



**ORACLE®**

**SPC BENCHMARK 2™**  
**FULL DISCLOSURE REPORT**

**ORACLE CORPORATION**  
**ORACLE ZFS STORAGE ZS5-2**

**SPC-2™ V1.6**

**SUBMITTED FOR REVIEW: MARCH 29, 2017**

**SUBMISSION IDENTIFIER: B12001**

## **First Edition – March 2017**

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# AUDIT CERTIFICATION



Steve Johnson  
 Oracle Corporation  
 500 Eldorado Blvd.  
 Broomfield, CO 80021

March 27, 2017

I verified the SPC Benchmark 2™ (SPC-2™ V1.6) test execution and performance results of the following Tested Storage Product:

### Oracle ZFS Storage ZS5-2

The results were:

<b>SPC-2 MBPS™</b>	<b>24,397.12</b>
<b>SPC-2 Price-Performance™</b>	<b>\$8.89/SPC-2 MBPS™</b>
Total ASU Capacity	8,383.776 GB
Data Protection Level	Protected 2 ( <i>Mirroring</i> )
Total Price (including 3-year maintenance)	\$217,011.94
Currency Used	U.S. Dollars
Target Country for Availability, Sales and Support	USA

In my opinion, these performance results were produced in compliance with the SPC requirements for the benchmark. In particular, the following requirements were reviewed and found compliant with V1.6 of the SPC Benchmark 2™ specification:

- A Letter of Good Faith, signed by a senior executive.
- The following Data Repository items were verified by information supplied by Oracle Corporation:
  - Physical Storage Capacity and requirements
  - Configured Storage Capacity and requirement
  - Addressable Storage Capacity and requirements
  - Capacity of each Logical Volume and requirements
  - Capacity of each Application Storage Unit (ASU) and requirements
- The total Application Storage Unit (ASU) Capacity was filled with random data, using an auditor-approved tool, prior to execution of the SPC-2 Tests.

- The accuracy of the Benchmark Configuration diagram
- The tuning parameters used to configure the Benchmark Configuration
- SPC-2 Workload Generator commands and parameters used for the audited SPC-2 Test Runs.
- The following Host System requirements were verified by information supplied by Oracle Corporation:
  - The type of Host Systems, including the number of processors and the amount of main memory
  - The presence and version number of the SPC-2 Workload Generator on each Host System.
  - The TSC boundary within each Host System.
- The execution of the following Tests, including all Test Phases and Test Runs, was found compliant with all applicable requirements and constraints.
  - Large Database Query Test
  - Large File Processing Test
  - Video on Demand Delivery Test
  - Data Persistence Test
- The submitted pricing information met all applicable requirements and constraints.

The Full Disclosure Report for this result was prepared in accordance with the disclosure requirements set forth in the specification for the benchmark. The report, prepared by InfoSizing and reviewed by Oracle Corporation, can be found at [www.storageperformance.org](http://www.storageperformance.org) under the Submission Identifier B12001.

Additional Audit Notes:

None.

Respectfully Yours,



Doug Johnson, Certified SPC Auditor



# LETTER OF GOOD FAITH

ORACLE®

Oracle America, Inc. 500 Eldorado Boulevard phone +1.303.464.4000  
Broomfield oracle.com  
Colorado 80021

March 13, 2017  
From:  
**Oracle Corporation**  
**Steven A. Johnson**  
**500 Eldorado Blvd.**  
**Broomfield, CO 80021**

To: Doug Johnson  
Infosizing  
20 Kreg Lane  
Manitou Springs, CO 80829

Subject: SPC-2 Letter of Good Faith for the **Oracle's Sun ZFS Storage ZS5-2**

Oracle Corporation 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 V1.6 of the SPC-2 benchmark specification.

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

Sincerely,

  
\_\_\_\_\_  
Scott Tracy - Vice President

3/20/17  
\_\_\_\_\_  
Date of Signature

## EXECUTIVE SUMMARY

### Test Sponsor and Contact Information

Test Sponsor and Contact Information	
<b>Test Sponsor Primary Contact</b>	Oracle – <a href="http://www.oracle.com">http://www.oracle.com</a> Steven Johnson – <a href="mailto:steven.a.johnson@oracle.com">steven.a.johnson@oracle.com</a> 500 Eldorado Blvd. Broomfield, CO 80021 Phone: (303) 272-9476
<b>Test Sponsor Alternate Contact</b>	Oracle – <a href="http://www.oracle.com">http://www.oracle.com</a> Jason Schaffer – <a href="mailto:jason.schaffer@oracle.com">jason.schaffer@oracle.com</a> 500 Eldorado Blvd. Broomfield, CO 80021 Phone: (303) 272-4743
<b>Auditor</b>	InfoSizing – <a href="http://www.sizing.com/">http://www.sizing.com/</a> Doug Johnson – <a href="mailto:doug@sizing.com">doug@sizing.com</a> 63 Lourdes Drive Leominster, MA 01453 Phone: (978) 343-6562

### Revision Information and Key Dates

Revision Information and Key Dates	
<b>SPC-2 Specification revision number</b>	V1.6
<b>SPC-2 Workload Generator revision number</b>	V1.2.0
<b>Date Results were first used publicly</b>	March 29, 2017
<b>Date FDR was submitted to the SPC</b>	March 29, 2017
<b>Date the TSC will be available for shipment to customers</b>	April 5, 2017
<b>Date the TSC completed audit certification</b>	March 27, 2017

### Tested Storage Product Description

Oracle ZFS Storage Appliance ZS5-2 is a high-performance, unified NAS/SAN system that provides converged cloud storage enabling on-premises storage to seamlessly access public cloud services and features industry-leading Oracle Database integration, in a cost-effective high-availability configuration. Dynamic caching between DRAM, flash cache, all flash, HDD, and cloud storage allows these systems to deliver extreme performance and superior efficiency for demanding enterprise applications and unpredictable cloud workloads. The ZFS Storage ZS5-2 offers simplified set up and management combined with advanced, intuitive management and fine-grained analytics tools. Through deep co-engineering integration, Oracle Database sends cues to the Oracle ZFS Storage Appliance ZS5-2 system, allowing it to intelligently process database I/O and automatically and dynamically tune itself for optimal performance. The ZFS Storage ZS5-2 can scale to 1.5 TB Memory, 72 CPU cores, and 3 PB capacity, with up to 204 TB of Flash Cache in a high-availability configuration. ZFS Storage Appliances deliver full suite of data services such as file, block and object protocols including connectivity over Ethernet, InfiniBand; data reduction technologies such as compression, deduplication, thin provisioning and advanced security options.

## 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.

**Data Protection Level of Protected 2** using **Mirroring**, which configures two or more identical copies of user data.

**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.*

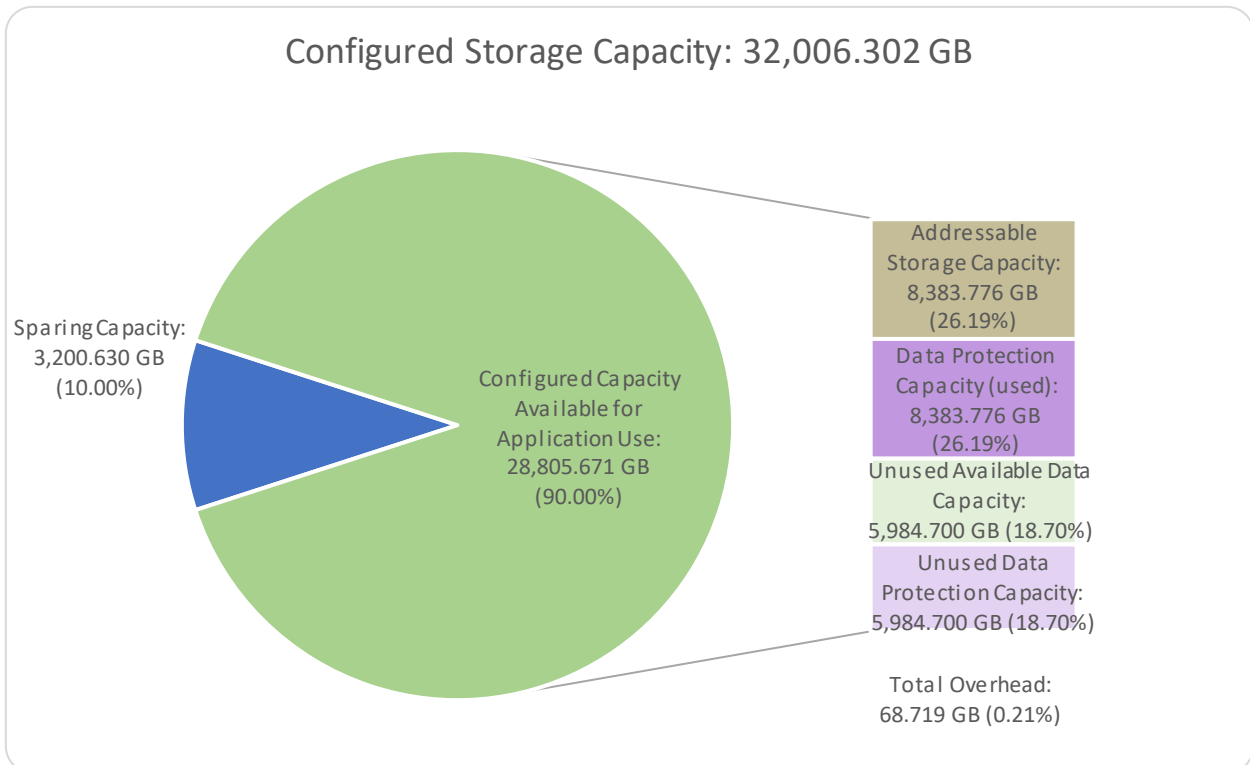
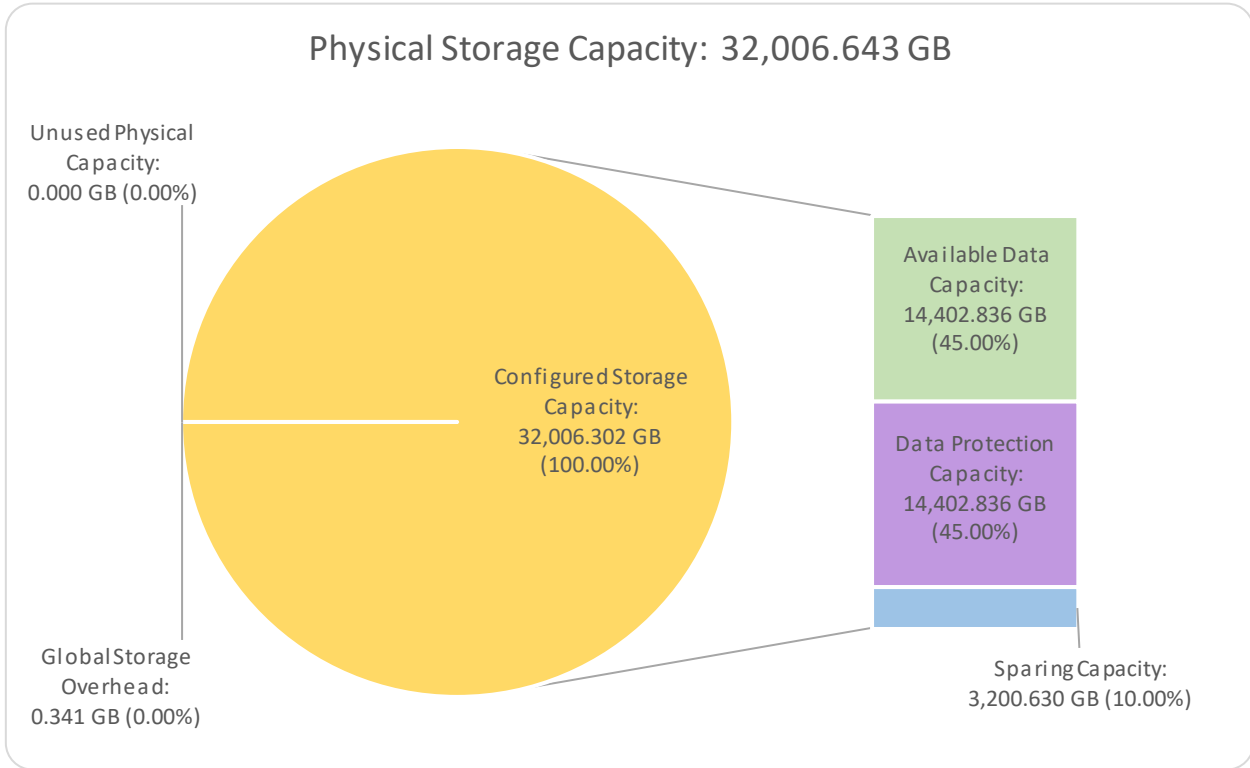
**Currency Used** is formal name for the currency used in calculating the **Total Price** and **SPC-2 Price-Performance™**. That currency may be the local currency of the **Target Country** or the currency of a difference country (*non-local currency*).

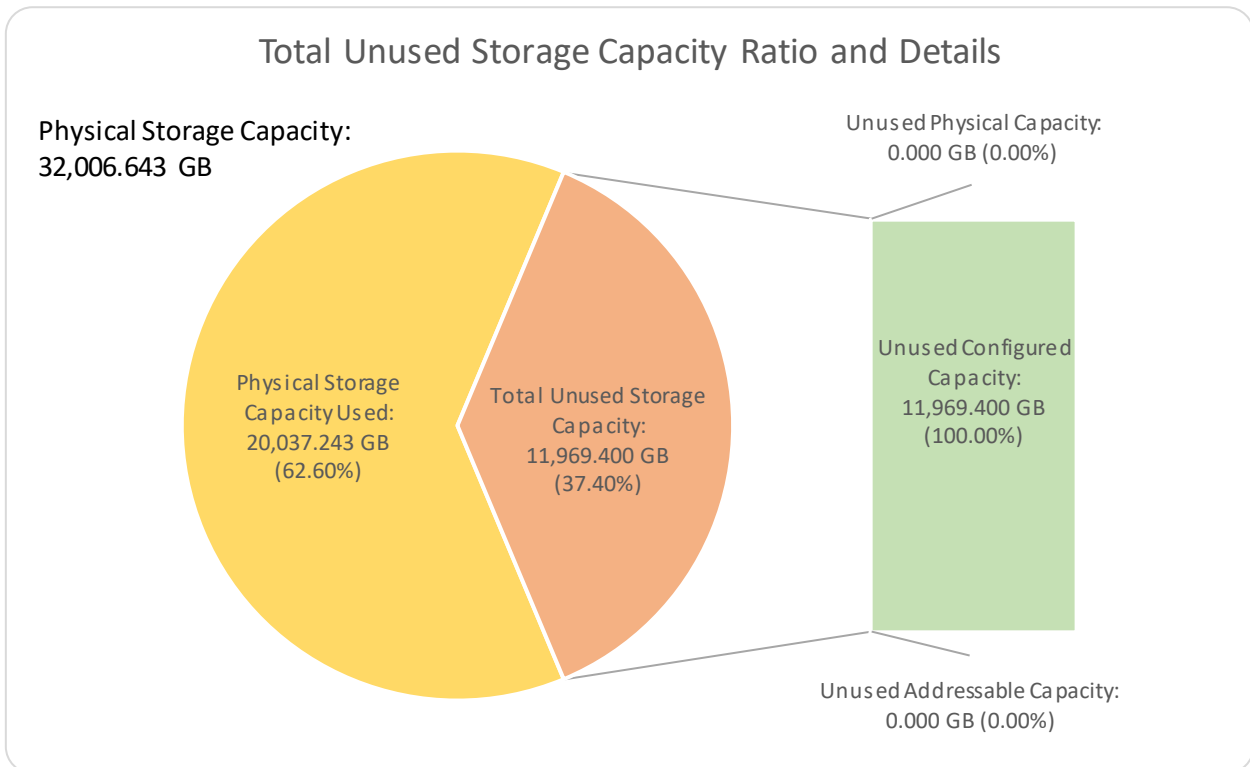
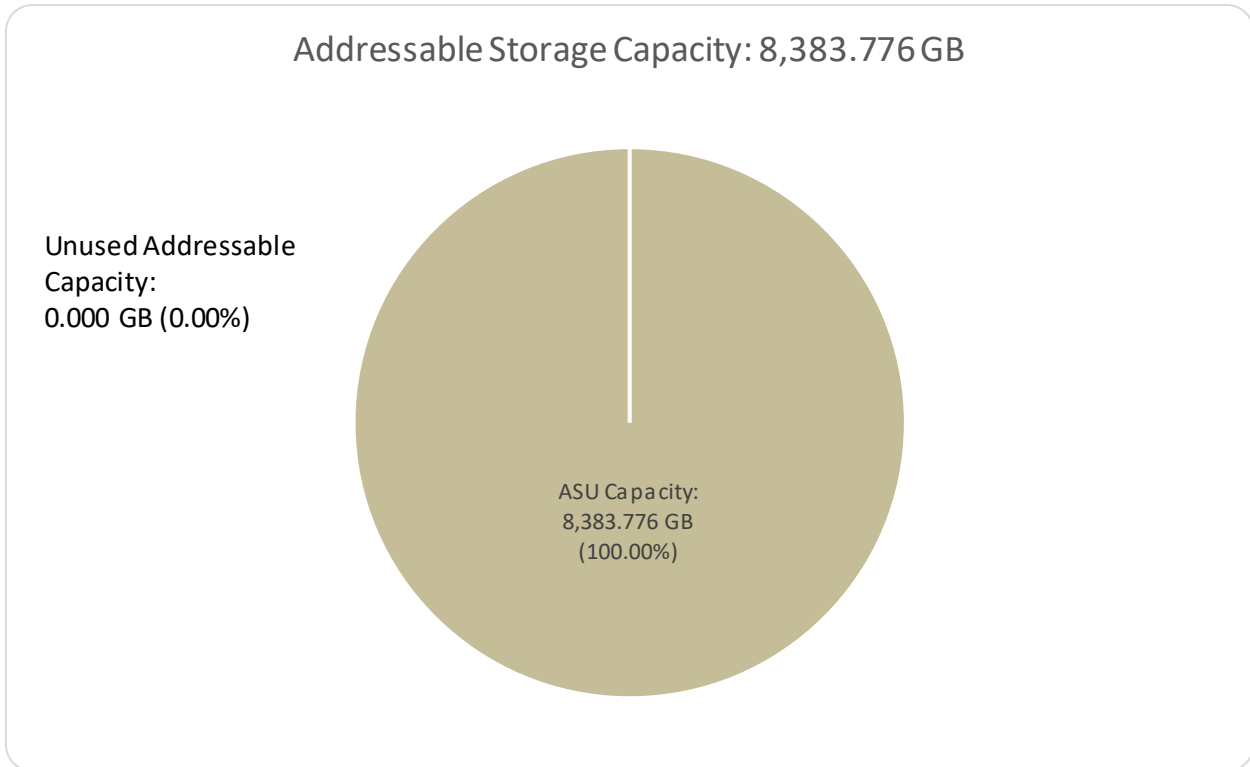
The **Target Country** is the country in which the Priced Storage Configuration is available for sale and in which the required hardware maintenance and software support is provided either directly from the Test Sponsor or indirectly via a third-party supplier.

SPC-2 Reported Data				
Oracle ZFS Storage ZS5-2				
SPC-2 MBPS™	SPC-2 Price-Performance	ASU Capacity (GB)	Total Price	Data Protection Level
24,397.12	\$8.89	8,383.776	\$217,011.94	Protected 2 (Mirroring)
<i>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).</i>				
<b>Currency Used:</b>		<b>"Target Country":</b>		
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	19,997.48			\$10.85
Write Only:				
1024 KiB Transfer	11,961.22	512	23.36	
256 KiB Transfer	11,883.74	512	23.21	
Read-Write:				
1024 KiB Transfer	18,782.75	512	36.69	
256 KiB Transfer	18,986.04	512	37.08	
Read Only:				
1024 KiB Transfer	29,064.06	512	56.77	
256 KiB Transfer	29,307.04	512	57.24	
<i>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).</i>				
SPC-2 Large Database Query (LDQ) Reported Data				
	Data Rate (MB/second)	Number of Streams	Data Rate per Stream	Price-Performance
LDQ Composite	28,814.51			\$7.53
1024 KiB Transfer Size				
4 I/Os Outstanding	29,395.56	512	57.41	
1 I/O Outstanding	29,267.33	512	57.16	
64 KiB Transfer Size				
4 I/Os Outstanding	28,238.18	512	55.15	
1 I/O Outstanding	28,356.95	512	55.38	
<i>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).</i>				
SPC-2 Video On Demand (VOD) Reported Data				
	Data Rate (MB/second)	Number of Streams	Data Rate per Stream	Price-Performance
	24,379.39	31,000	0.79	\$8.90

## 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.





<b>SPC-2 Storage Capacity Utilization</b>	
Application Utilization	26.19%
Protected Application Utilization	52.50%
Unused Storage Ratio	37.40%

**Application Utilization:** Total ASU Capacity (8,383.776 GB) divided by Physical Storage Capacity (32,006.643 GB).

**Protected Application Utilization:** Total ASU Capacity (8,383.776 GB) plus total Data Protection Capacity (14,402.836 GB) minus unused Data Protection Capacity (5,984.700 GB) divided by Physical Storage Capacity (32,006.643 GB).

**Unused Storage Ratio:** Total Unused Capacity (11,969.400 GB) divided by Physical Storage Capacity (32,006.643 GB) and may not exceed 45%.

## Priced Storage Configuration Pricing

Part Number	Description	Quantity	US List	Total List	Discount	Net Price
7112310	Oracle ZFS Storage ZS5-2: controller	2	\$22,878	\$45,756	40.00%	\$27,454
7111036	One 16 GB DDR4-2133 DIMM (for factory installation)	48	\$394	\$18,912	20.00%	\$15,130
7110371	Oracle Storage 12 Gb SAS-3 HBA PCIe, low profile: 16 Port (for factory installation)	2	\$1,183	\$2,366	40.00%	\$1,420
7113645	Cable: 3 meters, mini SAS HD to mini SAS HD (for factory installation)	8	\$110	\$880	40.00%	\$528
7104073	Oracle Dual Port QDR InfiniBand Adapter M3 (for factory installation)	6	\$2,740	\$16,440	40.00%	\$9,864
7105174	QSFP to QSFP passive copper cable: 3 meter (for factory installation)	12	\$180	\$2,160	40.00%	\$1,296
333A-25-15-NEMA	Power cord: North America and Asia, 2.5 meters, 5-15P plug, C13 connector, 15 A (for factory installation)	4	\$13	\$52	40.00%	\$31
7113126	Oracle Storage Drive Enclosure DE3-24P: base chassis (for factory installation)	2	\$3,706	\$7,412	40.00%	\$4,447
7115078	One 800 GB 2.5-inch SAS SSD with marlin bracket (for factory installation)	40	\$2,770	\$110,800	40.00%	\$66,480
6331A-N	2.5-inch HDD filler panel (for factory installation)	8	\$0	\$0	20.00%	\$0
333A-25-15-NEMA	Power cord: North America and Asia, 2.5 meters, 5-15P plug, C13 connector, 15 A (for factory installation)	4	\$13	\$52	40.00%	\$31
X2821A-Z-N	Sun Datacenter Switch IB-36 is a 1RU 36 port managed QDR InfiniBand Switch. The switch utilizes standard QSFP connectors. Comes with redundant power supplies.	2	\$14,980	\$29,960	40.00%	\$17,976
X2121A-3M-N	QSFP to QSFP passive copper cable:	16	\$180	\$2,880	40.00%	\$1,728
X311L-N	Pwrcord,N.A./Asia,2.5m, 5-15P,15A,C13	4	\$13	\$52	40.00%	\$31
7104074	Oracle Dual Port QDR InfiniBand Adapter M3	8	\$2,740	\$21,920	40.00%	\$13,152.00
	Oracle Premium Support for Systems: 1-Year 7/24, 2 hour response time.	3	\$0	\$93,471	0.00%	\$57,444
	<b>TOTALS</b>			<b>\$353,113</b>		<b>\$217,011.94</b>

The above pricing includes the following:

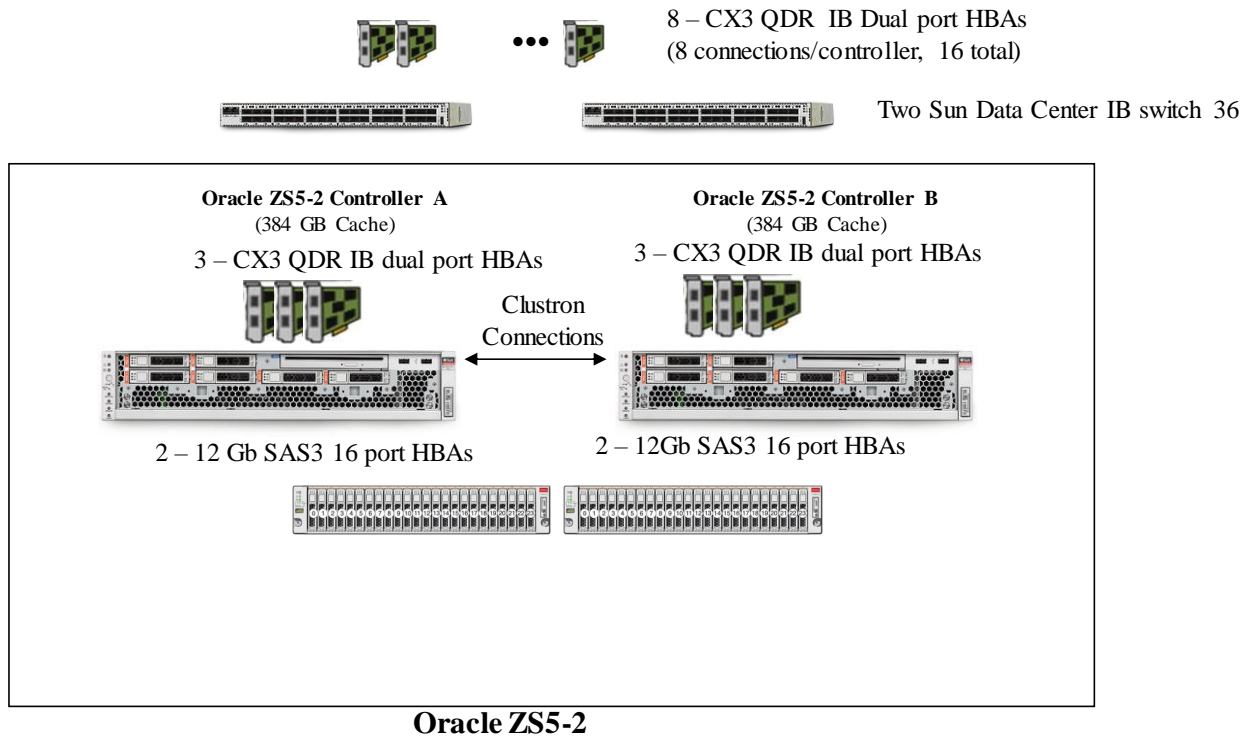
- Acknowledgement of new and existing hardware and/or software problems within four hours.
- Onsite presence of a qualified maintenance engineer or provision of a customer replaceable part within four hours of the above acknowledgement for any hardware failure that results in an inoperative Priced Storage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



## Differences between Tested Storage Configuration and Priced Storage Configuration

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

### Priced Storage Configuration Diagram



- 40 – 800 GB SSD SAS3 Disk Drives
- 2 – Oracle ZFS ZS5-2 controllers (Cluster configuration) 384 GB cache per controller
- 6 – QDR IB dual-port HBAs (3 HBAs per controller) 6 – QDR connections per controller, 12 total, 12 used
- 4 – 12 Gb SAS3 16-port HBAs(2 HBAs per controller)(8 – 12 Gb SAS3 connections per controller, 16 total, 8 used)
- 2 – Oracle Storage Drive Enclosure DE3-24P
- 40 – 800 GB SSD SAS3 Disk Drives

## Priced Storage Configuration Components

Priced Storage Configuration
8 – Oracle Dual Port QDR IB Adapter M3 CX-3 (2 per host)
2 – Sun Datacenter Switch IB-36 QDR
<b>Oracle ZFS Storage ZS5-2</b> 2 – Oracle ZFS ZS5-2 controllers (cluster configuration) 384 GiB cache/memory per controller (768 GiB total)
6 – Oracle Dual Port QDR IB Adapter M3 CX-3 (3 per controller) providing: 6 – QDR InfiniBand front-end connections per controller (12 – QDR InfiniBand front-end connections total, 12 used)
4 – Oracle Storage 12 Gb SAS-3 16-port adapters (2 per controller) providing: (2 adapters per controller) (1 adapter per controller included with base unit) 4 physical SAS ports per adapter 4 logical SAS connections per physical port 16 logical SAS connections per adapter 8 physical SAS ports per controller 32 logical SAS connections per controller (64 logical connections total, 32 used)
2 – Oracle Storage Drive Enclosures DE3-24P
40 – 800 GB SSD SAS3 disk drives (20 disk drives per enclosure)

## **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/Tested Storage Configuration Diagram**

#### **Clause 10.6.6**

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

Please see [Benchmark Configuration / Tested Storage Configuration 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.*

Please see [Storage Network Configuration Diagram](#).

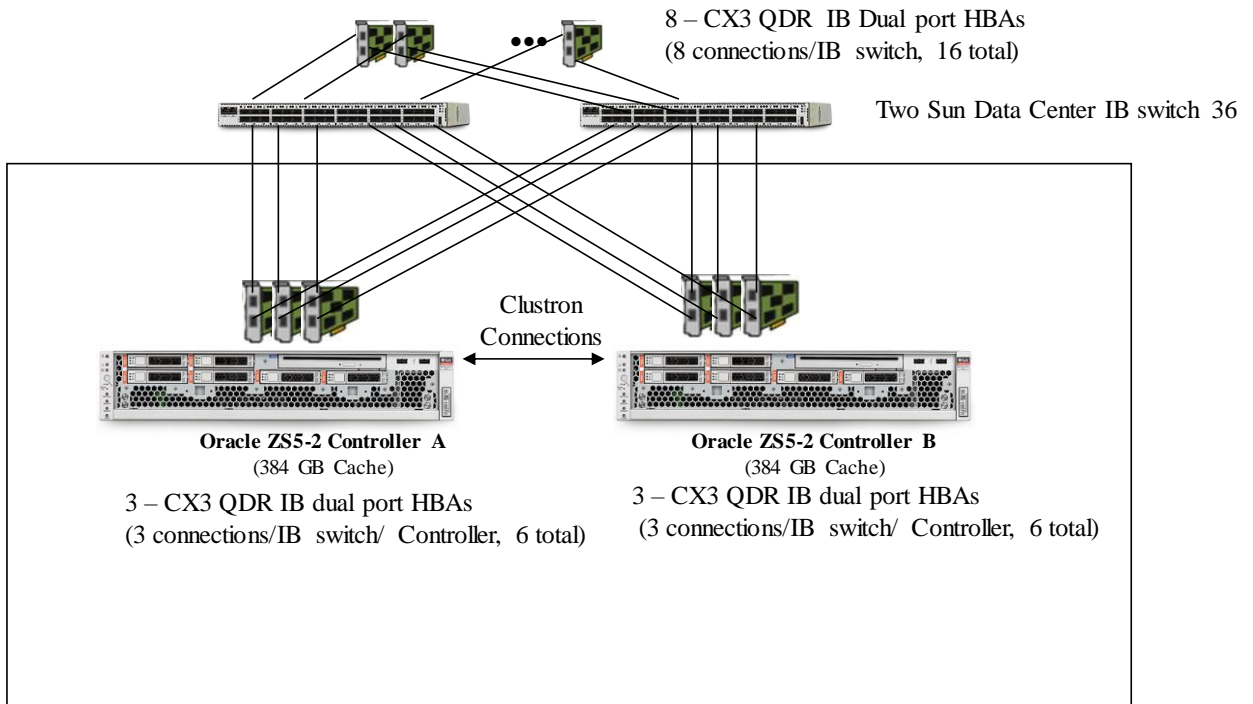
### **Host System and Tested Storage Configuration Table**

#### **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.*

Please see [Host System and Tested Storage Configuration Components](#).

# Storage Network Configuration Diagram



Details of the storage network configuration are presented in [Appendix C](#).

# Benchmark Configuration/Tested Storage Configuration Diagram

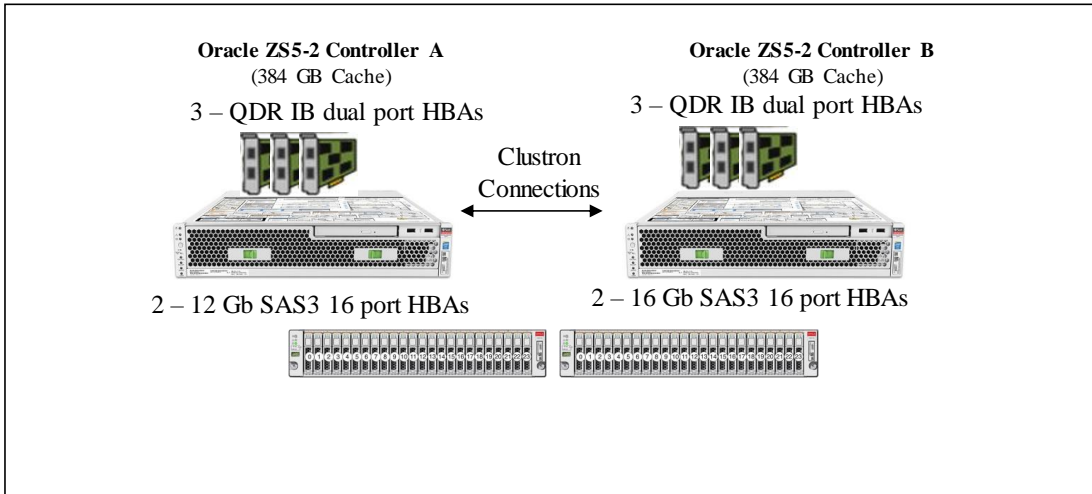
4 x Oracle Sun Fire X4-2 Server W/2 Dual Port QDR IB HBAs



8 – QDR dual-port HBAs (2 HBA per server)  
2 – QDR IB connections per HBA  
(32 total connections, 16 per switch)



Two Sun Data Center IB switch 36



40 – 800 GB SSD SAS3 Disk Drives

- 2 – Oracle ZFS ZS5-2 controllers (Cluster configuration) 384 GB cache per controller
- 6 – QDR IB dual-port HBAs (3 HBAs per controller) 6 – QDR connections per controller, 12 total, 12 used
- 4 – 12 Gb SAS3 16-port HBAs(2 HBAs per controller)(8 – 12 Gb SAS3 connections per controller, 16 total, 8 used)
- 2 – Oracle Storage Drive Enclosure DE3-24P
- 40 – 800 GB SSD SAS3 Disk Drives

## Host System and Tested Storage Configuration Components

Host Systems
<p><b>4 – Oracle Sun Server X4-2L</b>, each with:</p> <ul style="list-style-type: none"> <li>2 – Intel® Xeon® E5-2690 V2 2.99 Ghz processors,</li> <li>10 Cores, 25 MB Intel® Smart Cache</li> <li>128 GB main memory</li> <li>Oracle Solaris 11.3 x86 64-bit</li> <li>PCIe Gen3</li> </ul>
Tested Storage Configuration
8 – Oracle Dual Port QDR IB Adapter M3 CX-3 (2 per host)
2 – Sun Datacenter Switch IB-36 QDR
<p><b>Oracle ZFS Storage ZS5-2</b></p> <ul style="list-style-type: none"> <li>2 – Oracle ZFS ZS5-2 controllers (cluster configuration)</li> <li>384 GiB cache/memory per controller (768 GiB total)</li> </ul>
<ul style="list-style-type: none"> <li>6 – Oracle Dual Port QDR IB Adapter M3 CX-3 (3 per controller) providing:                             <ul style="list-style-type: none"> <li>6 – QDR InfiniBand front-end connections per controller</li> <li>(12 – QDR InfiniBand front-end connections total, 12 used)</li> </ul> </li> </ul>
<ul style="list-style-type: none"> <li>4 – Oracle Storage 12 Gb SAS-3 16-port adapters (2 per controller) providing:                             <ul style="list-style-type: none"> <li>(2 adapters per controller)</li> <li>(1 adapter per controller included with base unit)</li> <li>4 physical SAS ports per adapter</li> <li>4 logical SAS connections per physical port</li> <li>16 logical SAS connections per adapter</li> <li>8 physical SAS ports per controller</li> <li>32 logical SAS connections per controller</li> <li>(64 logical connections total, 32 used)</li> </ul> </li> </ul>
2 – Oracle Storage Drive Enclosures DE3-24P
40 – 800 GB SSD SAS3 disk drives (20 disk drives per enclosure)

## 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.

Please see [Appendix B: Customer Tunable Parameters and Options](#).

## Tested Storage Configuration 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 (Clause 10.6.6.1), 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.

Please see [Appendix C: Tested Storage Configuration Creation](#).

## 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.

Please see [Appendix D: SPC-2 Workload Generator Storage Commands and Parameter Files](#).

## 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.

Please see [Appendix D: SPC-2 Workload Generator Storage Commands and Parameter Files](#).

# 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](#) 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.

## 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.*

### Storage Capacities

The Physical Storage Capacity consisted of 32,006.643 GB distributed over 40 disk drives each with a formatted capacity of 800,166,076,416 GB. There was 0.000 GB (0.00%) of Unused Storage within the Physical Storage Capacity. Global Storage Overhead consisted of 0.341 GB (0.00%) of the Physical Storage Capacity. There was 11,969.400 GB (37.40%) 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 (*Mirroring*) capacity was 14,402.836 GB of which 8,418.136 GB was utilized. The total Unused Storage was 11,969.400 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.*

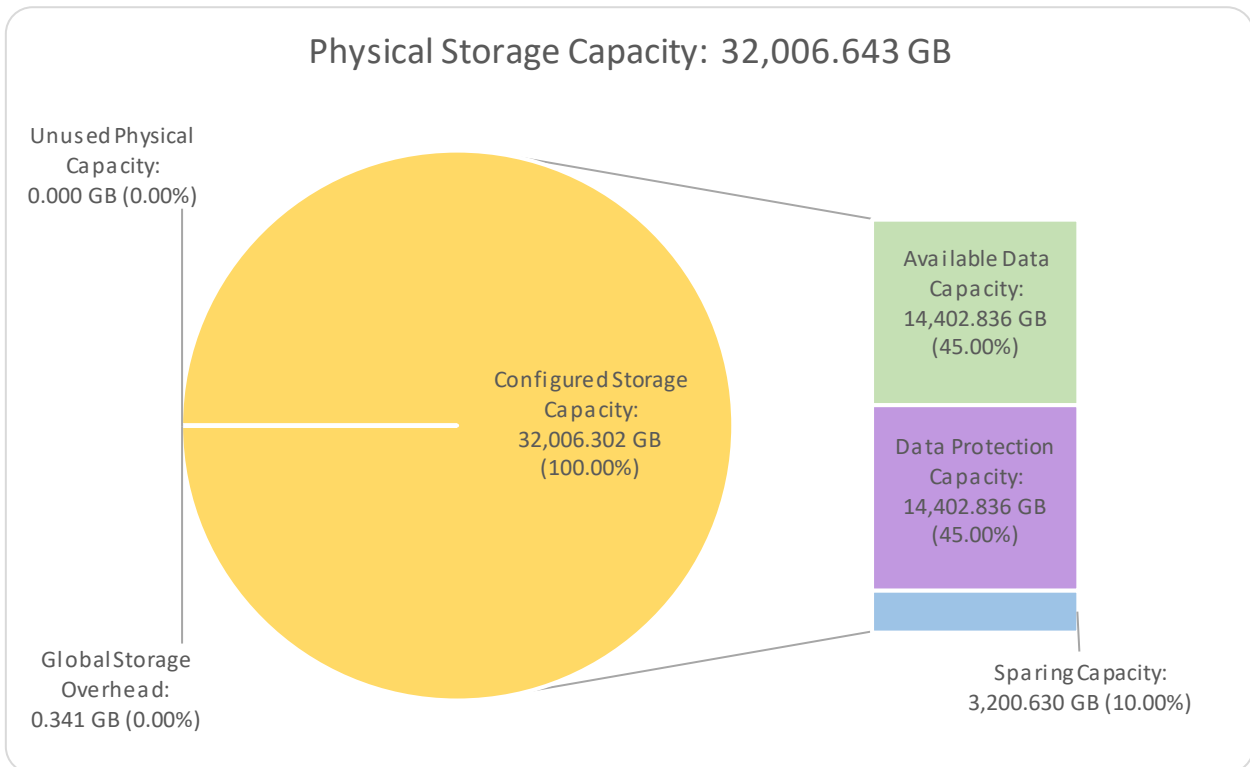
SPC-2 Storage Capacities		
Storage Hierarchy Component	Units	Capacity
Total ASU Capacity	Gigabytes (GB)	8,383.776
Addressable Storage Capacity	Gigabytes (GB)	8,383.776
Configured Storage Capacity	Gigabytes (GB)	32,006.302
Physical Storage Capacity	Gigabytes (GB)	32,006.643
Data Protection ( <i>Mirroring</i> )	Gigabytes (GB)	14,402.836
Required Storage ( <i>overhead/sparing</i> )	Gigabytes (GB)	3,269.350
Global Storage Overhead	Gigabytes (GB)	0.341
Total Unused Storage	Gigabytes (GB)	11,969.400

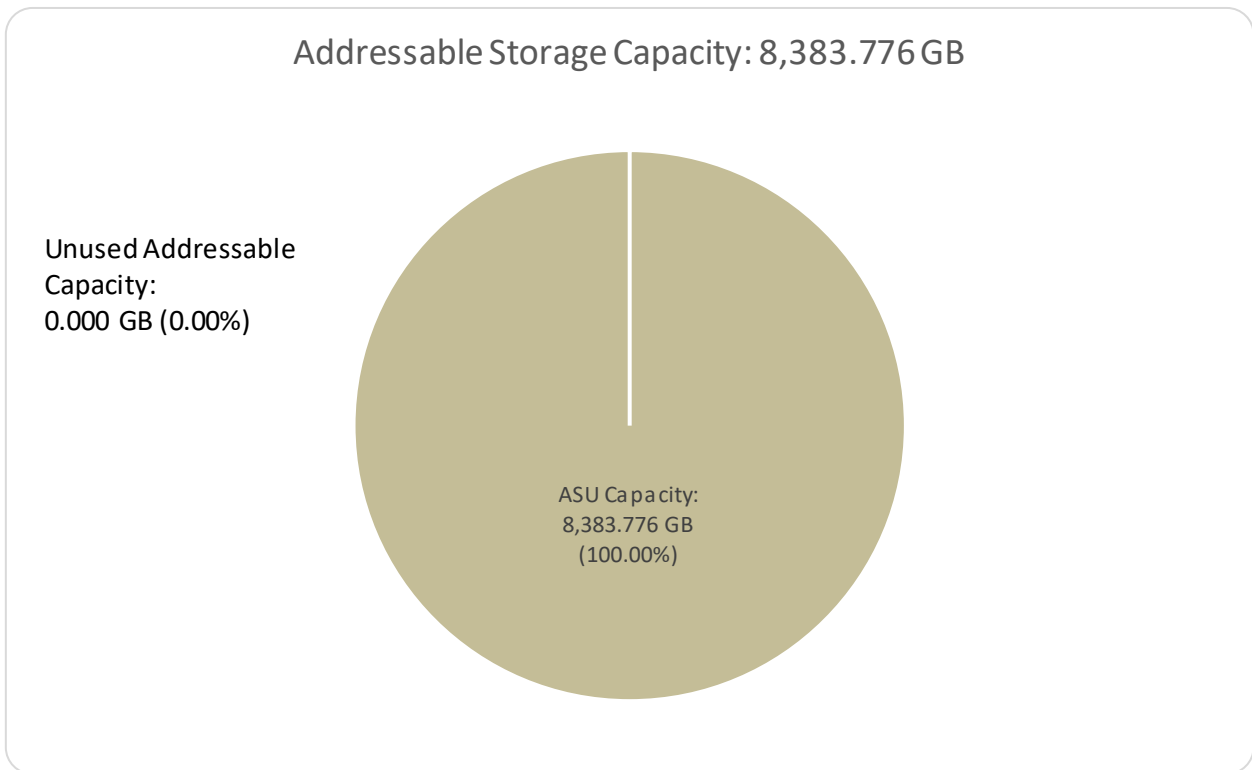
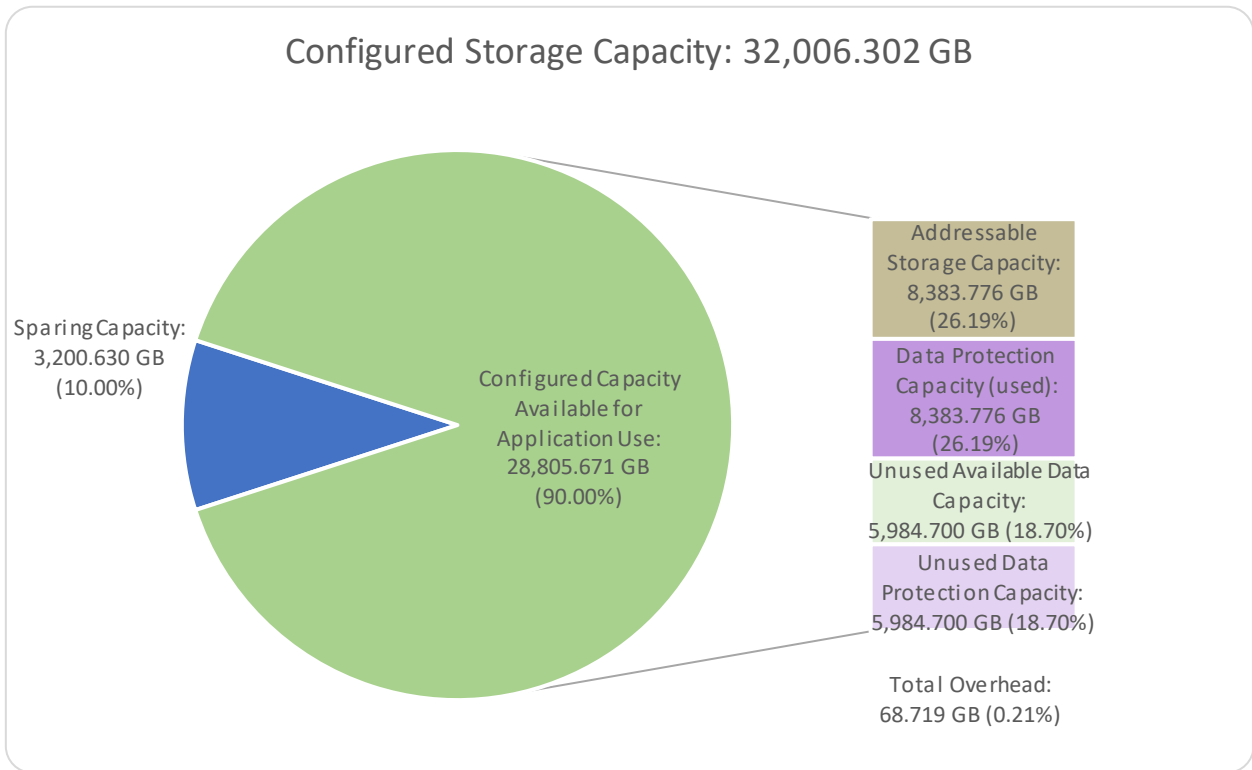


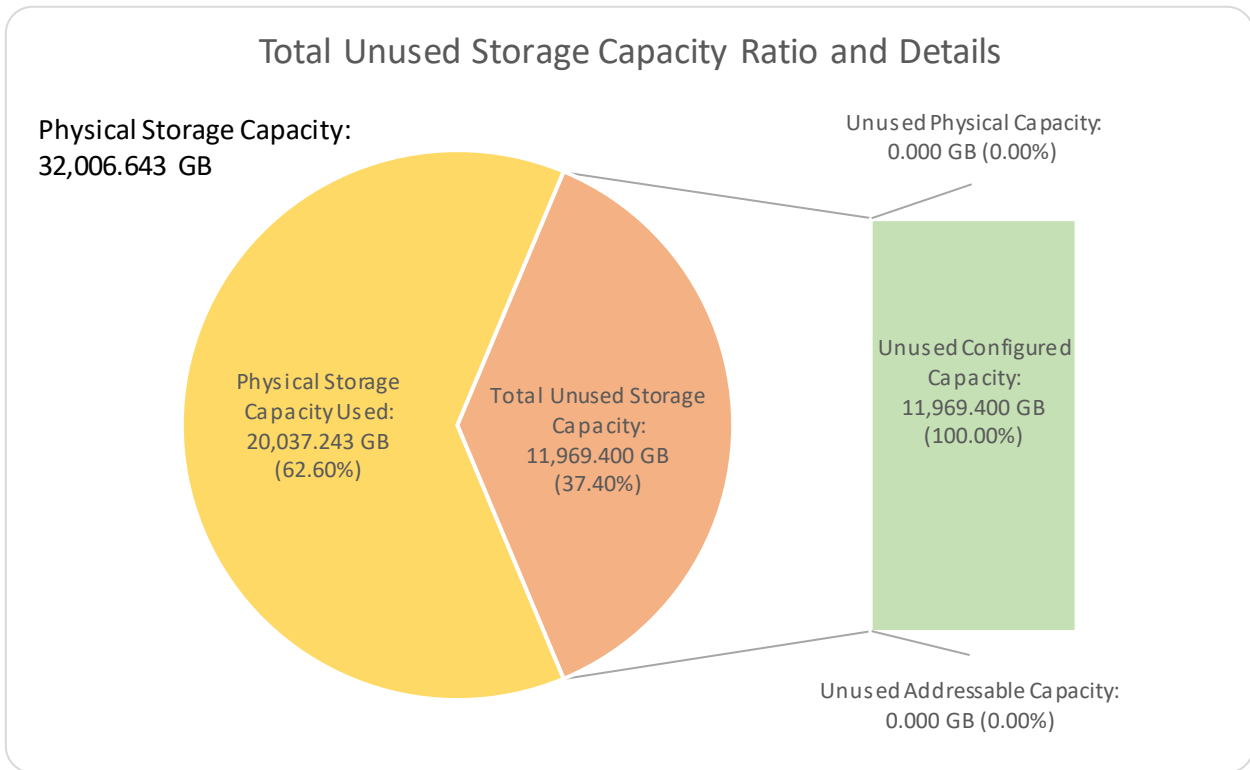
### Storage Hierarchy Ratios

	Addressable Storage Capacity	Configured Storage Capacity	Physical Storage Capacity
<b>Total ASU Capacity</b>	100.00%	26.19%	26.19%
<b>Data Protection (<i>mirroring</i>)</b>		45.00%	45.00%
<b>Addressable Storage Capacity</b>		26.19%	26.19%
<b>Required Storage</b>		10.21%	10.21%
<b>Configured Storage Capacity</b>			100.00%
<b>Global Storage Overhead</b>			0.00%
<b>Unused Storage:</b>			
<b>Addressable</b>	0.00%		
<b>Configured</b>		37.40%	
<b>Physical</b>			0.00%

### Storage Capacity Charts







## 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	26.19%
Protected Application Utilization	52.50%
Unused Storage Ratio	37.40%

## 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 (8,383.776 GB)			
	Total Capacity (GB)	Capacity Used (GB)	Capacity Unused (GB)
32 Logical Volumes	261.993 per LV	261.993 per LV	0.000 per LV

Please see the Storage Definition (sd) entries in [Appendix D: SPC-2 Workload Generator Storage Commands and Parameter Files](#) 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](#) 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 value
  - 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 value
    - 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 value
    - 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 - Overview

### 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.*

## **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](#).

## **Test Results File**

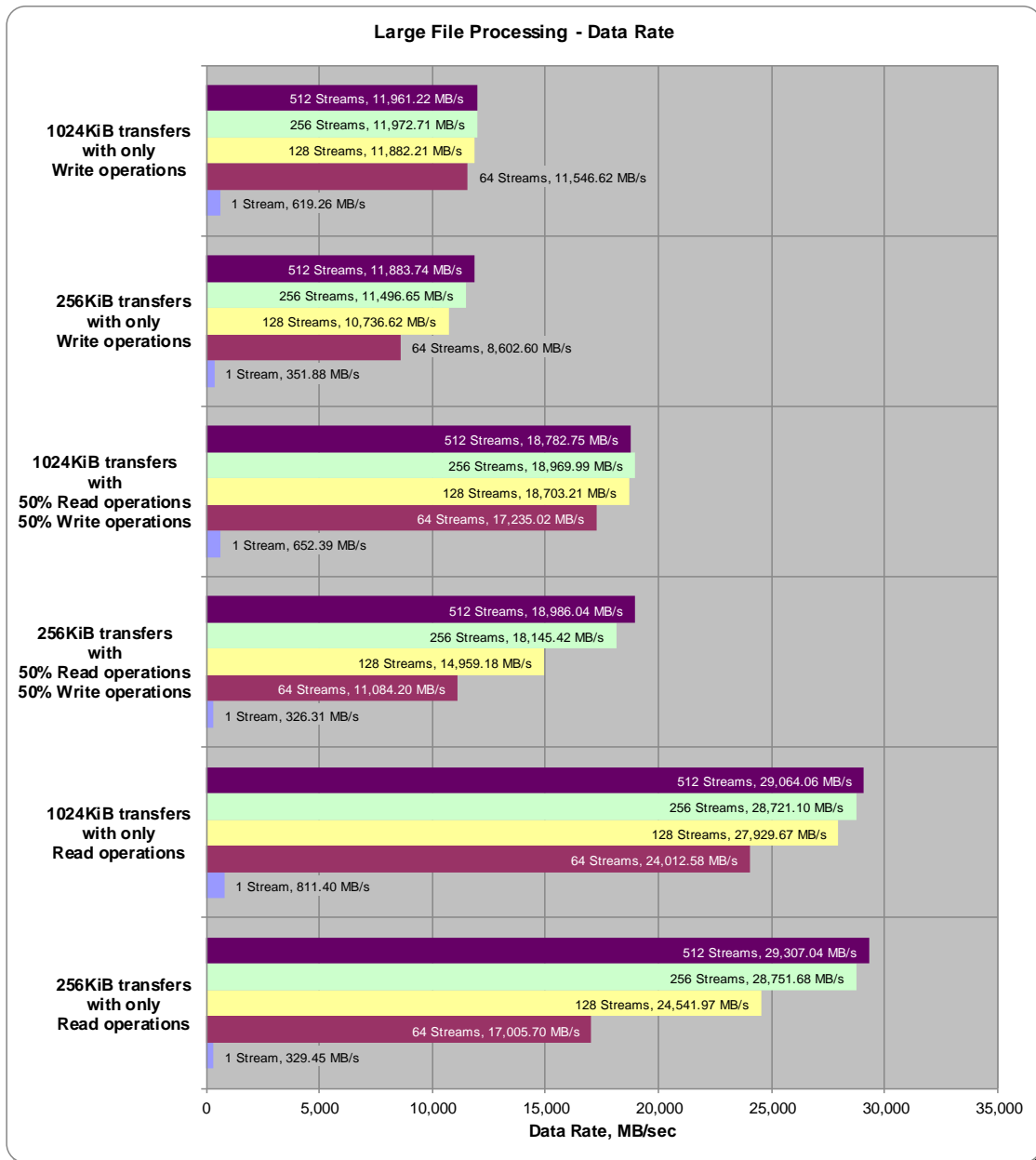
A link to the SPC-2 Test Results file generated from the Large File Processing Test Runs is listed below.

[SPC-2 Large File Processing Test Results File](#)

**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	64 Streams	128 Streams	256 Streams	512 Streams
Write 1024KiB	619.26	11,546.62	11,882.21	11,972.71	11,961.22
Write 256KiB	351.88	8,602.60	10,736.62	11,496.65	11,883.74
Read/Write 1024KiB	652.39	17,235.02	18,703.21	18,969.99	18,782.75
Read/Write 256KiB	326.31	11,084.20	14,959.18	18,145.42	18,986.04
Read 1024KiB	811.40	24,012.58	27,929.67	28,721.10	29,064.06
Read 256KiB	329.45	17,005.70	24,541.97	28,751.68	29,307.04

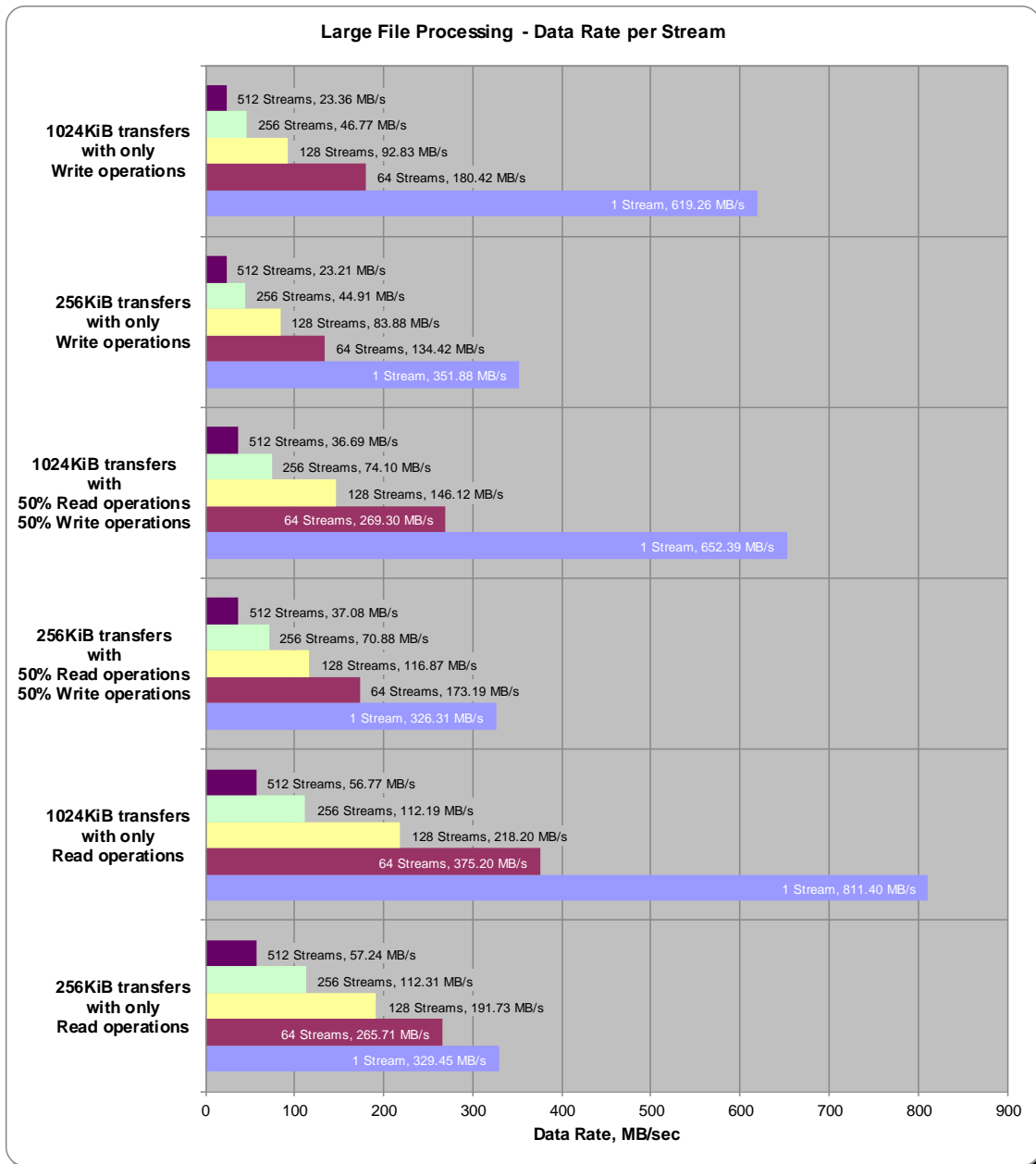




### Average Data Rate per Stream

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	64 Streams	128 Streams	256 Streams	512 Streams
Write 1024KiB	619.26	180.42	92.83	46.77	23.36
Write 256KiB	351.88	134.42	83.88	44.91	23.21
Read/Write 1024KiB	652.39	269.30	146.12	74.10	36.69
Read/Write 256KiB	326.31	173.19	116.87	70.88	37.08
Read 1024KiB	811.40	375.20	218.20	112.19	56.77
Read 256KiB	329.45	265.71	191.73	112.31	57.24

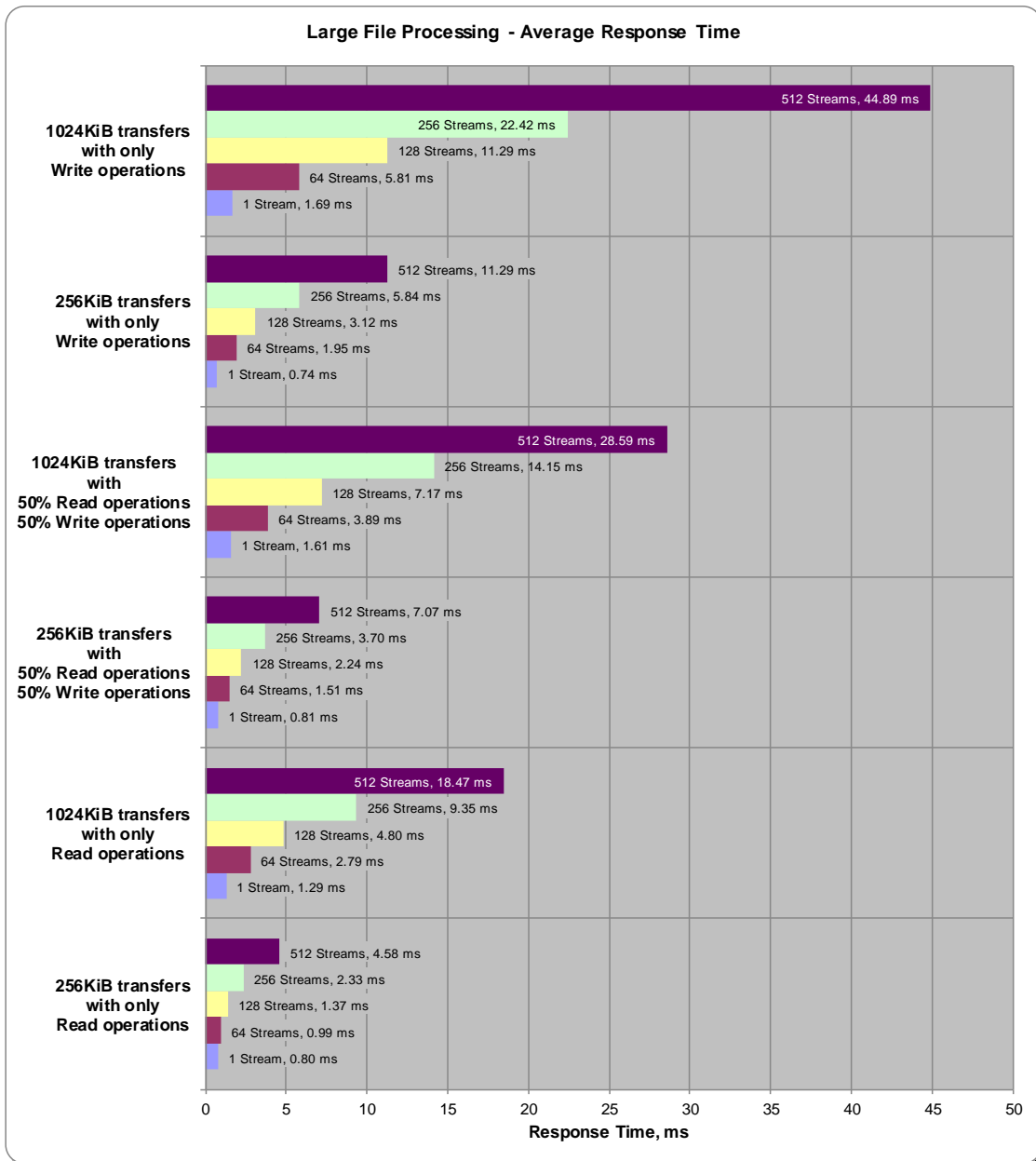


Large File Processing Test

**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	64 Streams	128 Streams	256 Streams	512 Streams
Write 1024KiB	1.69	5.81	11.29	22.42	44.89
Write 256KiB	0.74	1.95	3.12	5.84	11.29
Read/Write 1024KiB	1.61	3.89	7.17	14.15	28.59
Read/Write 256KiB	0.81	1.51	2.24	3.70	7.07
Read 1024KiB	1.29	2.79	4.80	9.35	18.47
Read 256KiB	0.80	0.99	1.37	2.33	4.58



## 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.

### **1,024 KiB Transfer Size Test Run**

The link below provides data for the following test run periods.

- Ramp-Up
- Measurement Interval
- Run Out / Ramp-Down

#### [1,024 KiB Transfer Size Test Run Data](#)

The link below provides the following graphs.

- Average Data Rate – Complete Test Run
- Average Data Rate – Measurement Interval (MI) Only
- Average Data Rate per Stream
- Average Response Time

#### [1,024 KiB Transfer Size Test Run Graphs](#)

### **256 KiB Transfer Size Test Run**

The link below provides data for the following test run periods.

- Ramp-Up
- Measurement Interval

## Large File Processing Test

- Run Out / Ramp-Down

[256 KiB Transfer Size Test Run Data](#)

The link below provides the following graphs.

- Average Data Rate – Complete Test Run
- Average Data Rate – Measurement Interval (MI) Only
- Average Data Rate per Stream
- Average Response Time

[256 KiB Transfer Size Test Run Graphs](#)

## 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.

### 1,024 KiB Transfer Size Test Run

The link below provides data for the following test run periods.

- Ramp-Up
- Measurement Interval
- Run Out / Ramp-Down

[1,024 KiB Transfer Size Test Run Data](#)

The link below provides the following graphs.

- Average Data Rate – Complete Test Run
- Average Data Rate – Measurement Interval (MI) Only

## Large File Processing Test

- Average Data Rate per Stream
- Average Response Time

[1,024 KiB Transfer Size Test Run Graphs](#)

## **256 KiB Transfer Size Test Run**

The link below provides data for the following test run periods.

- Ramp-Up
- Measurement Interval
- Run Out / Ramp-Down

[256 KiB Transfer Size Test Run Data](#)

The link below provides the following graphs.

- Average Data Rate – Complete Test Run
- Average Data Rate – Measurement Interval (MI) Only
- Average Data Rate per Stream
- Average Response Time

[256 KiB Transfer Size Test Run Graphs](#)

## **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.

## **1,024 KiB Transfer Size Test Run**

The link below provides data for the following test run periods.

- Ramp-Up
- Measurement Interval
- Run Out / Ramp-Down

### [1,024 KiB Transfer Size Test Run Data](#)

The link below provides the following graphs.

- Average Data Rate – Complete Test Run
- Average Data Rate – Measurement Interval (MI) Only
- Average Data Rate per Stream
- Average Response Time

### [1,024 KiB Transfer Size Test Run Graphs](#)

## **256 KiB Transfer Size Test Run**

The link below provides data for the following test run periods.

- Ramp-Up
- Measurement Interval
- Run Out / Ramp-Down

### [256 KiB Transfer Size Test Run Data](#)

The link below provides the following graphs.

- Average Data Rate – Complete Test Run
- Average Data Rate – Measurement Interval (MI) Only
- Average Data Rate per Stream
- Average Response Time

### [256 KiB Transfer Size Test Run Graphs](#)

## Large Database Query Test - Overview

### 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.

## **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](#).

## **Test Results File**

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

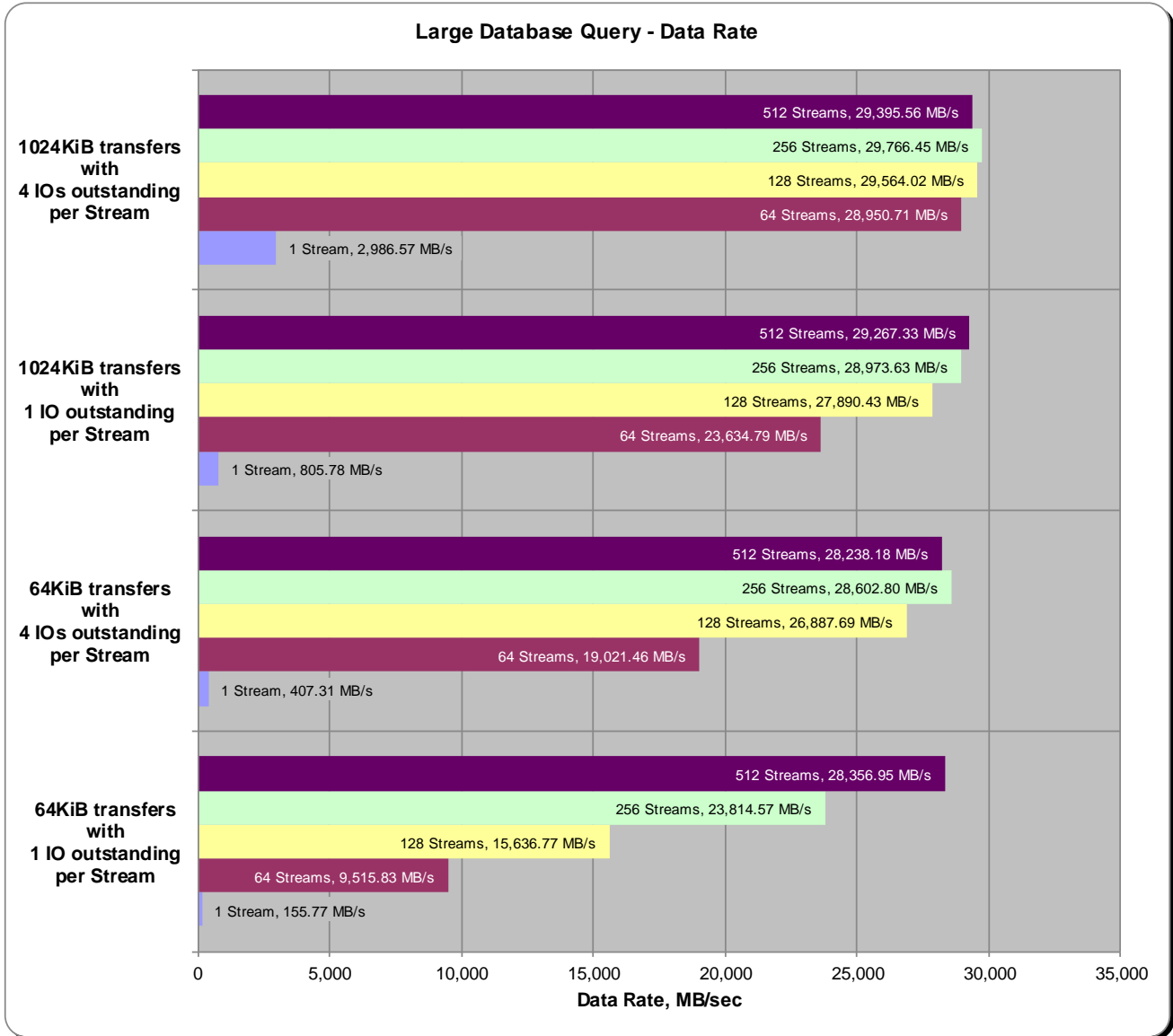
[SPC-2 Large Database Query Test Results File](#)

Large Database Query Test

**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	64 Streams	128 Streams	256 Streams	512 Streams
1024KiB w/ 4 IOs/Stream	2,986.57	28,950.71	29,564.02	29,766.45	29,395.56
1024KiB w/ 1 IO/Stream	805.78	23,634.79	27,890.43	28,973.63	29,267.33
64KiB w/ 4 IOs/Stream	407.31	19,021.46	26,887.69	28,602.80	28,238.18
64KiB w/ 1 IO/Stream	155.77	9,515.83	15,636.77	23,814.57	28,356.95



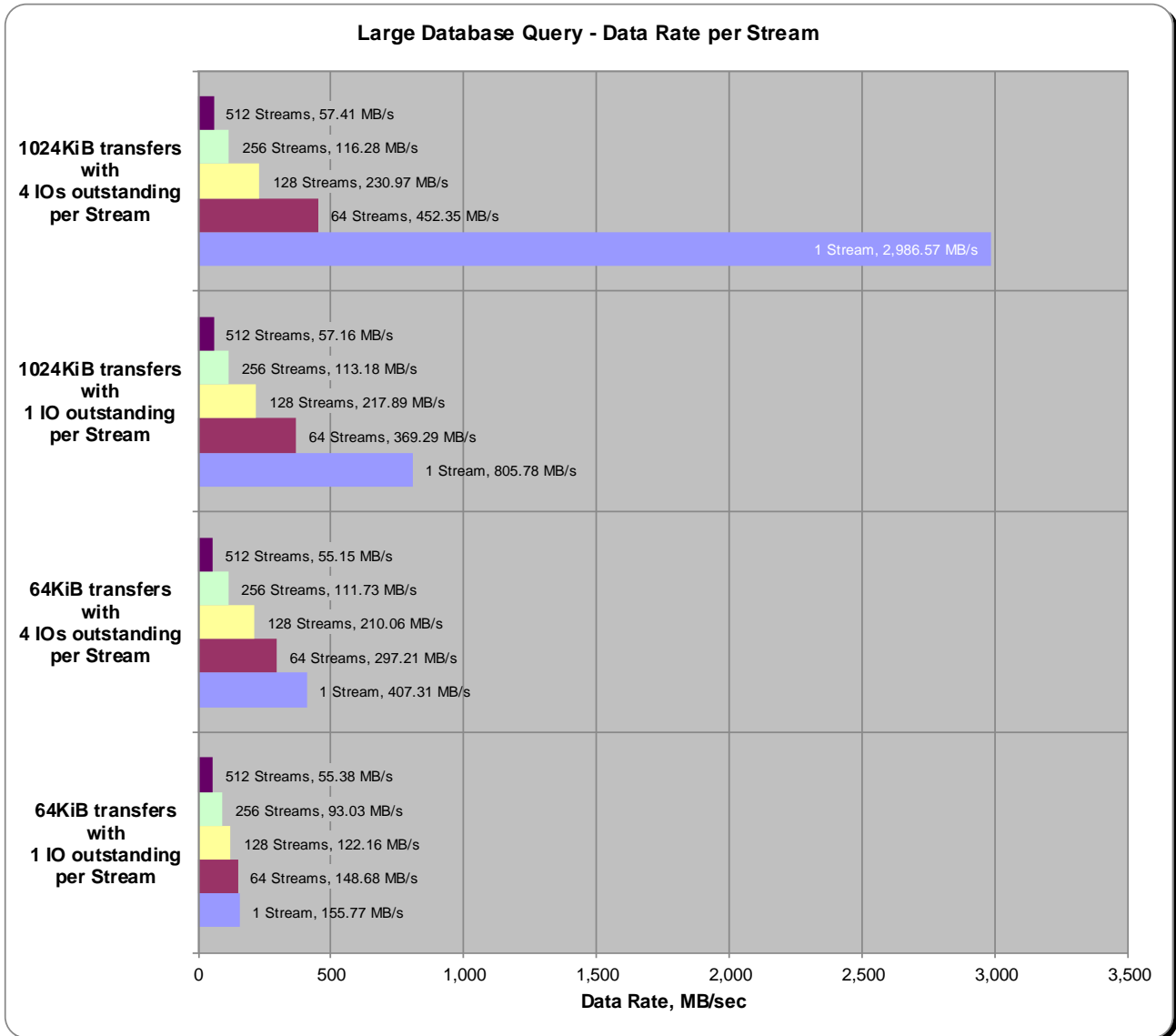


Large Database Query Test

**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	64 Streams	128 Streams	256 Streams	512 Streams
1024KiB w/ 4 IOs/Stream	2,986.57	452.35	230.97	116.28	57.41
1024KiB w/ 1 IO/Stream	805.78	369.29	217.89	113.18	57.16
64KiB w/ 4 IOs/Stream	407.31	297.21	210.06	111.73	55.15
64KiB w/ 1 IO/Stream	155.77	148.68	122.16	93.03	55.38

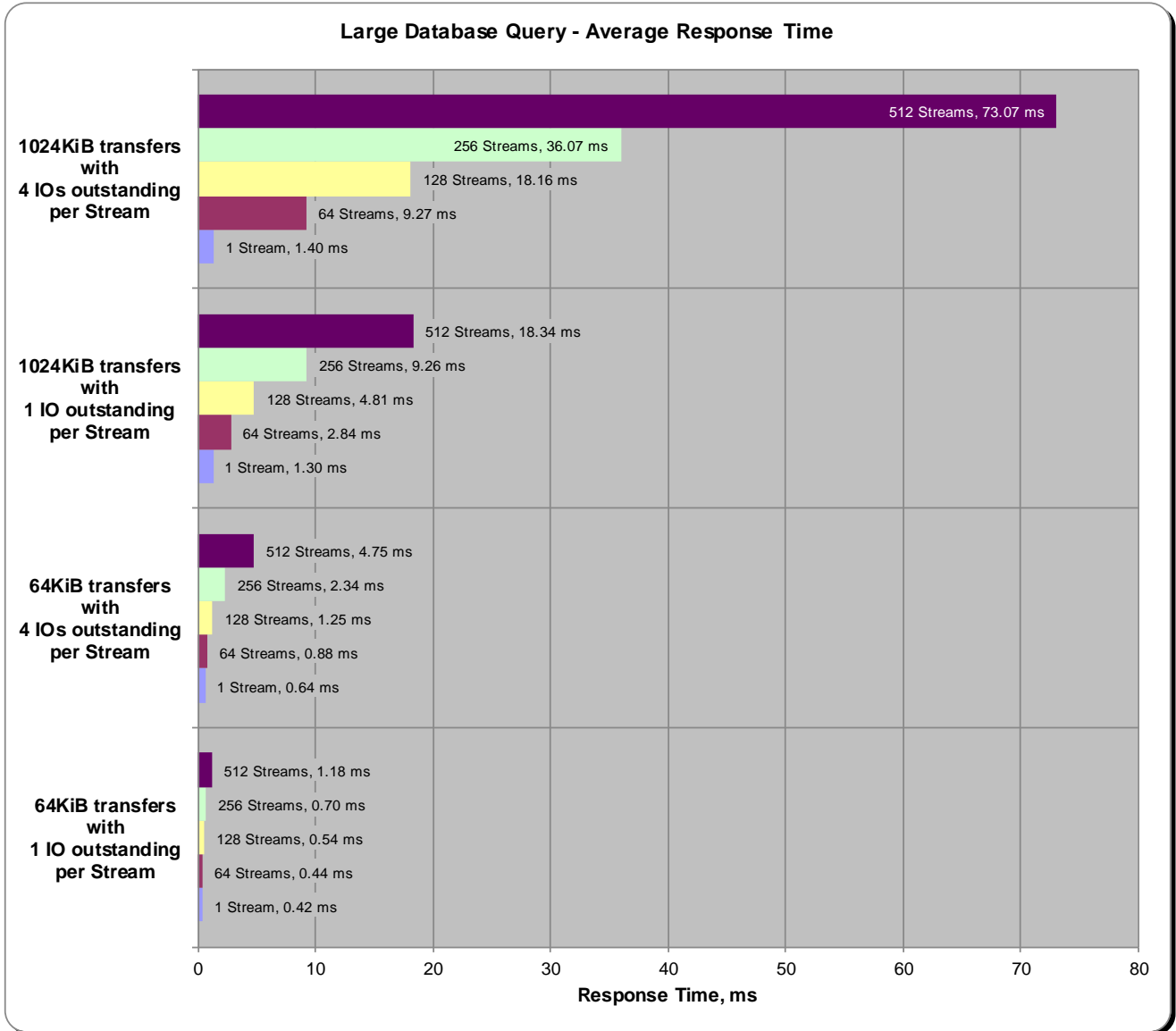


Large Database Query Test

**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	64 Streams	128 Streams	256 Streams	512 Streams
1024KiB w/ 4 IOs/Stream	1.40	9.27	18.16	36.07	73.07
1024KiB w/ 1 IO/Stream	1.30	2.84	4.81	9.26	18.34
64KiB w/ 4 IOs/Stream	0.64	0.88	1.25	2.34	4.75
64KiB w/ 1 IO/Stream	0.42	0.44	0.54	0.70	1.18



## Large Database Query Test – 1,024 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.

### **4 Outstanding I/Os Test Run**

The link below provides data for the following test run periods.

- Ramp-Up
- Measurement Interval
- Run Out / Ramp-Down

#### [4 Outstanding I/Os Test Run Data](#)

The link below provides the following graphs.

- Average Data Rate – Complete Test Run
- Average Data Rate – Measurement Interval (MI) Only
- Average Data Rate per Stream
- Average Response Time

#### [4 Outstanding I/Os Test Run Graphs](#)

### **1 Outstanding I/O Test Run**

The link below provides data for the following test run periods.

- Ramp-Up
- Measurement Interval

## Large Database Query Test

- Run Out / Ramp-Down

[1 Outstanding I/O Test Run Data](#)

The link below provides the following graphs.

- Average Data Rate – Complete Test Run
- Average Data Rate – Measurement Interval (MI) Only
- Average Data Rate per Stream
- Average Response Time

[1 Outstanding I/O Test Run Graphs](#)

## 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.

### 4 Outstanding I/Os Test Run

The link below provides data for the following test run periods.

- Ramp-Up
- Measurement Interval
- Run Out / Ramp-Down

[4 Outstanding I/Os Test Run Data](#)

The link below provides the following graphs.

- Average Data Rate – Complete Test Run

## Large Database Query Test

- Average Data Rate – Measurement Interval (MI) Only
- Average Data Rate per Stream
- Average Response Time

[4 Outstanding I/Os Test Run Graphs](#)**1 Outstanding I/O Test Run**

The link below provides data for the following test run periods.

- Ramp-Up
- Measurement Interval
- Run Out / Ramp-Down

[1 Outstanding I/O Test Run Data](#)

The link below provides the following graphs.

- Average Data Rate – Complete Test Run
- Average Data Rate – Measurement Interval (MI) Only
- Average Data Rate per Stream
- Average Response Time

[1 Outstanding I/O Test Run Graphs](#)

## 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:*
  - a. The number Streams specified.*
  - b. The Ramp-Up duration in seconds.*
  - c. The Measurement Interval duration in seconds.*
  - d. The average data rate, in MB per second, for the Measurement Interval.*
  - e. 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:*
  - a. The number Streams specified.*
  - b. 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.*

## **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](#).

## **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](#)

### **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

<b>SPC-2-VOD</b>	<b>TR1</b>
Number of Streams	31,000
Ramp-up Time, sec	1,200
Measurement Interval, sec	7,200
Average Data Rate, MB/sec	24,379.39
Per Stream Data Rate, MB/sec	0.79
Average Response Time, ms	1.46
Average Max Response Time, ms	10.56

### **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.

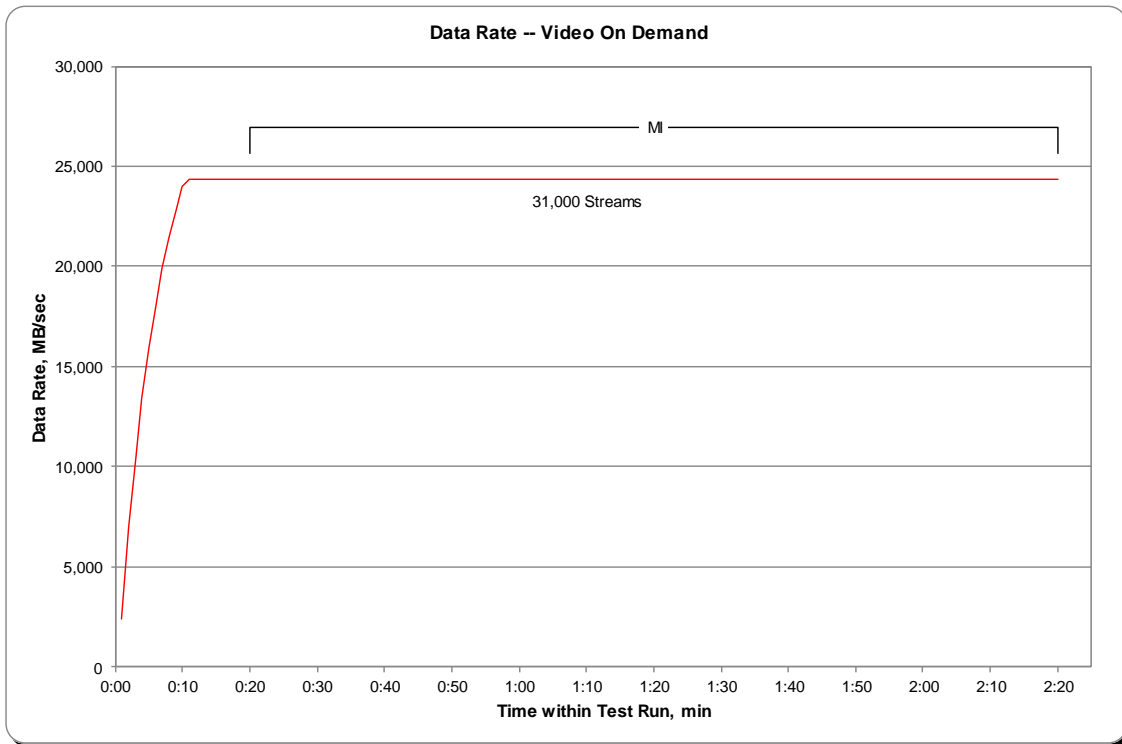
Video on Demand Delivery Test

TR1	31,000 Streams				TR1	31,000 Streams				TR1	31,000 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	2,422.89	0.67	0.82	7.51	0:48:00	24,379.40	0.79	1.41	7.65	1:35:00	24,377.89	0.79	1.45	6.79
0:02:00	6,979.78	0.77	0.81	21.98	0:49:00	24,379.44	0.79	1.42	7.92	1:36:00	24,379.46	0.79	1.45	7.74
0:03:00	10,430.42	0.77	0.90	22.49	0:50:00	24,379.55	0.79	1.42	7.04	1:37:00	24,379.46	0.79	1.45	20.37
0:04:00	13,380.99	0.78	0.88	19.36	0:51:00	24,379.26	0.79	1.42	6.99	1:38:00	24,379.91	0.79	1.46	8.13
0:05:00	15,910.32	0.78	0.95	18.07	0:52:00	24,379.40	0.79	1.42	6.82	1:39:00	24,379.45	0.79	1.45	6.81
0:06:00	18,062.86	0.78	1.04	14.83	0:53:00	24,379.42	0.79	1.42	6.14	1:40:00	24,379.85	0.79	1.45	9.60
0:07:00	19,907.51	0.78	1.14	7.02	0:54:00	24,379.36	0.79	1.42	6.97	1:41:00	24,379.53	0.79	1.46	7.53
0:08:00	21,478.10	0.78	1.25	34.82	0:55:00	24,378.27	0.79	1.42	7.53	1:42:00	24,379.30	0.79	1.47	7.56
0:09:00	22,846.84	0.78	1.33	9.45	0:56:00	24,378.74	0.79	1.42	10.07	1:43:00	24,378.86	0.79	1.48	15.35
0:10:00	23,963.47	0.78	1.43	13.00	0:57:00	24,378.59	0.79	1.42	7.71	1:44:00	24,379.32	0.79	1.49	10.89
0:11:00	24,379.34	0.79	1.47	7.47	0:58:00	24,379.31	0.79	1.42	7.70	1:45:00	24,379.27	0.79	1.49	6.64
0:12:00	24,379.49	0.79	1.47	8.52	0:59:00	24,379.43	0.79	1.42	7.51	1:46:00	24,379.89	0.79	1.49	7.39
0:13:00	24,379.43	0.79	1.47	7.11	1:00:00	24,379.38	0.79	1.42	8.52	1:47:00	24,379.36	0.79	1.49	18.54
0:14:00	24,379.07	0.79	1.47	15.49	1:01:00	24,378.69	0.79	1.44	7.21	1:48:00	24,379.92	0.79	1.49	11.67
0:15:00	24,379.48	0.79	1.47	20.02	1:02:00	24,379.45	0.79	1.46	8.86	1:49:00	24,379.86	0.79	1.49	8.47
0:16:00	24,378.27	0.79	1.47	7.96	1:03:00	24,379.52	0.79	1.49	14.57	1:50:00	24,380.14	0.79	1.50	7.86
0:17:00	24,378.33	0.79	1.47	7.22	1:04:00	24,379.91	0.79	1.49	46.70	1:51:00	24,379.39	0.79	1.51	7.51
0:18:00	24,381.33	0.79	1.47	7.91	1:05:00	24,379.33	0.79	1.50	47.76	1:52:00	24,379.99	0.79	1.50	9.00
0:19:00	24,379.37	0.79	1.46	10.96	1:06:00	24,379.01	0.79	1.48	18.04	1:53:00	24,378.16	0.79	1.50	8.74
0:20:00	24,379.30	0.79	1.47	16.33	1:07:00	24,378.99	0.79	1.49	9.11	1:54:00	24,380.58	0.79	1.50	7.66
0:21:00	24,379.94	0.79	1.45	11.91	1:08:00	24,379.49	0.79	1.49	8.76	1:55:00	24,378.12	0.79	1.50	7.73
0:22:00	24,378.82	0.79	1.44	15.52	1:09:00	24,379.81	0.79	1.48	8.29	1:56:00	24,380.47	0.79	1.50	8.21
0:23:00	24,378.79	0.79	1.43	15.25	1:10:00	24,379.86	0.79	1.49	7.72	1:57:00	24,379.41	0.79	1.51	21.08
0:24:00	24,379.98	0.79	1.43	6.39	1:11:00	24,379.39	0.79	1.49	8.67	1:58:00	24,378.78	0.79	1.50	9.07
0:25:00	24,379.44	0.79	1.43	15.49	1:12:00	24,379.61	0.79	1.50	12.95	1:59:00	24,379.34	0.79	1.51	18.62
0:26:00	24,378.79	0.79	1.44	12.06	1:13:00	24,379.41	0.79	1.50	10.01	2:00:00	24,379.27	0.79	1.51	16.81
0:27:00	24,379.41	0.79	1.43	7.19	1:14:00	24,379.44	0.79	1.50	8.49	2:01:00	24,379.90	0.79	1.49	8.85
0:28:00	24,378.93	0.79	1.42	8.65	1:15:00	24,379.94	0.79	1.50	13.40	2:02:00	24,378.89	0.79	1.48	9.05
0:29:00	24,380.04	0.79	1.42	6.59	1:16:00	24,378.87	0.79	1.50	8.99	2:03:00	24,379.99	0.79	1.46	7.21
0:30:00	24,379.97	0.79	1.43	10.74	1:17:00	24,379.44	0.79	1.51	17.34	2:04:00	24,378.84	0.79	1.45	9.19
0:31:00	24,378.81	0.79	1.43	8.42	1:18:00	24,378.89	0.79	1.49	8.17	2:05:00	24,379.96	0.79	1.45	12.32
0:32:00	24,379.02	0.79	1.43	7.90	1:19:00	24,379.87	0.79	1.50	10.39	2:06:00	24,379.88	0.79	1.45	6.84
0:33:00	24,379.39	0.79	1.43	8.36	1:20:00	24,379.27	0.79	1.50	9.00	2:07:00	24,379.52	0.79	1.44	11.40
0:34:00	24,380.01	0.79	1.43	7.44	1:21:00	24,380.58	0.79	1.49	7.44	2:08:00	24,380.00	0.79	1.43	8.39
0:35:00	24,378.28	0.79	1.43	7.13	1:22:00	24,380.55	0.79	1.49	11.46	2:09:00	24,378.81	0.79	1.43	13.30
0:36:00	24,379.13	0.79	1.45	19.38	1:23:00	24,379.73	0.79	1.48	7.92	2:10:00	24,380.04	0.79	1.43	14.62
0:37:00	24,379.48	0.79	1.43	9.02	1:24:00	24,379.51	0.79	1.48	12.69	2:11:00	24,378.91	0.79	1.43	12.28
0:38:00	24,379.58	0.79	1.43	7.08	1:25:00	24,379.49	0.79	1.48	7.04	2:12:00	24,379.44	0.79	1.43	7.73
0:39:00	24,379.41	0.79	1.43	7.96	1:26:00	24,379.25	0.79	1.46	7.64	2:13:00	24,379.06	0.79	1.43	7.63
0:40:00	24,379.37	0.79	1.43	18.31	1:27:00	24,379.86	0.79	1.45	11.79	2:14:00	24,379.39	0.79	1.43	7.11
0:41:00	24,379.86	0.79	1.44	7.69	1:28:00	24,379.82	0.79	1.45	7.99	2:15:00	24,379.97	0.79	1.43	6.74
0:42:00	24,379.93	0.79	1.44	6.79	1:29:00	24,379.42	0.79	1.45	11.05	2:16:00	24,380.00	0.79	1.43	8.12
0:43:00	24,379.32	0.79	1.44	8.10	1:30:00	24,379.23	0.79	1.45	10.55	2:17:00	24,379.44	0.79	1.43	11.64
0:44:00	24,379.47	0.79	1.44	25.27	1:31:00	24,379.47	0.79	1.46	6.97	2:18:00	24,379.36	0.79	1.43	6.66
0:45:00	24,379.26	0.79	1.42	8.21	1:32:00	24,379.12	0.79	1.46	8.06	2:19:00	24,380.02	0.79	1.43	6.79
0:46:00	24,379.39	0.79	1.41	6.89	1:33:00	24,379.36	0.79	1.45	7.37	2:20:00	24,379.34	0.79	1.43	6.32
0:47:00	24,379.57	0.79	1.41	6.29	1:34:00	24,379.81	0.79	1.45	7.60	0:00:00	0.00	0.00	0.00	0.00

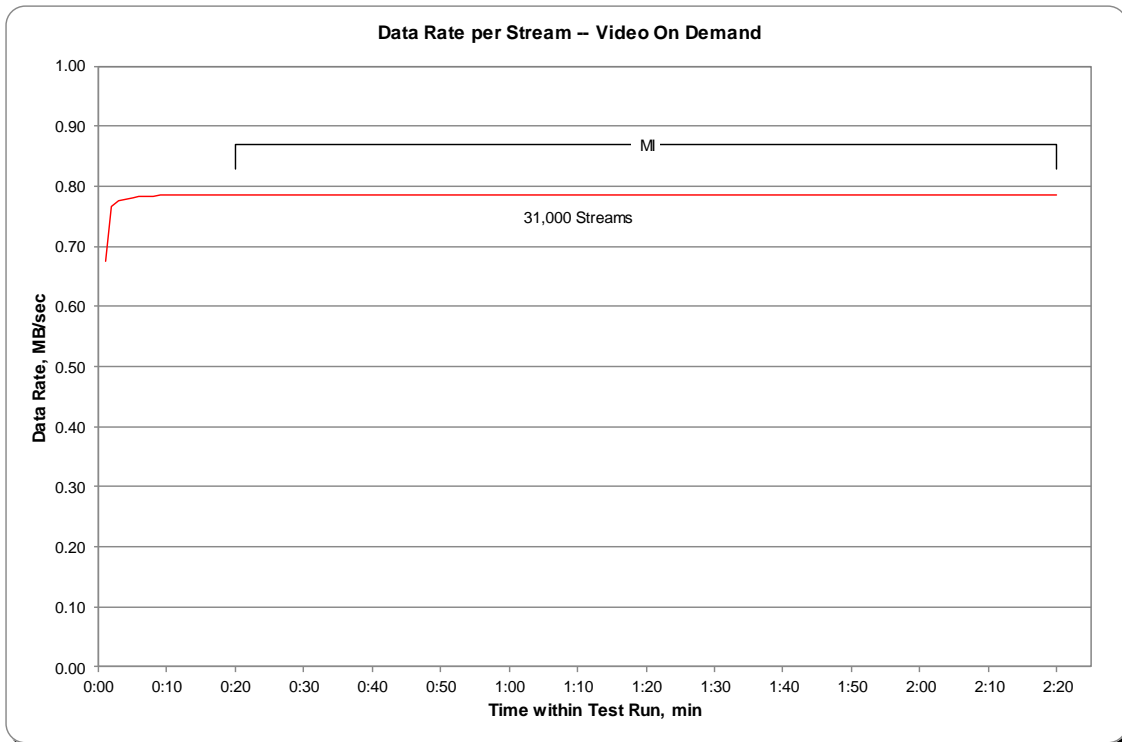


Video on Demand Delivery Test

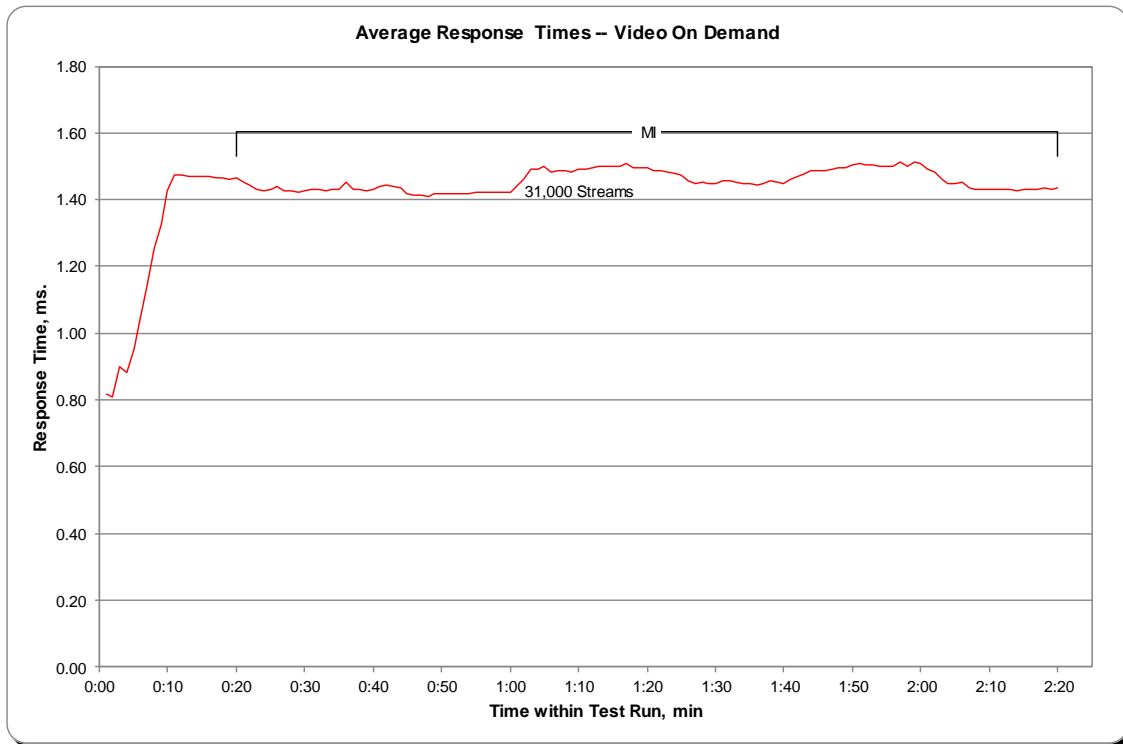
### Average Data Rate Graph



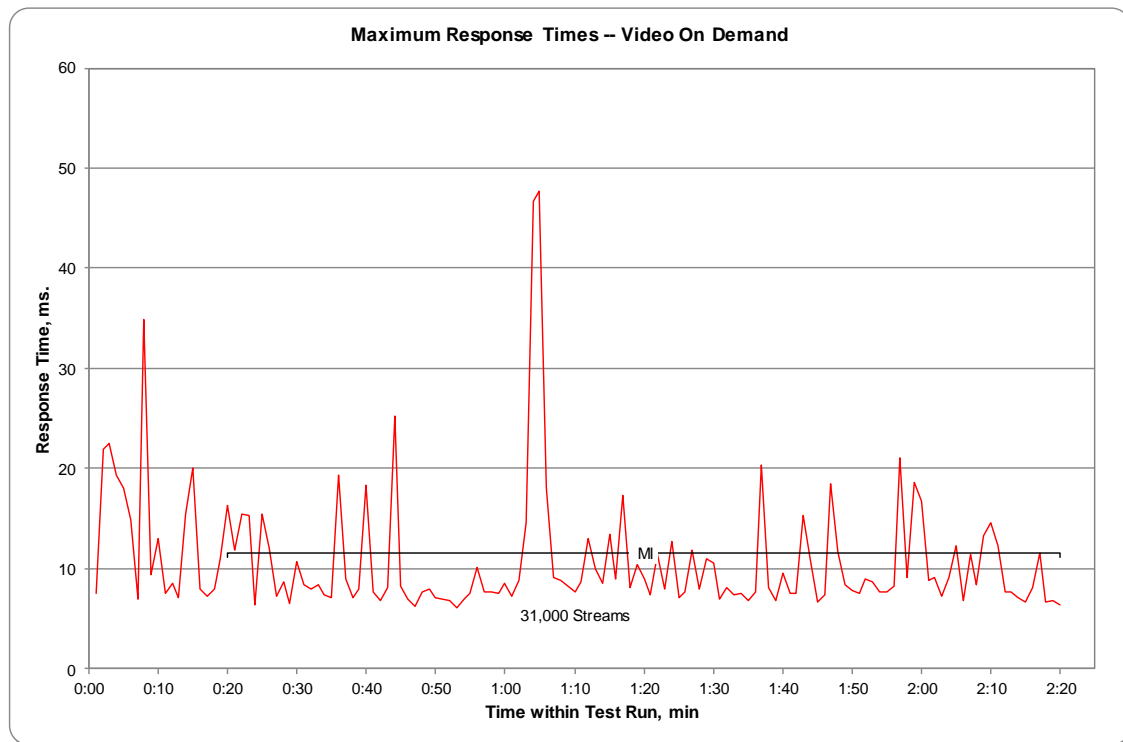
### Average Data Rate per Stream Graph



### Average Response Time Graph



### 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.*

## **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](#).

## **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

**Test Results**

<b>Data Persistence Test Results</b>	
Data Persistence Test Number: 1	
Total Number of Logical Blocks Written	5,381,315
Total Number of Logical Blocks Re-referenced	1,477,517
Total Number of Logical Blocks Verified	3,903,798
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 Oracle ZFS Storage ZS5-2, as documented in this SPC-2 Full Disclosure Report, will be available for customer purchase and shipment on 4/5/2017.

## **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 Audit of the Oracle ZFS Storage ZS5-2.

## 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 gibibyte (GiB) is equal to 1,073,741,824 ( $2^{30}$ ) bytes.
- A tebibyte (TiB) is equal to 1,099,511,627,776 ( $2^{40}$ ) bytes.
- A pebibyte (PiB) is equal to 1,125,899,906,842,624 ( $2^{50}$ ) bytes.
- An exbibyte (EiB) is equal to 1,152,921,504,606,846,967 ( $2^{60}$ ) bytes.

## SPC-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 SPC2 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:  $T_2T_3$  and Test Run 2:  $T_7T_8$* ).

**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:  $T_4T_5$  and Test Run 2:  $T_9T_{10}$* ). 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:  $T_0T_2$  and Test Run 2:  $T_5T_7$* ).

**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:  $T_3T_4$  and Test Run 2:  $T_8T_{10}$* ). 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 RampDown 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.

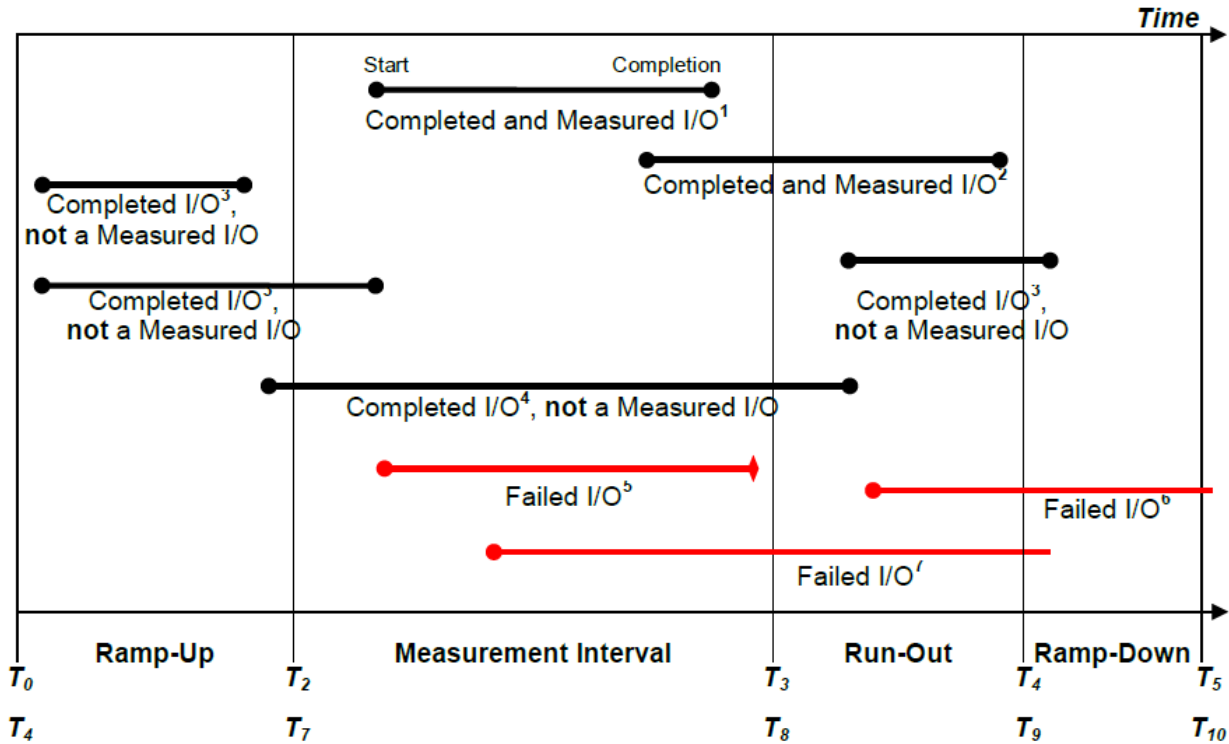
Each of the five Test Runs in a Test Run Sequence will share the same attributes with the exception of the number of Streams. For example:

- 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<sup>1</sup>:** I/O started and completed within the Measurement Interval.

**Completed and Measured I/O<sup>2</sup>:** I/O started within the Measurement Interval and completed within Ramp Down.

**Completed I/O<sup>3</sup>:** I/O started before or after the Measurement Interval – not measured.

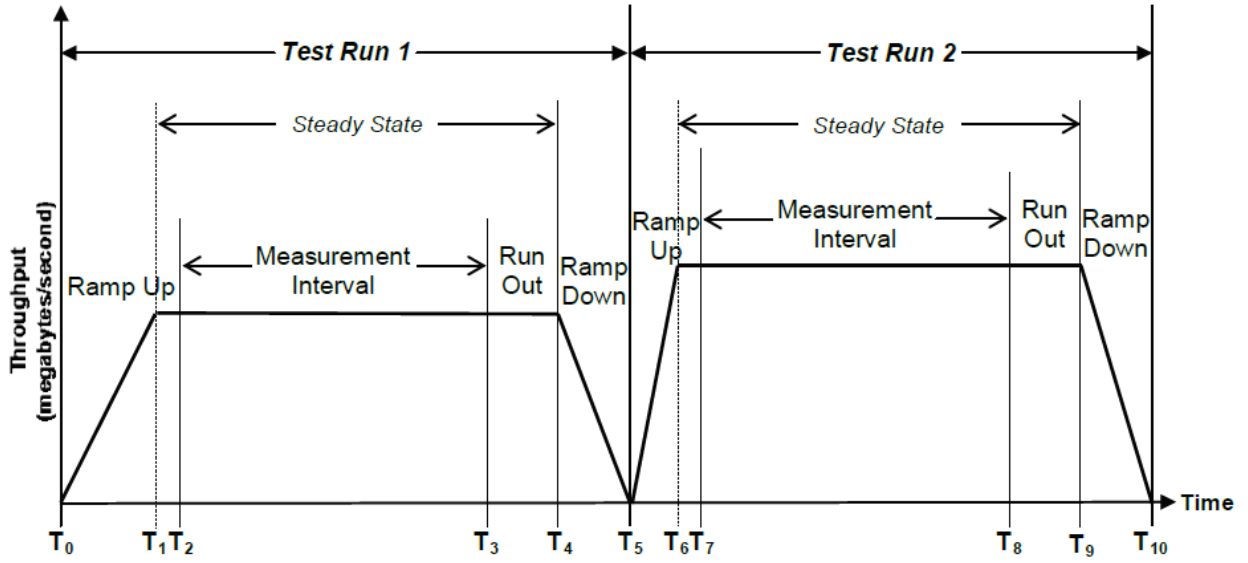
**Completed I/O<sup>4</sup>:** I/O started before and completed after the Measurement Interval – not measured.

**Failed I/O<sup>5</sup>:** Signaled as failed by System Software.

**Failed I/O<sup>6</sup>:** I/O did not complete prior to the end of Ramp-Down.

**Failed I/O<sup>7</sup>:** I/O did not complete prior to the end of Run-Out.

# SPC-2 Test Run Components



## APPENDIX B: CUSTOMER TUNABLE PARAMETERS AND OPTIONS

### Solaris System Parameters

The following Solaris system parameter entries were changed in the `/etc/system` file for each Host System:

```
set sd:sd_max_throttle=8
```

*defines the max queue depth per lun*

# **APPENDIX C: TESTED STORAGE CONFIGURATION CREATION**

## **Assign Host Names and IP Addresses**

The Oracle ZFS Storage ZS5-2 Appliance is shipped with Quick Start instruction that provide details for assigning host names, IP addresses and Clustron cards. The Clustron cards support communication between storage controllers.

## **Configure the Tested Storage Configuration (TSC)**

The Oracle ZFS Storage ZS5-2 Appliance includes two controllers, referenced below as **A** and **C**. The TSC will be configured using the scripts described below, which are performed on the Master Host System via the “root” user. All referenced scripts appear at the end of this section.

## **Build the ZS5-2 Cluster**

The script, [Build-Cluster.sh](#), will invoke scripts to:

- Build RAID pools on each controller 1 per controller
- Create 16 volumes on each pool
- Format and align LUNS
- Create all disk listing and parameter files

## **Build RAID Pools**

The script, [Build 2T 1P.sh](#) will create 2 RAID Mirror Pools per controller Each of the pools is a 36 with 4 spares

## **Create Volumes**

The script, [Build-Vols-2T-Cluster.sh](#), will create 16 volumes on each controller. All 32 volumes are accessible by both controllers.

## **Format and Align LUNs**

The script, [Label-64bit-Multi-Host-spc2e.sh](#), uses [ldq-512.txt](#) and [lfp-512.txt](#) to create SPC-2 parameter files and will create a volume listing from the two controllers in order to format and align the LUNs. In addition, this script is used to create various documentation listings and configuration files used in the benchmark execution.

Text files created by [Label-64bit-Multi-Host-spc2e.sh](#):

- [Cluster HW list.txt](#): Physical hardware list from both controllers of the ZS5-2 cluster
- [Cluster Lun List.txt](#): Logical Volume listing from the cluster
- [disklist.txt](#): Logical volume listing form the master client
- [prvtoc.txt](#): Logical volume prvtoc listing from the master client
- [pre.txt](#): Vdbench parameter file for pre-filling logical volumes
- [spc2-vod.txt](#): SPC-2 VOD parameter file
- [spc2-ldq.txt](#): SPC-2 LDQ parameter file
- [spc2-lfp.txt](#): SPC-2 LFP parameter file
- [spc2-persist1.txt](#): SPC-2 Persist 1 parameter file
- [spc2-persist2.txt](#): SPC-2 Persist 2 parameter file

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

### **ASU Pre-Fill**

Please see [Pre-Fill Params File](#)

### **Large Database Query Test**

Please see [LDQ Params File](#)

### **Large File Processing Test**

Please see [LFP Params File](#)

### **Video on Demand Delivery Test**

Please see [VOD Params File](#)

### **Persistence Test Run 1 (write phase)**

Please see [Persist1 Params File](#)

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

Please see [Persist2 Params File](#)

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

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

The script [run-x52-ssd.sh](#) executes the following:

- Collects various configuration information required for the audit
- The required ASU pre-fill
- The SPC-2 Tests:
  - Large File Processing (LFP)
  - Video on Demand (VOD)
  - Large Database Query (LDQ)
  - SPC-2 Persistence – Test Run 1 (write phase)
- Various housekeeping in support of the test execution

### **Persistence Test Run 2 (read phase)**

The script [run-x52-ssd.sh-P2](#), was invoked to execute SPC-2 Persistence Test Run 2 (read phase) after the required TSC power off/power on cycle.

## **APPENDIX F: THIRD PARTY QUOTATION**

No third party items were used in the Priced Storage Configuration.