd12,lun=\\.\PhysicalDrive12
```

Large File Processing Test (LFP)

```
* Large File Processing Test (LFP)

*Master Host Definition Parameter
host=localhost,jvms=3,maxstreams=100
*Remote Host Definition Parameter
host=(bmr720bx),jvms=3,maxstreams=100,shell=spc2
```

Common Commands/Parameters – LFP, LDQ and VOD Tests

```
maxlatestart=0
reportinginterval=5
segmentlength=512m

rd=default,rampup=180,periods=90,measurement=180,runout=45,rampdown=15,buffers=1


* LFP, "write" Test Phase
rd=default,rdpct=0,xfersize=1024k
rd=TR1_SPC-2-FP2.0,streams=96
rd=TR2_SPC-2-FP2.0,streams=48
rd=TR3_SPC-2-FP2.0,streams=24
rd=TR4_SPC-2-FP2.0,streams=12
rd=TR5_SPC-2-FP2.0,streams=1

rd=default,xfersize=256k
rd=TR6_SPC-2-FP2.0,streams=96
rd=TR7_SPC-2-FP2.0,streams=48
rd=TR8_SPC-2-FP2.0,streams=24
rd=TR9_SPC-2-FP2.0,streams=12
rd=TR10_SPC-2-FP2.0,streams=1

* LFP, "read-write" Test Phase
rd=default,rdpct=50,xfersize=1024k
rd=TR11_SPC-2-FP2.0,streams=96
rd=TR12_SPC-2-FP2.0,streams=48
rd=TR13_SPC-2-FP2.0,streams=24
rd=TR14_SPC-2-FP2.0,streams=12
rd=TR15_SPC-2-FP2.0,streams=1

rd=default,xfersize=256k
rd=TR16_SPC-2-FP2.0,streams=96
rd=TR17_SPC-2-FP2.0,streams=48
rd=TR18_SPC-2-FP2.0,streams=24
rd=TR19_SPC-2-FP2.0,streams=12
rd=TR20_SPC-2-FP2.0,streams=1

* LFP, "read" Test Phase
rd=default,rdpct=100,xfersize=1024k
rd=TR21_SPC-2-FP2.0,streams=96
rd=TR22_SPC-2-FP2.0,streams=48
rd=TR23_SPC-2-FP2.0,streams=24
rd=TR24_SPC-2-FP2.0,streams=12
rd=TR25_SPC-2-FP2.0,streams=1
```

```
rd=default,xfersize=256k
rd=TR26_SPC-2-FP2.0,streams=96
rd=TR27_SPC-2-FP2.0,streams=48
rd=TR28_SPC-2-FP2.0,streams=24
rd=TR29_SPC-2-FP2.0,streams=12
rd=TR30_SPC-2-FP2.0,streams=1
```

Large Database Query Test (LDQ)

```
* Large File Processing Test (LFP)


*Master Host Definition Parameter
host=localhost,jvms=3,maxstreams=100
*Remote Host Definition Parameter
host=(bmr720bx),jvms=3,maxstreams=100,shell=spc2
```

Common Commands/Parameters – LFP, LDQ and VOD Tests

```
maxlatestart=0
reportinginterval=5
segmentlength=512m

rd=default,rampup=180,periods=90,measurement=180,runout=45,rampdown=15,buffers=1


* LFP, "write" Test Phase
rd=default,rdpct=0,xfersize=1024k
rd=TR1_SPC-2-FP2.0,streams=96
rd=TR2_SPC-2-FP2.0,streams=48
rd=TR3_SPC-2-FP2.0,streams=24
rd=TR4_SPC-2-FP2.0,streams=12
rd=TR5_SPC-2-FP2.0,streams=1

rd=default,xfersize=256k
rd=TR6_SPC-2-FP2.0,streams=96
rd=TR7_SPC-2-FP2.0,streams=48
rd=TR8_SPC-2-FP2.0,streams=24
rd=TR9_SPC-2-FP2.0,streams=12
rd=TR10_SPC-2-FP2.0,streams=1

* LFP, "read-write" Test Phase
rd=default,rdpct=50,xfersize=1024k
rd=TR11_SPC-2-FP2.0,streams=96
rd=TR12_SPC-2-FP2.0,streams=48
rd=TR13_SPC-2-FP2.0,streams=24
rd=TR14_SPC-2-FP2.0,streams=12
rd=TR15_SPC-2-FP2.0,streams=1

rd=default,xfersize=256k
rd=TR16_SPC-2-FP2.0,streams=96
rd=TR17_SPC-2-FP2.0,streams=48
rd=TR18_SPC-2-FP2.0,streams=24
rd=TR19_SPC-2-FP2.0,streams=12
rd=TR20_SPC-2-FP2.0,streams=1

* LFP, "read" Test Phase
rd=default,rdpct=100,xfersize=1024k
rd=TR21_SPC-2-FP2.0,streams=96
rd=TR22_SPC-2-FP2.0,streams=48
rd=TR23_SPC-2-FP2.0,streams=24
```

```
rd=TR24_SPC-2-FP2.0,streams=12
rd=TR25_SPC-2-FP2.0,streams=1

rd=default,xfersize=256k
rd=TR26_SPC-2-FP2.0,streams=96
rd=TR27_SPC-2-FP2.0,streams=48
rd=TR28_SPC-2-FP2.0,streams=24
rd=TR29_SPC-2-FP2.0,streams=12
rd=TR30_SPC-2-FP2.0,streams=1
```

Logical Volume Initialization and Video on Demand Delivery (VOD)

```
* Video on Demand Test (VOD)

*Master Host Definition Parameter
host=localhost,jvms=6,maxstreams=1000
*Remote Host Definition Parameter
host=(bmr720bx),jvms=6,maxstreams=1000,shell=spc2
```

Common Commands/Parameters – LFP, LDQ and VOD Tests

```
maxlatestart=0
videosegmentduration=1200
maxlatevod=0
reportinginterval=5

* Official RD
rd=default,rampup=1200,periods=600,measurement=7200,runout=45,rampdown=15

rd=TR1_SPC-2-VOD11.0,streams=5800,buffers=8
```

Common Commands/Parameters – SPC-2 Persistence Test

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

```
host=localhost,jvms=1,maxstreams=100
host=(bmr720bx),jvms=1,maxstreams=100,shell=spc2

sd=default,size=4753757044736

*** From Host bmr720bw ***
sd=sd1,host=localhost,lun=\\.\PhysicalDrive1
sd=sd2,host=localhost,lun=\\.\PhysicalDrive2
sd=sd3,host=localhost,lun=\\.\PhysicalDrive3
sd=sd4,host=localhost,lun=\\.\PhysicalDrive4
sd=sd5,host=localhost,lun=\\.\PhysicalDrive5
sd=sd6,host=localhost,lun=\\.\PhysicalDrive6
sd=sd7,host=localhost,lun=\\.\PhysicalDrive7
sd=sd8,host=localhost,lun=\\.\PhysicalDrive8
sd=sd9,host=localhost,lun=\\.\PhysicalDrive9
sd=sd10,host=localhost,lun=\\.\PhysicalDrive10
sd=sd11,host=localhost,lun=\\.\PhysicalDrive11
sd=sd12,host=localhost,lun=\\.\PhysicalDrive12

*** From Host bmr720bx ***
sd=sd1,host=bmr720bx,lun=\\.\PhysicalDrive1
```

```
sd=sd2,host=bmr720bx,lun=\\.\PhysicalDrive2
sd=sd3,host=bmr720bx,lun=\\.\PhysicalDrive3
sd=sd4,host=bmr720bx,lun=\\.\PhysicalDrive4
sd=sd5,host=bmr720bx,lun=\\.\PhysicalDrive5
sd=sd6,host=bmr720bx,lun=\\.\PhysicalDrive6
sd=sd7,host=bmr720bx,lun=\\.\PhysicalDrive7
sd=sd8,host=bmr720bx,lun=\\.\PhysicalDrive8
sd=sd9,host=bmr720bx,lun=\\.\PhysicalDrive9
sd=sd10,host=bmr720bx,lun=\\.\PhysicalDrive10
sd=sd11,host=bmr720bx,lun=\\.\PhysicalDrive11
sd=sd12,host=bmr720bx,lun=\\.\PhysicalDrive12

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

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

```
* Persistence Write Phase
```

Common Commands/Parameters – SPC-2 Persistence Test

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

rd=default,rdpct=0,xfersize=1024k
rd=TR1-72s_SPC-2-persist-w,streams=96
```

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

```
* Persistence Read Phase
```

Common Commands/Parameters – SPC-2 Persistence Test

```
maxpersistenceerrors=10

rd=default,buffers=1,rdpct=100,xfersize=1024k
rd=TR1-72s_SPC-2-persist-r
```

APPENDIX E: SPC-2 WORKLOAD GENERATOR EXECUTION COMMANDS AND PARAMETERS

ASU Pre-Fill, Large File Processing Test, Large Database Query Test, Video on Demand Delivery Test, and SPC-2 Persistence Test Run 1 *(write phase)*

The script, **phase1.spc2.bat**, was executed to invoke the following in an uninterrupted execution sequence:

- The command to execute required ASU prefill.
- The command to create the first storage configuration listing required for a remote audit.
- The commands to execute the Large File Processing (LFP) Test, Large Database Query (LDQ) Test, Video on Demand Delivery (VOD) Test and SPC-2 Persistence Test Run 1 *(write phase)*.
- The command to create an optional storage configuration listing at the end of the initial test execution sequence.

After successful completion of the above initial test execution sequence followed by the required TSC power off/power on cycle, the **phase2.spc2.bat** script was executed to run SPC-2 Persistence Test Run 2 *(read phase)*.

phase1.spc2.bat

```
@echo off

echo "ASU prefill started......"
cd \bench\vdbench\vdbench50401
call vdbench -f \bench\vdbench\spc2\spc2_prefill.parm -o \bench\vdbench\spc2\PreFill
cd \bench\vdbench\spc2
echo "ASU prefill complete....."

set PATH=c:\java\bin;%ORIGPATH%

rem Directory where this is executed from:
set dir=%~dp0

rem set current class path
set cp=%~dp0


echo "Capture a storage profile at the start of the run....."
cd "\Program Files (x86)\StorageManager\client"
smcli 10.113.168.241 10.113.168.242 -c "show storageArray time; show storageArray
profile; show storageArray time;" -o \bench\vdbench\spc2\config_at_start.txt -quick
cd \bench\vdbench\spc2

java -Xmx1536m -Xms512m -Xss96k -cp %cp% vdbench -w SPC2 -f lfp.parm -o 052215.init
-init

java -Xmx1536m -Xms512m -Xss96k -cp %cp% vdbench -w SPC2 -f lfp.parm -o 052215.lfp6

java -Xmx1536m -Xms512m -Xss96k -cp %cp% vdbench -w SPC2 -f ldq.parm -o 052215.ldq6
```

```
java -Xmx1536m -Xms512m -Xss96k -cp %cp% vdbench -w SPC2 -f vod.parm -o 052215.vod6

java -Xmx1536m -Xms512m -Xss96k -cp %cp% vdbench -w SPC2 -f persist1.audit -o
052215.persist1



echo "Capture a storage profile at the end of the run....."
cd "\Program Files (x86)\StorageManager\client"
smcli 10.113.168.241 10.113.168.242 -c "show storageArray time; show storageArray
profile; show storageArray time;" -o \bench\vdbench\spc2\config_at_mid.txt -quick
cd \bench\vdbench\spc2
```

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

phase2.spc2.bat

```
rem @echo off

set PATH=c:\java\bin;%ORIGPATH%

rem Directory where this is executed from:
set dir=%~dp0

rem set current class path
set cp=%~dp0


java -Xmx1536m -Xms512m -Xss96k -cp %cp% vdbench -w SPC2 -f persist2.audit -o
052215.persist2


echo "Capture a storage profile at the end of the run....."
cd "\Program Files (x86)\StorageManager\client"
smcli 10.113.168.241 10.113.168.242 -c "show storageArray time; show storageArray
profile; show storageArray time;" -o \bench\vdbench\spc2\config_at_end.txt -quick
cd \bench\vdbench\spc2
```

APPENDIX F: THIRD-PARTY QUOTES

QLogic QLE2672-CK HBA's

ServerSupply
Supplying Technology to Meet Your Needs

Office Hours Mon-Fri 9:30 AM- 7:00 PM EST
750 Shames Dr. Westbury, NY 11590
800-778-7759 516-334-7700 Fax: 516-334-7727
Gov, Edu and Approved Businesses Fax PO to 516 334-7727

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HOME | ABOUT US | LOGIN | VIEW CART | POLICIES | SUPPORT | CONTACT US | 1 item(s) in cart

SEARCH Database Lookup GO | Search By System | Free Ground Shipping in USA 48 States

Returning Customers: E-mail Address | Password | LOGIN | Forgot password? | Register

Order Information

QTY	Part Number	Description	Price	Subtotal
Delete 4	QLE2672-CK	QLOGIC - SANBLADE 16GB FC DUAL PORT PCIE HBA WITH HIGH PROFILE BRACKET(QLE2672-CK). IN STOCK.	$1,235.00	$4,940.00
			Merchandise Subtotal :	$4,940.00

Shipping - Billing Info

Ship To

Ship To Company NetApp
Attention Pavan Panduranga
Street Address 495 E JAVA DRIVE
Suite/Unit/Apt
City Sunnyvale State CA Zipcode 94089

Bill To Copy Ship To

Bill To Company NetApp
Attention Pavan Panduranga
Street Address 495 E JAVA DRIVE
Suite/Unit/Apt
City Sunnyvale State CA Zip 94089

Purchase Order Optional
Contact Phone 4088227260 * Contact Fax
Your Email ppandura@netapp.com *
Create Password * Must be Alphanumeric and minimum 7 characters
Confirm Password *

Tax Exempt | Blind Drop Ship

Payment Options

Credit / Debit Card | PayPal 1% Discount | Wire Transfer | Other Explain:

Select Credit Card Type
Name on Card Card Number
Card Expires on Month Year Security Code
Save this card for future orders

Shipping Options

USA 48 States APO FPO AK HI PR

Free Ground $0.00 + NoTax $0.00 = $4,940.00 Total

Comments - NY Tax Exempt EIN Fax Certificate to 516 334-7727
Edu Gov and Lrg Business Fax PO to 516 334-7727

Additional Comments Section

I have read and agree to Server Supply's Terms and Conditions

Submit Order

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Fibre Channel Cables

View Online

CDW CART FOR REVIEW

CDW PEOPLE WHO GET IT

Account Message:
This email was sent to you from: **VALUED CUSTOMER**

Sender Comments:
Cables

CART DETAILS

ITEM	QTY	PART #	UNIT PRICE	EXT. PRICE
Tripp Lite 2M 10Gb Duplex Multimode 50/125 OM3 Fiber Cable LC/LC Aqua 6ft Part#: N820-02M UNSPSC: 26121604 Go to Site	1	1148024	$22.99	$22.99

Sub Total:	$22.99
GRAND TOTAL:	**$22.99**