



SPC BENCHMARK-1™ (SPC-1)

OFFICIAL SPECIFICATION

Revision 1.10.1 – Effective 27 September 2006

“The First Industry Standard Storage Benchmark”

Storage Performance Council (SPC)

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DOCUMENT HISTORY

<u>Effective Date</u>	<u>Version</u>	<u>Description</u>
9 October 2001	1.0	The first official release of the SPC Benchmark-1™ (SPC-1) specification. Approved unanimously by the SPC membership.
16 October 2001	1.0.1	Editorial changes
01 January 2002	1.1	Editorial changes to 3.2.1 New clause 3.4 (Address Range Selection Function-ARF) Changes to Tables 3.1 and 3.2 based on ARF
29 January 2002	1.2	Revisions to support Offered and Measured Load requirements and constraints
13 March 2002	1.3	Revisions to support “open model” workload – Clause 3 Revision to clarify the use of non-TSC components – (4.1.1) Revisions to clarify Test Phase transitions (5.4.2, 5.4.3) Revision to Ramp Test Run duration (5.4.2.3.2) Revision to delete the BC power cycle requirement in the Repeatability Test (5.4.3.14)
9 July 2002	1.4	Addition of Price-Performance as a primary metric Revisions to ASU-LV Mappings requirements (Approved 8 May 2002)
9 September 2002	1.5	Updated SPC membership list Clarification for republished results – Clause 10.7 Added an FDR revision history – Clause 9.2.4.3.2 Added the Repeatability test data to the FDR – Clause 9.2.4.6.4 Clarification of the Audit – Clause 10 Revision of Remote Audit requirements – Clause 10.6 Various editorial revisions (Approved 11 July 2002)
20 January 2003	1.6	Updated SPC membership list Editorial changes to Clauses 5.3.2, 5.4.2.1.3, 5.4.2.2.8, 5.4.2.3.6 5.4.3.3, 9.2.4.3.5, 9.2.4.7.1, 9.2.4.7.2, 9.2.4.7.3, and 9.2.4.7.4. Clarification of Physical Storage Capacity in and what is included (Clauses 2.2.1 and 2.2.2).

<u>Effective Date</u>	<u>Version</u>	<u>Description</u>
20 January 2003	1.6	<p>Clarification of the roles of SPC-1 Toolkit documentation (Clause 5.3.1).</p> <p>Clarification of terms and test sequencing (Clause 5.4.1) (<i>specification revision approved on 21 November 2002</i>)</p> <p>Clarification of Repeatability Test Phase sequencing (Clause 5.4.3)</p> <p>Revision of Customer Tunable Parameter and Options documentation (Clause 9.2.4.5.1).</p> <p>Added Storage Capacities and Relationships diagram requirement (Clause 9.2.4.6.1).</p> <p>Clarification of the transition from the Sustainability Test Phase to the IOPS Test Phase (5.4.2.2).</p>
20 July 2003	1.7	<p>(<i>Approved 21 May 2003</i>)</p> <p>Addition of Parity (RAID5)/User Data Copy (Mirroring), Required Storage, Global Storage Overhead, and Unused Storage (Clause 2.1, Figure 2-1, Clauses 2.2.3, 2.2.4, and 2.3.2)</p> <p>Clarification of excluded storage (Clause 2.2.5).</p> <p>Change Transfer Alignment from N/A to 8 (Clause 3.5.3, Table 3-3).</p> <p>Require an unchanged Benchmark Configuration between Tests, Test Phases, and Test Runs (Clauses 5.3.3 and 6.3.5).</p> <p>Clarify requirements for documenting logical TSC creation (Clause 9.2.4.5.2).</p> <p>Require disclosure of SPC-1 Workload Generator configuration file (Clause 9.2.4.5.3).</p> <p>Clarified storage capacity reporting (Clauses 9.2.4.3.3, 9.2.4.6.1, and 9.2.4.6.2).</p> <p>Revised to include User Data Copy/Parity, Required Storage, Global Storage Overhead, and Unused Storage (Clause 9.2.4.6.1, Table 9-9).</p> <p>New table to disclose storage ratios (Clause 9.2.4.6.1, Table 9-10).</p>
10 January 2004	1.8.0	<p><i>Approved 29 July 2003</i></p> <p>Revised Figure 2-1 and Clauses 2.2.4, 0, and 2.4.3 to clarify Unused Storage.</p> <p>Revised Figure 9-10 to correspond to the above revised Figure 2-1.</p> <p>Added a new Data Protection Level, Other Protection Level, and renamed Unrestricted to Unprotected (Clause 2.4.5).</p> <p>Revised Clause 9.2.4.3.3, footnote #5 to require a description of the data protection provided when Other Protection Level is selected.</p> <p>Revised Clause 9.2.4.6.1, Table 9-9, and Table 9-10 to report separately any storage capacity used for parity and/or user data copy when Other Protection Level is selected.</p>

<u>Effective Date</u>	<u>Version</u>	<u>Description</u>
		<i>Approved 16 September 2003</i>
		Revised Clause 6.4 so that when specific conditions are met the Test Sponsor is not required to shutdown and power cycle the Host System(s) as a part of the Persistence Test.
		Revised Clause 0.2 to include a definition of 'Test Sponsor'.
		Revised Clauses 9.2.4.2 and 10.6.1 to require specific content and format for the Test Sponsor Letter of Good Faith.
		Revised Appendix D (page 119) from an example to a template for the Letter of Good Faith, consistent with the above revisions to 9.2.4.2 and 10.6.1.
		Revised Clause 8.1 to change 'Benchmarked TSC' to 'TSC' and 'Priced TSC' to Priced Storage Configuration. (TSC=Tested Storage Configuration)
		Added Clauses 9.2.4.3.7 and 9.2.4.11.3 to require the disclosure of any differences between the TSC and Priced Storage Configuration.
		Revised Clause 10.6.9 to verify that any differences between the TSC and Priced Storage Configuration would not result in the Priced Storage Configuration providing less than the reported performance of the TSC.
		Consolidated the disclosure of the Availability Date/Availability into to a single clause by combining the intent of Clauses 9.2.4.9 and 9.2.4.12 into a single clause, 9.2.4.9, and deleting the remaining clause, 9.2.4.12.
		Revised Clause 10.6.10 to require the Auditor review of the Full Disclosure Reports addresses both completeness and accuracy.
		<i>Approved 11 November 2003</i>
		Revised Table 9-13 to document when the Host System is not shutdown and power cycled as part of the Persistence Test.
		Revised Clause 10.6.7 to include the audit requirements when the Host System is not shutdown and power cycled as part of the Persistence Test.
		Revised Clauses 9.2.4.1, 9.2.4.3.7, and 9.4 to clarify the disclosure requirements for revisions to an existing FDR.
		New Clause 10.8 to clarify the requirements when a revised FDR results in component changes to the original Priced Storage Configuration.
		Revised Clause 10.3 to include a Peer Review of revisions to an existing FDR.
		New Clause 9.2.4.3.5 to include Table 9-9: SPC-1 Storage Capacities in the Executive Summary.

<u>Effective Date</u>	<u>Version</u>	<u>Description</u>
13 March 2005	1.9.0	<p><i>Approved 12 January 2005</i></p> <p>Revised Clause 3.1.3 to define “decimal” (<i>powers of ten</i>) and “binary” (<i>powers of two</i>) measurement units.</p> <p>Revised Transfer Alignment in Table 3.2 to be 8 (<i>512 byte blocks</i>) rather than 16 (<i>512 byte blocks</i>).</p> <p>Added the specific unit of measure for Transfer Alignment and Transfer Size in Table 3.1, 3.2, and 3.3</p> <p>New Clause 4.3.2.3 to allow System Software to provide RAID 0 (striping) and/or data protection functionality to the TSC.</p> <p>Revised Clause 4.3.2.4 to explicitly exclude caching/pre-fetching by System Software.</p> <p>Revised 4.5.1, describing the conditions that cause a Host System to become a priced TSC component.</p> <p>Revised Clause 4.5.2 to clarify the use of multiple, independent storage subsystem configurations.</p> <p>Revised Clauses 9.2.4.4.1 and 9.2.4.4.2 to remove the requirement for a separate storage network diagram if sufficient detail is provided in the BC configuration.</p> <p>New Clause 4.6.8, which excludes the use of all file system functionality rather than just file cache functionality.</p> <p>Various revisions to Clause 4 to more clearly describe Benchmark Configuration, Tested Storage Configuration, Host System(s), and System Software.</p> <p>Revised Clause 5.3.3 to clarify that the Benchmark Configuration is to remain unchanged across Tests, Test Phases, and Test Runs.</p> <p>Revised Clause 5.4.2 and added Clause 5.4.3 to require a specific, uninterrupted SPC-1 Test sequence.</p> <p>Revised Clauses 5.4.3, 5.4.3.2.12, 5.4.3.3.9, 5.4.3.3.10, 5.4.4, and 5.4.4.1 in support of the above requirement.</p> <p>Revised Clause 9.2.4.7.1 to require the FDR contain a Response Time Frequency Distribution graph and table as well as an Average Response Time Distribution graph and table.</p> <p>Revised Clauses 4.5.1, 8.1.1.2, and 8.1.2 to clarify when a Host System is included as a priced TSC component, specifically with regards to Logical Volume Manager functionality.</p>

<u>Effective Date</u>	<u>Version</u>	<u>Description</u>
19 March 2006	1.10.0	<p><i>Approved 18 January 2006</i></p> <p>Revised Clause 8.1.1.2 to remove the requirement for pricing maintenance for HBAs included in the Priced Storage Configuration.</p> <p>Revised Clause 9.2.4.9 to all the use of “Currently Available” for the SPC-1 Availability Date in the case where all components that comprise the Priced Storage Configuration are currently available for customer order and shipment.</p> <p>Revise Clause 4.3 and add Clause 4.6 to introduce and define the term “Tested Storage Product”, which will become the focal point of SPC-1 results and the source of labeling for each result.</p> <p>Added Clauses 4.6.1 and 4.6.2 to define two categories of SPC-1 results based on the absence or presence of all storage devices as a standard part of the Tested Storage Product.</p> <p>Revised Clause 4.5.1 to be consistent with the introduction of a Tested Storage Product as the focal point for each SPC-1 result.</p> <p>Added Clause 7.2.6 to require statement of the appropriate TSP category when there is a public reference to a specific SPC-1 result.</p> <p>Revised Clause 9.2.3 to use the formal TSP name on the FDR title page rather than the TSC name.</p> <p>Revised Clause 9.2.4.3.3 and Table 9.8 to include an entry for the appropriate TSC category value.</p>
27 September 2006	1.10.1	<p><i>Approved 27 September 2006</i></p> <p>Revised Clauses 4.6.1 and 4.6.2 to clarify the SPC-1 Results categorization requirements.</p> <p>Added Clause 9.2.4.3.3 to require a brief description of the Tested Storage Product in the Executive Summary.</p>

Table of Contents

CLAUSE 0 : INTRODUCTION	11
0.1 PREAMBLE.....	11
0.2 GENERAL GUIDELINES.....	12
0.3 MEASUREMENT GUIDELINES	14
0.4 DISCLAIMER.....	14
0.5 SPC BENCHMARK SERIES	14
CLAUSE 1 : WORKLOAD ENVIRONMENT.....	15
1.1 BUSINESS AND APPLICATION ENVIRONMENT	15
1.2 HIGH-LEVEL WORKLOAD MODEL.....	15
CLAUSE 2 : DATA REPOSITORY.....	16
2.1 SPC-1 STORAGE HIERARCHY	16
2.2 PHYSICAL STORAGE CAPACITY (PSC).....	16
2.3 CONFIGURED STORAGE CAPACITY (CSC)	17
2.4 ADDRESSABLE STORAGE CAPACITY (ASC)	17
2.5 LOGICAL VOLUMES (LV)	18
2.6 APPLICATION STORAGE UNITS (ASUS)	19
CLAUSE 3 : WORKLOAD AND I/O OPERATION PROFILE	21
3.1 DEFINITIONS.....	21
3.2 SPC-1 WORKLOAD.....	22
3.3 SPC-1 PARAMETER TYPES	22
3.4 SPC-1 WORKLOAD PARAMETERS	25
3.5 TECHNICAL WORKLOAD DESCRIPTION.....	28
CLAUSE 4 : BENCHMARK CONFIGURATION (BC), TESTED STORAGE CONFIGURATION (TSC), AND WORKLOAD GENERATOR.....	32
4.1 OVERVIEW.....	32
4.2 BENCHMARK CONFIGURATION COMPONENT AVAILABILITY AND SUPPORT	32
4.3 BENCHMARK CONFIGURATION COMPONENTS	32
4.4 BENCHMARK CONFIGURATION (BC) EXAMPLES	33
4.5 TESTED STORAGE CONFIGURATION (TSC)	34
4.6 TESTED STORAGE PRODUCT (TSP)	39
4.7 SPC-1 WORKLOAD GENERATOR.....	40
CLAUSE 5 : TEST MEASUREMENT REQUIREMENTS (EXECUTION RULES).....	46
5.1 SUPPORTING DEFINITIONS.....	46
5.2 SYSTEM SCALING	48
5.3 REQUIREMENTS AND CONSTRAINTS	49
5.4 SPC-1 PERFORMANCE TESTS.....	51
CLAUSE 6 : DATA PERSISTENCE REQUIREMENTS AND TEST.....	61
6.1 INTRODUCTION	61
6.2 PERSISTENCE TEST VALIDATION.....	61
6.3 SPC-1 PERSISTENCE TEST CONSTRAINTS	61
6.4 DATA PERSISTENCE TEST PROCEDURE	61
CLAUSE 7 : REPORTED METRICS	63
7.1 SPC-1 PRICE-PERFORMANCE	63

7.2	PRIMARY METRICS REQUIREMENTS	63
7.3	ADDITIONAL METRICS REQUIREMENTS	64
CLAUSE 8 : PRICING	65	
8.1	PRICED COMPONENTS	65
8.2	PRICING METHODOLOGY	66
8.3	REQUIRED REPORTING.....	68
CLAUSE 9 : FULL DISCLOSURE	70	
9.1	SUPPORTING DEFINITIONS.....	70
9.2	FULL DISCLOSURE REPORT (FDR) REQUIREMENTS	79
9.3	AVAILABILITY OF THE FULL DISCLOSURE REPORT	95
9.4	REVISIONS TO A PREVIOUSLY SUBMITTED FDR.....	95
CLAUSE 10 : AUDIT & RESULTS SUBMISSION.....	97	
10.1	INTRODUCTION.....	97
10.2	SPC-1 RESULT VALIDATION.....	97
10.3	PEER REVIEW.....	98
10.4	AUDIT	98
10.5	AUDIT METHODS	100
10.6	AUDIT PROCEDURES	100
10.7	REPUBLISHING AN SPC-1 BENCHMARK RESULT	104
10.8	COMPONENT SUBSTITUTION IN A REVISED FDR	104
Appendix A: Example Results File.....	105	
Appendix B: Example Persistence Test Results File	110	
Appendix C: Example Summary Results File	111	
Appendix D: Letter of Good Faith Template	119	
Appendix E: The Hierarchical Reuse Random Walk	120	
Appendix F: References.....	121	

Table of Figures

Figure 2-1: SPC-1 Storage Hierarchy	16
Figure 2-2: Sample ASU-to-Logical Volume Address Mappings	19
Figure 4-1: Sample BC Configurations – Direct Attach Storage Controller	33
Figure 4-2: Sample Configurations – Network Storage	34
Figure 4-3: Embedded or External Controller – External Storage Devices	36
Figure 4-4: Embedded Storage Controller – Embedded Storage Devices.....	37
Figure 4-5: Network Storage –External Storage Controller and Storage Devices	38
Figure 4-6: Workload Generator Functional Components	40
Figure 4-7: Workload Generator Components, I/O Streams and ASUs.....	41
Figure 4-8: ASU Relationship To Multiple Hosts	43
Figure 4-9: Multi-Host Workload Requirements	43
Figure 4-10: Measurement Boundary.....	44
Figure 4-11: Measurement Boundary in an UNIX System Implementation.....	45
Figure 5-1: Sample Test Run	47
Figure 5-2: I/O Completion Types	48
Figure 5-3: Key SPC-1 Test Objectives.....	51
Figure 5-4: Summary of SPC-1 Tests	53
Figure 5-5: Sustainability Test Phase	55
Figure 5-6: Sustainability & IOPS Test Phases	56
Figure 5-7: Primary Metrics Test.....	58
Figure 5-8: Repeatability Test.....	60
Figure 9-1: Response Time Frequency Distribution (by occurrence)	70
Figure 9-2: I/O Request Throughput Distribution.....	72
Figure 9-3: Average Response Time Distribution.....	73
Figure 9-4: Data Rate Distribution	74
Figure 9-5: Response Time Ramp Distribution	76
Figure 9-6: Response Time/Throughput Function.....	77
Figure 9-7: Simple Response Time Throughput Curve	78
Figure 9-8: BC/TSC Configuration Diagram.....	85
Figure 9-9: Storage Network Configuration Diagram.....	87
Figure 9-10: SPC-1 Storage Capacities and Relationships	90
Figure 10-1: Creation and Submission of SPC-1 Results.....	97

Table of Tables

Table 3-1: ASU 1 Parameter Types and Values.....	30
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Table 3-2: ASU 2 Parameter Types and Values.....	30
Table 3-3: ASU 3 Parameter Types and Values.....	31
Table 9-1: Response Time Frequency Distribution	71
Table 9-2: I/O Request Throughput Distribution	71
Table 9-3: Average Response Time Distribution	73
Table 9-4: Data Rate Distribution	75
Table 9-5: Response Time Ramp Distribution	78
Table 9-6: Test Sponsor and Contact Information.....	80
Table 9-7: Revision Information and Key Dates.....	81
Table 9-8: Summary of Results	82
Table 9-9: SPC-1 Storage Capacities.....	89
Table 9-10: SPC-1 Storage Hierarchy Ratios.....	90
Table 9-11: Logical Volume Capacity and ASU Mapping	91
Table 9-12: Repeatability Test Results	93
Table 9-13: Data Persistence Test Results	94

Clause 0: Introduction

0.1 Preamble

The SPC Benchmark-1™ (SPC-1) is a sophisticated performance measurement workload for storage subsystems. The benchmark simulates the demands placed upon on-line, non-volatile storage in a typical server class computer system. SPC-1 provides measurements in support of real world environments characterized by:

- Demanding total I/O throughput requirements.
- Sensitive I/O response time constraints.
- Dynamic workload behaviors.
- Substantial storage capacity requirements.
- Diverse user populations and expectations.
- Data persistence requirements to ensure preservation of data without corruption or loss.

SPC-1 is designed as a source of comparative storage subsystem performance information. It is intended to provide value throughout the storage product lifecycle (e.g. development of product requirements; product implementation; performance tuning; capacity planning, market positioning; and purchase evaluations).

In view of the broad applicability of the SPC-1 benchmark, it is anticipated that readers may wish to approach the present document via a variety of starting points. For example:

- Readers who need only a quick overview of the benchmark itself can obtain one by examining Clause 1 (broad introduction to the benchmark structure) and Table 3-1, Table 3-2, and Table 3-3 (the I/O workload characteristics presented in tabular form).
- Readers who wish a detailed understanding of the benchmark should, in addition, consult Clause 2 (organization of storage), Clause 3 (organization of I/O), and Clause 4 (benchmark usage in specific configurations).
- Readers who are examining or referring to test results obtained by running the SPC-1 benchmark should minimally examine Clause 7 (reported metrics). Clause 5 (execution rules) is also recommended for such readers.
- Readers who wish to actually run an SPC-1 benchmark test should minimally examine Clause 2, Clause 5, and Clause 7.
- Finally, readers who wish to submit SPC-1 benchmark results for posting by the SPC must read the entire SPC-1 specification to ensure compliance with its provisions.

The SPC-1 specification is intended to be vendor and platform independent. Any vendor should be able to sponsor and publish an SPC-1 benchmark, provided their tested configuration satisfies the performance, integrity, and availability requirements of the specification. Further, the benchmark is intended to be meaningful across a broad range of system configurations and storage topologies including:

- *Different storage components*: the specification allows virtually any combination of storage technologies in a system configuration. Implementers are free to use any combination of storage types and to select the level of redundancy and reliability that best showcases their solution.
- *Various interconnect topologies*: the benchmark has been designed to allow for all forms of system and network interconnection. New network-based solutions (i.e., SANs) and more traditional host-based systems can both produce accurate and meaningful benchmark results.
- *Varied task assignments*: SPC-1 allows vendors to optimally demonstrate the performance features of their storage solutions. In addition and regardless of implementation choices, SPC-1 will provide a means of robust and reliable performance verification.
- *Adaptive scheduling, caching and resource allocation*: By relying on a diverse and sophisticated model of the storage workload that systems will encounter in the field, SPC-1 will provide a fair evaluation of the quality of automated performance optimization algorithms throughout the storage subsystem.

Rather than requiring or favoring a particular implementation, it is the goal of the SPC-1 benchmark specification to provide a robust, verifiable, reproducible environment within which the relative strengths of differing design and configuration approaches can be evaluated.

0.2 General Guidelines

The purpose of SPC benchmarks is to provide objective, relevant, and verifiable data to purchasers of I/O subsystems. To that end, SPC specifications require that benchmark tests be implemented with system platforms and products that:

1. Are generally available to users.
2. A significant percentage of the users in the target market segment (server class systems) would implement.
3. Are relevant to the market segment that SPC-1 benchmark represents.

In addition, all SPC benchmark results are required to be sponsored by a distinctly identifiable entity, which is referred to as the Test Sponsor. The Test Sponsor is responsible for the submission of all required SPC benchmark results and materials. The Test Sponsor is responsible for the completeness, accuracy, and authenticity of those submitted results and materials as attested to in the required Letter of Good Faith (see Appendix D). A Test Sponsor is not required to be a SPC member and may be an individual, company, or organization.

The use of new systems, products, technologies (hardware or software) and pricing is encouraged so long as they meet the requirements above. Specifically prohibited are benchmark systems, products, pricing (hereafter referred to as "implementations") whose primary purpose is performance optimization of SPC benchmark results without any corresponding applicability to real-world applications and environments. In other words, all "benchmark specials," implementations that improve benchmark results but not general, real-world performance are prohibited.

The following characteristics should be used as a guide to judge whether a particular implementation is a “benchmark special”. It is not required that each point below be met, but that the cumulative weight of the evidence be considered to identify an unacceptable implementation. Absolute certainty or certainty beyond a reasonable doubt is not required to make a judgment on this complex issue. The question that must be answered is this: based on the available evidence, does the clear preponderance (the greater share or weight) of evidence indicate that this implementation is a “benchmark special”?

The following characteristics should be used to judge whether a particular implementation is a benchmark special:

- Is the implementation generally available, documented, and supported?
- Does the implementation have significant restrictions on its use or applicability that limits its use beyond SPC benchmarks?
- Is the implementation or part of the implementation poorly integrated into the larger product?
- Does the implementation take special advantage of the limited nature of SPC benchmarks (e.g., I/O Request profile, I/O Request mix, I/O Request concurrency and/or resource contention) in a manner that would not be generally applicable to the environment the benchmark represents?
- Is the use of the implementation discouraged by the vendor? (This includes failing to promote the implementation in a manner similar to the Test Sponsor’s other products and technologies.)
- Does the implementation require uncommon sophistication on the part of the end-user, programmer, or system administrator?
- Is the packaging or pricing unusual or non-customary for the vendor or unusual or non-customary to normal business practices? The following pricing practices are suspect:
 - Availability of a discount to a small subset of possible customers.
 - Discounts documented in an unusual or non-customary manner.
 - Pricing featured as a close-out or one-time special.
 - Unusual or non-customary restrictions on transferability of product, warranty or maintenance on discounted items.
- Is the implementation being commonly used or purchased by a majority of end-users in the market area the benchmark represents? If the implementation is not currently being used by end-users, is there any evidence to indicate that it will be used by a significant number of users?

To assure the equitable application of this standard, the SPC has created a robust system of audit and peer review. It is the goal of the SPC to assure that only those results, which represent accurate and meaningful product performance, will be endorsed as official SPC results.

0.3 Measurement Guidelines

SPC benchmark results are expected to be accurate representations of subsystem performance. Therefore, stringent measurement, auditing, and reporting guidelines are mandated by this specification. In general, fidelity and candor must be maintained in reporting any anomalies in the results, even if not specified in the benchmark requirements.

More detailed measurement, evaluation and disclosure requirements can be found in the body of the specification.

0.4 Disclaimer

While this workload models a rich multi-user environment that emulates a broad range of server applications, it neither represents the entire range of I/O requirements for server systems nor precisely mimics any particular application. In addition, the extent to which anyone is capable of achieving the results reported by a vendor is highly dependent upon how closely the customer's application maps to the SPC-1 workload. The extrapolation of SPC-1 results to other environments is therefore not recommended.

Actual system performance is highly dependent upon specific workload characteristics, platform configuration, and application-specific tuning. Relative system performance will vary as a result of these and other factors. Thus, SPC-1 should not be used as a substitute for customer application benchmarking when critical performance requirements are called for.

SPC-1 uses terminology and metrics that are similar to other benchmarks. This similarity does not imply that results from this benchmark are comparable with other benchmarks.

0.5 SPC Benchmark Series

SPC-1 is the first of a series of storage oriented system benchmarks. It utilizes a framework within which all SPC benchmarks will operate. SPC-1 is the first instantiation of a benchmark within the SPC framework.

Clause 1: Workload Environment

1.1 Business and Application Environment

SPC-1 is comprised of a set of I/O operations designed to demonstrate the performance of a storage subsystem while performing the typical functions of a business critical application. SPC-1 represents a segment of applications characterized by predominately random I/O operations and requiring both queries as well as update operations (for example: OLTP systems, database systems, or mail server applications).

1.2 High-Level Workload Model

The segment of applications represented by SPC-1 covers a broad range of user profiles, business functions and system configurations. Since the focus of SPC-1 is on the commonalities of those applications (e.g., high reliance on stored data, multi-user access, etc.), it was necessary to develop a model that would simplify the workload to the point that highlighted the similarities of its business segment while removing any conflicts and details that weren't central to performance evaluation. The model used in SPC-1 has two central scaling components:

- Business Scaling Units (BSUs)
- Application Storage Units (ASUs)

1.2.1 Business Scaling Units (BSUs)

Business Scaling Units (BSUs) are the benchmark's representation of an application's user population. Each BSU represents the aggregate IO load created by a specified number of users. By focusing the benchmark on this aggregated IO load, SPC-1 is able to provide a scalable stimulus for the tested system that will provide a broad test of the storage configuration without getting lost in the detail that would be necessary for the accurate modeling of any one application. The result will be a workload that will retain its relevance across many generations of a particular application and through a broad spectrum of possible applications.

SPC-1 will be scaled by increasing or decreasing the number of BSUs. A more detailed technical description of BSUs may be found in Clause 4.

1.2.2 Application Storage Units (ASUs)

In the same way that the BSU generalizes the IO load presented to a tested system by an application, Application Storage Units (ASUs) are used to abstract the storage configuration that must respond to that IO load. An ASU is the logical entity identified by the application as the destination or source of data that requires persistence beyond the execution of the application. If the BSU can be thought of as the source of the benchmark workload, then the ASU becomes the sink, providing the logical environment in which the abstracted workload is run.

An ASU represents an abstraction of storage media and does not require a particular physical implementation. The physical implementation is determined by the Test Sponsor and must meet the storage configuration requirements stated in Clause 3.1.1. See Clause 4.3 for examples of supported configurations.

Clause 2: Data Repository

2.1 SPC-1 Storage Hierarchy

The SPC-1 data repository segments storage components into five distinct roles:

- Physical Storage Capacity (PSC) defined in Clause 2.2.
- Configured Storage Capacity (CSC) defined in Clause 2.3.
- Addressable Storage Capacity (ASC) defined in Clause 2.4.
- Logical Volumes (LV) defined in Clause 2.5.
- Application Storage Unit (ASU) Capacity defined in Clause 2.6.

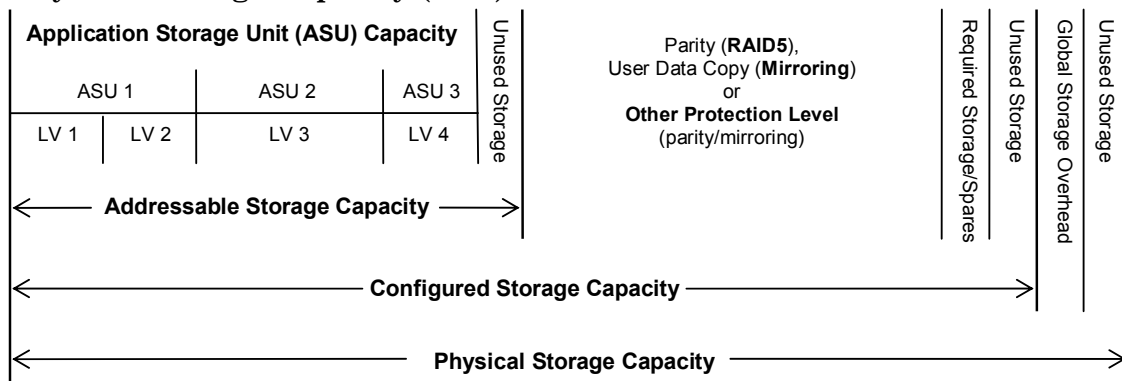
The relationship between the different storage capacities is illustrated in Figure 2-1.

Included in the above storage capacities are:

- Parity (RAID5 or Other Protection Level) and/or User Data Copy (Mirroring or Other Protection Level) defined in Clause 2.4.5.
- Required Storage/Spares defined in Clause 0.
- Global Storage Overhead defined in Clause 2.2.3.
- Unused Storage defined in Clauses 2.2.4, 0, and 2.4.3.

Figure 2-1: SPC-1 Storage Hierarchy

2.2 Physical Storage Capacity (PSC)



- 2.2.1 Physical Storage Capacity is the formatted capacity of all Storage Devices that are physically present in the Tested Storage Configuration.
- 2.2.2 All physical storage present in the TSC must be included in Physical Storage Capacity, whether or not it is cabled in or powered up.
- 2.2.3 Global Storage Overhead consists of the Physical Storage Capacity that is required for storage subsystem use, such as metadata, and unavailable for use by application programs such as the SPC-1 Workload Generator.

2.2.4 Unused Storage consists of the Physical Storage Capacity available for use but not included in the Required Storage/Spares, Parity/User Data Copy/Other Protection Level, Addressable Storage Capacity and Unused Storage described in Clauses 2.3.2 and 2.4.3.

2.2.5 Physical Storage Capacity excludes any storage, with the exception of Global Storage Overhead, that cannot be configured for use by the benchmark.

***Comment:** The intent of this clause is to accurately disclose the physical storage that could be configured for use by the benchmark or general purpose programs. For example, this would exclude the difference between unformatted and formatted storage or storage devices that have failed.*

2.2.6 Physical Storage Capacity must be greater than or equal to Configured Storage Capacity.

2.3 Configured Storage Capacity (CSC)

2.3.1 Configured Storage includes the Addressable Storage Capacity and any other storage devices or components of storage devices necessary to implement the Addressable Storage Capacity described in Clause 2.4 (example: hot spares, parity disks, journal disks, log disks, etc.)

Unused Storage consists of the portion of Configured Storage Capacity available for use but not included in Required Storage/Spares, Parity/User Data Copy/Other Protection Level, Addressable Storage Capacity, and the Unused Storage described in Clause 2.4.3.

2.3.2 Required Storage/Spares consists of:

- **RAID5:** The amount of Configured Storage Capacity required to implement the Addressable Storage Capacity, excluding the storage required for the three ASUs and parity.
- **Mirroring:** The amount of Configured Storage Capacity required to implement the Addressable Storage Capacity, excluding the storage required for the three ASUs and User Data Copies.
- **Other Protection Level:** The amount of Configured Storage Capacity required to implement the Addressable Storage Capacity, excluding the storage required for the three ASUs, parity, and User Data Copies.
- **Unprotected:** The amount of Configured Storage Capacity required to implement the Addressable Storage Configuration, excluding the storage required for the three ASUs.

Examples of Required Storage include storage for metadata, required or optionally selected spares, etc. See Clause 2.4.4 for the definitions of **RAID5**, **Mirroring**, **Other Protection Level**, and **Unprotected** as used in this benchmark.

2.3.3 Configured Storage Capacity must be equal to or greater than Addressable Storage Capacity.

2.4 Addressable Storage Capacity (ASC)

2.4.1 Addressable Storage Capacity represents the total storage that can be read and written by application programs on Host Systems and thus, is directly available for use by application programs that implement this benchmark.

2.4.2 Addressable Storage Capacity excludes any portion of the Configured Storage that is not available for use by an application program on Host Systems in the Benchmark Configuration.

***Comment:** The intent of this clause is to accurately disclose the storage that was configured for direct use by the benchmark as well as represent the amount of storage available for application use. For example, this would exclude the difference between the storage capacity used for storage management and not available for application use.*

- 2.4.3 Unused Storage is the difference between Addressable Storage Capacity and ASU Storage Capacity if they are not equal. This difference is counted twice if the Addressable Storage Capacity is mirrored.
- 2.4.4 Addressable Storage Capacity must be less than or equal to the Configured Storage Capacity.
- 2.4.5 Addressable Storage Capacity shall employ one of the following four data protection levels:
1. **RAID5:** User data is distributed across the disks in the array. Check data corresponding to user data is distributed across multiple disks in the form of bit-by-bit parity [\[Massiglia97\]](#).
 2. **Mirroring:** Two or more identical copies of user data are maintained on separate disks [\[Massiglia97\]](#).
 3. **Other Protection Level:** Any data protection other than **RAID5** or **Mirroring**.
 4. **Unprotected:** There is no data protection provided.

Selection of **RAID5**, **Mirroring**, or **Other Protection Level** as the level of data protection will require the same level of data protection for all three Application Storage Units (ASUs). Selection of **Unprotected** as the level of data protection will not require each ASU to use the same level of data protection.

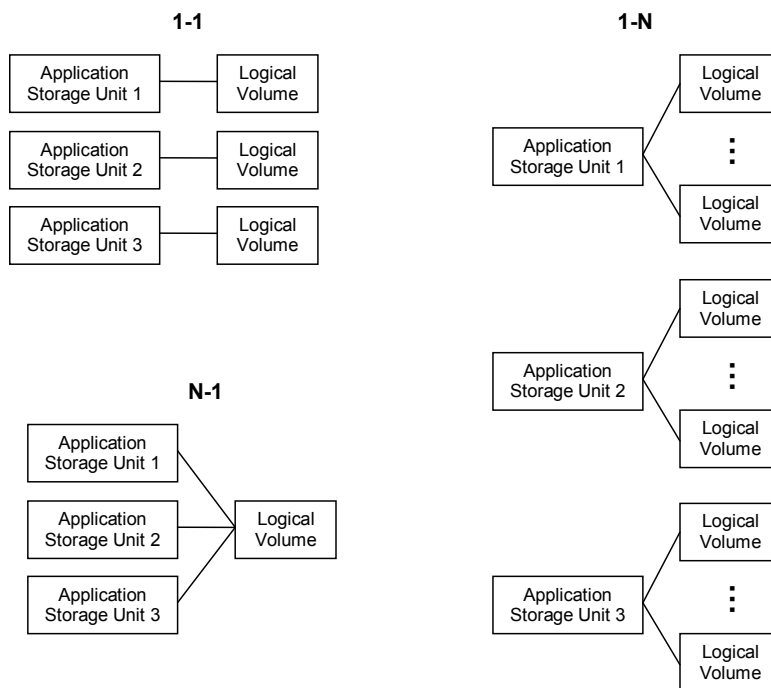
2.5 Logical Volumes (LV)

- 2.5.1 Logical Volumes (LV) represent the division of Addressable Storage Capacity into individually addressable logical units of storage used in the SPC-1 benchmark. Each Logical Volume must be implemented as a single contiguous address space.
- 2.5.2 Addressable Storage Capacity may contain one or more Logical Volumes.
- 2.5.3 The total capacity of all Logical volumes is equal to the Addressable Storage Capacity.
- 2.5.4 Examples of Logical Volumes include:
- A single physical disk drive.
 - A partition on a single physical disk drive.
 - Multiple disk drives configured in an array.
 - A single logical partition on a multi-drive array.
 - Multiple, non-contiguous segments of one or more physical disk drives.
 - A virtual disk accessed via a Storage Area Network (SAN).
 - A RAM disk.
 - A hierarchy of any of the above.

2.6 Application Storage Units (ASUs)

2.6.1 An Application Storage Unit (ASU) represents a logical interface between the Data Repository and the host-based programs that implement this benchmark and provide the persistent non-volatile storage (see Clause 6) read and written in the course of executing the benchmark. All Logical Volume to ASU mappings are permissible provided they satisfy the requirements in Clauses 2.6.3 through **Error! Reference source not found.** See Figure 2-2 for some example mappings.

Figure 2-2: Sample ASU-to-Logical Volume Address Mappings



2.6.2 Each ASU must be contained in a unique address space that is addressable by the workload generator as a contiguous set of logical blocks numbered from zero (0).

2.6.3 If an ASU is implemented on more than one Logical Volume, each Logical Volume must be of equal size.

2.6.4 If an ASU is implemented on multiple Logical Volumes and the size of the ASU is smaller than the combined Logical Volumes, the ASU will be evenly distributed across the Logical Volumes.

2.6.5 In the case of an ASU that is mapped to multiple Logical Volumes, the address mapping is a simple concatenation of volumes, within the constraint of Clause 2.6.4.

2.6.6 ASU Capacity consists of the Logical Volume storage capacity used to implement the required ASUs. If any portion of a Logical Volume is not utilized by any ASU, that portion of Logical Volume storage is not included in the ASU Capacity and is considered Unused Storage.

2.6.7 Total ASU Capacity must be less than or equal to total Logical Volume storage capacity.

2.6.8 SPC-1 defines three ASUs:

- The **Data Store** (ASU-1) holds raw incoming data for the application system. As the application system processes the data it may temporarily remain in the data store, be transferred to the user store, or be deleted. The workload profile for the Data Store is defined in Clause 3.5.1. ASU-1 will hold 45% of the total ASU Capacity.
- The **User Store** (ASU-2) holds information processed by the application system and is stored in a self-consistent, secure, and organized state. The information is principally obtained from the data store, but may also consist of information created by the application or its users in the course of processing. Its workload profile for the User Store is defined in Clause 3.5.2. ASU-2 will hold 45% of the total ASU Capacity.
- The **Log** (ASU-3) contains files written by the application system for the purpose of protecting the integrity of data and information the application system maintains in the Data and User stores. The workload profile for the Log is sequential and is defined in Clause 3.5.3. ASU-3 will hold 10% of the total ASU Capacity.

Clause 3: Workload and I/O Operation Profile

3.1 Definitions

Although many parameters associated with an I/O workload are self-explanatory, there are several that are subject to interpretation, particularly when the intent of SPC-1 is to support multiple operating systems and hardware platforms. For this reason, some preliminary definitions are needed to avoid ambiguity and/or confusion. It should be noted that the scope of these definitions is limited to SPC-1.

3.1.1 Logical Block

A logical block is the smallest directly addressable unit of storage on the ASU. It is a fixed quantity of 512 bytes. For an ASU with a block size of b and a capacity of n logical blocks, the capacity in bytes is equal to the product of b and n .

3.1.2 Logical Block Address (LBA)

The logical block address (LBA), which is sometime known as the logical block number (LBN), specifies the absolute address of a logical block on an ASU. For an ASU with a capacity of n logical blocks, it is a discrete value that ranges from a value of 0 (zero) for the first logical block on the ASU to a high of $n-1$ for the last logical block on the ASU.

3.1.3 Measurement Units

3.1.3.1 “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 these terms are defined in powers of 10. Specifically:

- 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.

3.1.3.2 “Binary” (powers of two) Measurement Units

The sizes reported by many operating system components use “power of two” measurements units rather than “power of ten” units. The following standardized definitions and terms are also valid and may be used in this specification.

- 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.
- A exbibyte (EiB) is equal to 1,152,921,504,606,846,967 (2^{60}) bytes.

3.2 SPC-1 Workload

SPC-1 is comprised of several distinct components, layered from highest to lowest level as follows:

- **SPC-1 Workload:** Three Application Storage Units.
- **Application Storage Unit Stream:** Eight *I/O Streams*.
- **I/O Stream:** A single, well-defined, sequence of *I/O Commands*.
- **I/O Command or I/O Request:** A single atomic unit of work to an Application Storage Unit.

3.2.1 SPC-1 Workload

The SPC-1 workload consists of three Application Storage Unit streams and represents the entire I/O workload.

3.2.2 Application Storage Unit (ASU) Stream

An Application Storage Unit stream consists of one or more I/O streams, and completely defines the I/O sent to a given ASU.

3.2.3 I/O Stream

An I/O stream consists of a sequence of one or more I/O commands. This I/O stream is initiated at a specific point during the I/O workload, and has a specific life. The sequence of individual commands within the I/O stream is fully defined by the workload parameters associated with the SPC-1 workload. One definition is required for each I/O stream contained in the SPC-1 workload, and is sufficient to characterize every I/O associated with that I/O stream.

3.2.4 I/O Command or I/O Request

An I/O command (or I/O Request) is the lowest level in the SPC-1 workload hierarchy. It completely defines a single command that transfers data to or from an Application Storage Unit. It is an entity that contains sufficient information to enable the SPC workload generator to issue an I/O operation to the Application Storage Unit in conformance with the SPC-1 workload.

As an example, an I/O command might contain the following items:

- Application Storage Unit identifier.
- The starting address of the data transfer.
- The byte count of the data transfer.
- The type of data transfer (read or write).
- A pointer to a buffer for transmission (writes) or reception (reads) of data.

3.3 SPC-1 Parameter Types

Each SPC-1 workload parameter is defined as being one of the following types.

3.3.1 Integer

An integer parameter is capable of storing discrete, signed values. The range is operating system and/or compiler dependent, but must be a minimum of 32 bits, including the sign bit (-2,147,483,648 to 2,147,483,647).

3.3.2 Long Integer

A long integer parameter is capable of storing discrete, signed values. The range is operating system and/or compiler dependent, but must be a minimum of 64 bits, including the sign bit (-9,223,372,036,854,775,808 to 9,223,372,036,854,775,807).

3.3.3 Real

A real parameter is capable of storing positive and negative continuous values. The range is operating system and/or compiler dependent, but must have a minimum range of from -10^{32} to 10^{32} with a minimum resolution of 16 significant digits.

3.3.4 ASCII string

An ASCII string parameter consists of a variable length sequence of ASCII characters (8 bits per character), with a zero byte terminating the string.

3.3.5 Distribution

The distribution is a special data type that has been implemented specifically for the SPC workload parameter list. This parameter contains sufficient information to characterize a distribution that may be used for certain parameters. This data type consists of several components.

3.3.5.1 Distribution type

The type of distribution is indicated by an integer variable. The legal types of distributions are:

- 0: Constant – A single number. The value of this number is contained in the first element of the distribution parameter list.
- 1: Uniform – A number that is uniformly distributed between (and including) two values. The lower of these values is contained in the first element of the distribution parameter list, and the upper value is contained in the second element.
- 2: Exponential – A number that is exponentially distributed with a mean value contained in the first element of the distribution parameter list.
- 3: Table – A table distribution is an n-dimensional array containing the discrete table values. There is no limit on the number of dimensions or entries in the array. The pointer component (section) of the distribution data type points to the start of the array. The contents of the array are undefined, and must be specified for each case.
4. Incremental: An ascending series of values. This distribution has four associated parameters, *incremental (start, startvar, stride, length)*.

The first parameter “start”, which is required, defines the first value of a monotonically increasing sequence. “start” is a real number [0,1] representing the mean of the location within the ASU address range that the sequence begins, given as a fraction of the total address range, and modified by the “startvar” parameter. The sequence will increase to the highest possible value, and then begin again at a new first value, repeating.

The second parameter “startvar”, which is optional, is a real number [0,1] representing the fraction of the total ASU extent through which the “start” value can be varied. If “startvar” is zero, the “start” value is always used when the first ASU address is required in a sequence. If “startvar” is nonzero, a new first value is computed each time the lowest ASU address is required, and is computed as a uniformly distributed random number within $\pm \text{startvar}/2$ of the mean, “start”. If “start+startvar/2” is > 1 , the value of 1 will be used for the upper limit of the first value in a sequence. If “start - startvar/2” is ≤ 0 , the value of 0 will be used for the lower limit of the first value of a sequence. If “startvar” is not present, its value is assumed to be zero.

The third parameter, “stride”, which is optional, defines the gap between values in the series. “stride” is an integer representing the number of blocks between each value in the series. Since I/O transfer size is variable, even within a stream, “stride” must be related to the I/O size. A “stride” of zero is used to generate a sequence of values in which the next value = old value + transfer size. If “stride” is not supplied, a value of zero is assumed. A “stride > 0 ” implies the new value = old value + transfer size + stride. A stride < 0 is always interpreted as a sequence of I/Os in which the address is always the same.

The fourth parameter, “length” which is optional, is used to define the upper extent of the generated sequence. “length” is a real number (0,1] representing the fraction of the total ASU address space over which the sequence is generated, relative to the first value of the sequence. “length” is added to each new computed first value to determine the upper extent of the series. If “length” is not present, the sequence will be generated from its start value, up to 1, and then will repeat beginning at the new start value.

If “Incremental” is used to generate a sequence of addresses for a stream of I/O references, the number of values in the sequence is controlled by the start and stop criteria of the I/O stream, which is a function of the stream link and termination criteria (3.4.12 and 3.4.13).

For example, incremental (0.35, 0.7, 8, 0.3) will generate a sequence with start address at 35% of the ASU extent, $\pm 35\%$. The sequence will have a gap of (8 blocks + Transfer size) between each I/O start address. The highest address generated will be 30% of the ASU extent higher than the first value, or at 70% of the ASU extent if the first value is at 40%. The sequence will continue until the stream is terminated through other means.

- 5: Random access pattern R1 – A random walk with “hierarchical reuse” behavior (see Appendix E), using a leaf size of 32768 bytes and parameters $k=6$, $v=.44$. Upon the first read to a given leaf, the first 4096-byte block is read from that leaf. Subsequent reads to the leaf read the second block, the third block, and so on, wrapping back to the first block after reading the last. (Note: if multiple, logically distinct random walks are occurring concurrently within the same ASU, the first and subsequent reads to a given leaf are implemented as just described, regardless of whether they are associated with the same or with logically distinct random walks).

- 6: Random access pattern W1 – Also a random walk with “hierarchical reuse” behavior, using a leaf size of 32768 bytes and parameters $k=6$, $v=.44$. The leaf L_0 initially selected in this manner, however, is then used to obtain the final leaf selection $L = 8 * \text{Floor}(L_0/8)$. Within the selected leaf, the 4096-byte block to be written is determined as follows. With 50 percent probability, the 4096-byte block is chosen using a random uniform distribution across all blocks of this size contained in the leaf. With the remaining 50 percent probability, the most recently read block is chosen. Once the full address of the write operation is obtained, as just described, then with an 85 percent probability, a single write is performed to the selected address. With the remaining 15 percent probability, *two* writes are performed to this address (that is, an exception occurs to the random walk scheme, in that no step is taken prior to the second write of the pair).

As new distributions become necessary, they will be added to this list in a monotonically increasing sequence.

3.3.5.2 Result type

The result type indicates whether the resulting value from the distribution is integer or real. There are three possible values for this field:

- 0: Integer – The output of the distribution is an integer.
- 1: Long - The output of the distribution is a long integer.
- 2: Real – The output of the distribution is a real number.

3.3.5.3 Distribution parameter list

The distribution parameters consist of a list of ten real numbers. The values contained in these fields may be used as part of the distribution function. The number of values that are used is function dependent, and may range from none to all ten.

3.3.5.4 Extended pointer

The extended pointer is used when it is necessary to include more than ten discrete parameters or when a singly dimensioned list is not adequate. The primary use of this pointer is when a table distribution is required. The data structure that is pointed to by this element is not defined by this document.

3.4 SPC-1 Workload Parameters

A set of parameters is required for each I/O stream that is present in the SPC-1 workload. These parameters are passed to the workload generator. The set of parameters will enable the workload generator to create and submit a stream of individual I/O commands to the application storage unit.

Conceptually, the workload generator will examine the parameters, and by using the values contained in these parameters, generate a sequence of I/O commands, with each individual command being issued at the appropriate time. All SPC workload parameters are present, but may not be applicable.

3.4.1 ASU Transfer Alignment

The ASU transfer alignment parameter determines whether the starting I/O address is aligned to any specific quantity. It is intended primarily for use with random accesses within a small range. This is due to the common practice of applications to only access data on certain address boundaries, such as database block size, page size, etc. In essence, this is a modulus operator that will, after a starting address has been determined, force that address to modulo n , where n is the ASU transfer alignment parameter, in blocks.

As an example, if the ASU transfer alignment parameter has a value of 16 (blocks), then each transfer address generated must be evenly divisible by 16.

3.4.1.1 Parameter type

The ASU transfer alignment parameter is an integer variable.

3.4.1.2 Acceptable values

The ASU transfer alignment parameter may take on any positive value greater than or equal to zero. The upper limit is set by media size and/or integer length. If the value of this parameter is zero, then ASU transfer alignment is disabled. If this parameter contains a non-zero value (n), then all transfer requests will be performed modulo n .

3.4.2 Data Re-reference

Data re-referencing occurs when an I/O references data that has been referenced previously. The purpose of the Data Re-reference specification is to allow those I/O streams that would benefit from a random access cache to realize those benefits by having the I/O stream perform the appropriate accesses.

3.4.2.1 Specification of Data Re-reference in SPC-1

In the SPC-1 benchmark, data re-reference is specified by applying an appropriate distribution to the selection of reference addresses. More specifically, certain streams of the SPC-1 benchmark, as specified in Clause 3.5, select the next reference address by performing a random walk. The sequence of addresses visited in the random walk includes both those where reads are performed, and those where writes are performed. The next step of the random walk is computed, based upon the most recent visit location, by applying distribution R1 when it is intended to perform a read, and distribution W1 when it is intended to perform a write.

3.4.3 Intensity Multiplier

The intensity multiplier indicates the ratio of the traffic intensity of this I/O stream relative to the total traffic intensity of all streams.

3.4.3.1 Parameter type

The intensity multiplier is a real (floating-point) variable.

3.4.3.2 Acceptable values

The intensity parameter may take on all positive values, including zero.

3.4.4 Memory Alignment

The memory alignment allows the data sent and received from the I/O operation to be placed in host computer memory on certain byte boundaries.

3.4.4.1 Parameter type

The memory alignment parameter is an integer variable specifying the byte alignment.

3.4.4.2 Acceptable values

The memory alignment parameter may take on any positive value greater than or equal to zero, although the most common cases will specify a power of 2. There are two cases:

1. A value of zero indicates that memory alignment is disabled.
2. A value of n indicates that all data transfers to and from memory will begin at a memory address that is evenly divisible by n bytes. As an example, in order to force quadword (64 bit) alignment, this parameter must be set to 8.

3.4.5 Model Type

The model type parameter indicates whether the I/O stream follows an open or closed model.

3.4.5.1 Parameter type

The model type is an integer variable.

3.4.5.2 Acceptable values

The model type parameter may take on one of the following values representing the workload type:

Open

Closed

3.4.6 Population

The population parameter specifies the number of execution instances associated with this stream (See Clause 4.7.2).

3.4.6.1 Parameter type

The population parameter is an integer variable.

3.4.6.2 Acceptable values

Each I/O stream of the SPC-1 benchmark has a population equal to the integer number of BSUs currently being run on the SUT.

3.4.7 Read Fraction

The read fraction parameter specifies the fraction of I/O commands that are reads.

3.4.7.1 Parameter type

The read fraction parameter is a distribution of real (floating-point) variables.

3.4.7.2 Acceptable values

The read fraction parameter may take on any positive real (floating point) value greater than or equal to zero and less than or equal to one.

3.4.8 Stream Identifier

The stream identifier, which is assigned by the SPC, is a value that uniquely identifies an I/O stream within a specific workload. The purpose of this parameter is to allow analysis programs to extract performance data for a specific I/O stream from a workload. Note that this value needs only to be unique within a workload; it is not required to be unique across all workloads.

3.4.8.1 Parameter type

This parameter is a variable length, zero terminated, ASCII string.

3.4.8.2 Acceptable values

No restriction is placed on this parameter.

3.4.9 Transfer Address

The transfer address parameter determines the target address of the next I/O that will be issued to the ASU. Note that bounds checking must be performed to ensure that the resulting address is greater than or equal to zero, and that the sum of the address and transfer size is less than or equal to the capacity of the ASU.

3.4.9.1 Parameter type

The transfer address parameter is a distribution variable.

3.4.9.2 Acceptable values

The transfer address value must be greater than or equal to zero, and the sum of the transfer address and the transfer size must be less than or equal the capacity of the ASU.

3.4.10 Transfer Size

The transfer size parameter specifies the number of blocks to transfer.

3.4.10.1 Parameter type

The transfer size parameter is a distribution of long integer variables.

3.4.10.2 Acceptable values

In the SPC-1 benchmark, most streams use a transfer size specified as a positive integer constant. Other streams use a transfer size as specified using the following tabular distribution:

SMIX = Table:{8,0.40}{16,0.24}{32,0.20}{64,0.08}{128,0.08}

3.4.11 Workload Identifier

The workload identifier, which is common to all I/O streams in the workload, is a unique value assigned by the SPC to identify a specific workload. The purpose of this parameter is to allow an analysis program to extract performance information for a specific workload from a test that includes more than one workload.

3.4.11.1 Parameter type

This parameter is a variable length, zero terminated, ASCII string.

3.4.11.2 Acceptable values

No restriction is placed on this parameter.

3.5 Technical Workload Description

SPC-1 is designed to demonstrate the performance of a storage system or storage components while performing the typical functions of a business application. SPC-1 represents a segment of applications characterized by predominately random I/O operations as typified by a mail server application but not limited to that specific application type.

The storage for the SPC-1 workload consists of three Application Storage Units:

- ASU 1 - Data Store
- ASU 2 - User Store

- ASU 3 – Log/Sequential Write

Each ASU is the target of an ASU stream that in turn is comprised of one or more distinct I/O streams. The I/O streams for each ASU are defined below by a set of parameters and parameter values.

Definitions and descriptions of each parameter type used to define the SPC-1 parameters may be found in Clause 3.4. Each SPC-1 parameter is defined and described in Clause 3.5.

3.5.1 ASU 1 - Data Store

The Data Store has four parallel I/O streams associated with it. There is a read and write stream that is uniformly distributed over the entire address space, as well as some highly localized I/O to specific areas of the ASU. Additionally, there is a sequential read stream present. The I/O intensity for ASU 1 represents 59.6% of the total SPC-1 I/O command traffic.

Table 3-1: ASU 1 Parameter Types and Values

Parameter Type	I/O Stream 1	I/O Stream 2	I/O Stream 3	I/O Stream 4
ASU	1	1	1	1
Transfer alignment (512 byte blocks)	8	8	8	8
Data re-reference	See Clause 3.4.2.1	See Clause 3.4.2.1	N/A	See Clause 3.4.2.1
Intensity multiplier	0.035	0.281	0.070	0.210
Memory alignment	8	8	8	8
Model type	Open	Open	Open	Open
Population	=BSU	=BSU	=BSU	=BSU
Read fraction	0.5	0.5	1.0	0.5
Stream identifier	"ASU 1-1"	ASU 1-2"	"ASU 1-3"	"ASU 1-4"
Transfer address	Uniform: 0.0 – 1.0	R1/W1: 0.15 – 0.2	Incremental (0.4, 0.4, 0, 0.1)	R1/W1: 0.7 – 0.75
Transfer size (512 byte blocks)	8	8	SMIX	8
Workload identifier	"SPC-1.00"	"SPC-1.00"	"SPC-1.00"	"SPC-1.00"

3.5.2 ASU 2 - User Store

There are three parallel I/O streams associated with ASU 2 - User Store. Similar to the ASU 1 - Data Store, the User Store also has read write streams that are randomly distributed across the entire address space of the ASU. There are also localized I/O streams, although there are fewer of these than are present on the Data Store. The I/O intensity for ASU 2 represents 12.3% of the total SPC-1 I/O command traffic.

Table 3-2: ASU 2 Parameter Types and Values

Parameter Type	I/O Stream 1	I/O Stream 2	I/O Stream 3
ASU	2	2	2
Transfer alignment (512 byte blocks)	8	8	8
Data re-reference	N/A	See Clause 3.4.2.1	N/A
Intensity multiplier	0.018	0.070	0.035
Memory alignment	8	8	8
Model type	Open	Open	Open
Population	=BSU	=BSU	=BSU
Read fraction	0.3	0.3	1.0
Stream identifier	"ASU 2-1"	"ASU 2-2"	"ASU 2-3"
Transfer address	Uniform: 0.0 – 1.0	R1/W1: 0.47 – 0.52	Incremental (0.4, 0.4, 0, 0.1)
Transfer size (512 byte blocks)	8	8	SMIX
Workload identifier	"SPC-1.00"	"SPC-1.00"	"SPC1.00"

3.5.3 ASU 3 – Log/Sequential Write

This stream represents logging and other sequential write activity. The I/O intensity for ASU 3 accounts for 28.1% of the total SPC-1 I/O command traffic.

Table 3-3: ASU 3 Parameter Types and Values

Parameter Type	I/O Stream 1
ASU	3
Transfer alignment (512 byte blocks)	8
Data re-reference	N/A
Intensity multiplier	0.281
Memory alignment	8
Model type	Open
Population	=BSU
Read fraction	0.0
Stream identifier	"ASU 3-1"
Transfer address	Incremental (0.35, 0.7, 0, 0.3)
Transfer size (512 byte blocks)	SMIX
Workload identifier	"SPC-1.00"

Clause 4: Benchmark Configuration (BC), Tested Storage Configuration (TSC), and Workload Generator

4.1 Overview

The Benchmark Configuration (BC) consists of all hardware and software components used in the execution of the SPC-2 benchmark. The Tested Storage Configuration (TSC) consists of all software and hardware necessary to implement and support the three configured Application Storage Units (ASUs) as defined in Clause 2.6.

4.2 Benchmark Configuration Component Availability and Support

All hardware and software used in the Benchmark Configuration must be commercially available and supported either as individual items or as a part of a larger package. Hardware and software used in the Benchmark Configuration that is NOT included in the Tested Storage Configuration is exempt from the preceding requirement if it is no longer commercially available and/or supported due to obsolescence.

Comment: The intent is to allow the use of components in the Benchmark Configuration that were at one time commercially available and supported as long as the components are not a part of the Tested Storage Configuration.

4.3 Benchmark Configuration Components

The Benchmark Configuration consists of the following components:

1. One or more Host Systems as defined in Clause 4.3.1.
2. All hardware and software needed to communicate between the Host System(s) and Tested Storage Configuration.
3. System Software, as defined in Clause 4.3.2.
4. The Tested Storage Configuration (TSC), defined in Clause 4.5.
5. The Tested Storage Product (TSP), defined in Clause 4.6.

4.3.1 Host System(s)

The Host System(s) consist of one or more computer systems where the System Software resides and executes the SPC-1 Workload Generator.

4.3.2 System Software

- 4.3.2.1 System Software, which may include the Host System's operating system, is responsible for presenting and managing unique names that instantiate the Application Storage Units (ASUs) to the SPC-1 Workload Generator, as well as organizing and managing the underlying Logical Volumes used to implement the ASUs.
- 4.3.2.2 System Software shall provide for error recovery, as well as all services needed to execute the SPC-1 Workload Generator on the Benchmark Configuration.
- 4.3.2.3 System Software may be used to implement RAID 0 (striping) and/or data protection functionality as defined in Clause 2.4.5.

4.3.2.4 System Software, executing on the Host System(s), shall not cache or buffer any data associated with implementing the ASUs on the BC nor be used to cache or buffer any ASU data.

4.4 Benchmark Configuration (BC) Examples

SPC-1 Test Sponsors may utilize a wide range of Benchmark Configurations. The diagrams in Figure 4-1 and Figure 4-2 are examples of acceptable Benchmark Configurations, but should not be considered as the only valid Benchmark Configurations.

A Test Sponsor may utilize a configuration that is different from the examples illustrated below. In such a case, the Test Sponsor is encouraged to contact the SPC prior to engaging in an Audit to ensure the proposed configuration will meet the SPC-1 benchmark requirements.

Figure 4-1: Sample BC Configurations – Direct Attach Storage Controller

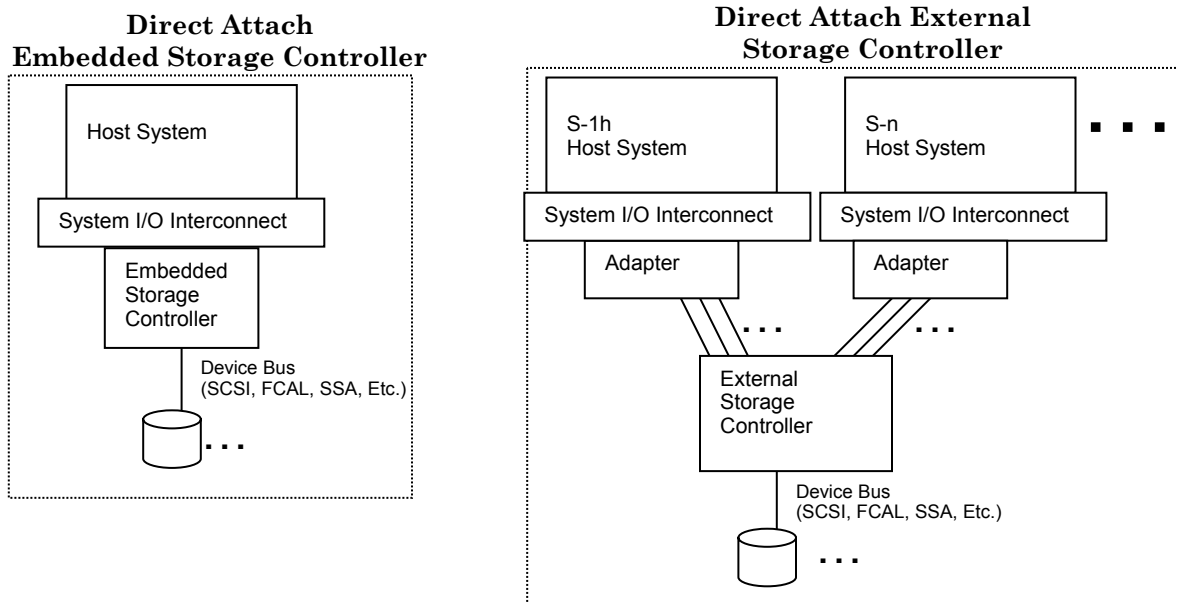
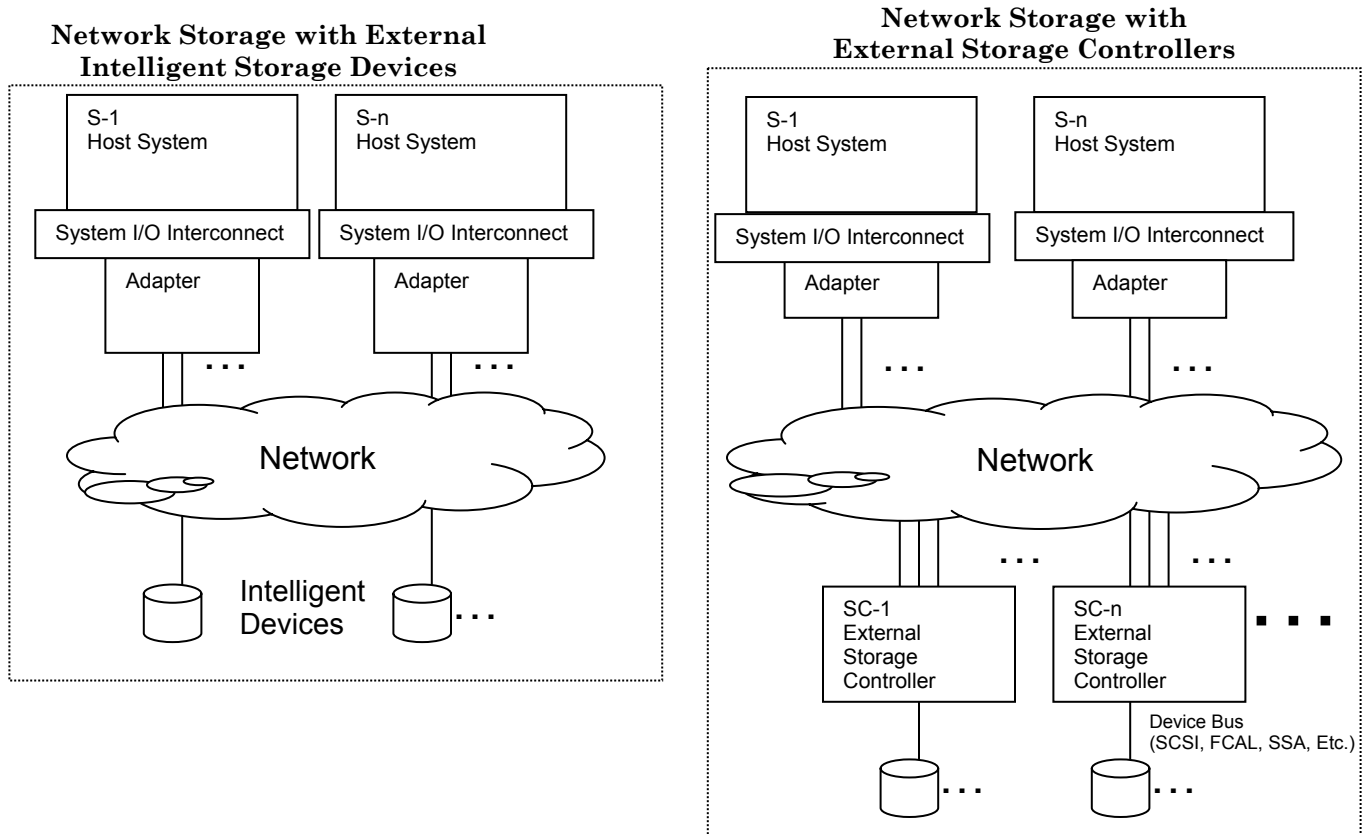


Figure 4-2: Sample Configurations – Network Storage



4.5 Tested Storage Configuration (TSC)

The Tested Storage Configuration (TSC) consists of all software and hardware necessary to implement and support the configured Application Storage Units (ASUs) as defined in Clause 2.6.

4.5.1 Host System as a Tested Storage Configuration (TSC) Component

Each Host System in the Benchmark Configuration (BC) must be included as a priced Tested Storage Configuration (TSC) component if any of the following conditions are true:

- The Host System contains an integral component that is a TSC hardware component, which cannot be unplugged and moved to a different Host System.
- The Host System contains storage devices that are connected internally as integral Host System components.
- System Software that provides data protection functionality, as defined in Clause 2.4.5, for the TSC.

An example of a TSC that includes the Host System as a priced TSC component is described in Clause 4.5.3.2 and illustrated in Figure 4-4.

System Software, executing on a Host System, which provides the following functionality for the TSC will not require the Host System to be included as a priced TSC component:

- Organize and manage the underlying Logical Volumes that comprise the Application Storage Units (ASUs). Data protection functionality is not included in this exemption.
- Present and manage unique names that instantiate the ASUs to the SPC-1 Workload Generator.
- Provide RAID 0 (striping).

Test Sponsors should request a recommendation from the Compliance Review Committee if the above wording does not clarify the TSC component status of a Host System in their Benchmark Configuration.

4.5.2 Multiple Storage Subsystem Configurations

A Test Sponsor may choose to configure multiple, independent storage subsystems in a Benchmark Configuration. In such a Benchmark Configuration, the multiple, independent storage subsystems must comprise an actual orderable storage configuration that a customer would purchase and not a collection of individually orderable products.

In such a configuration, the Application Storage Units will be configured across the storage subsystems and meet the requirements of Clause 2: Data Repository.

***Comment:** It is the intent of this clause that multiple, independent storage subsystems not be configured as a TSC solely for the purpose of this benchmark, which is prohibited in Clauses 0.2 and 8.2.2.1. A TSC that is a comprised of multiple, independent storage subsystems will be evaluated based on Clauses 0.2 and 8.2.2.1 for compliance with this clause.*

4.5.3 Tested Storage Configuration (TSC) Examples

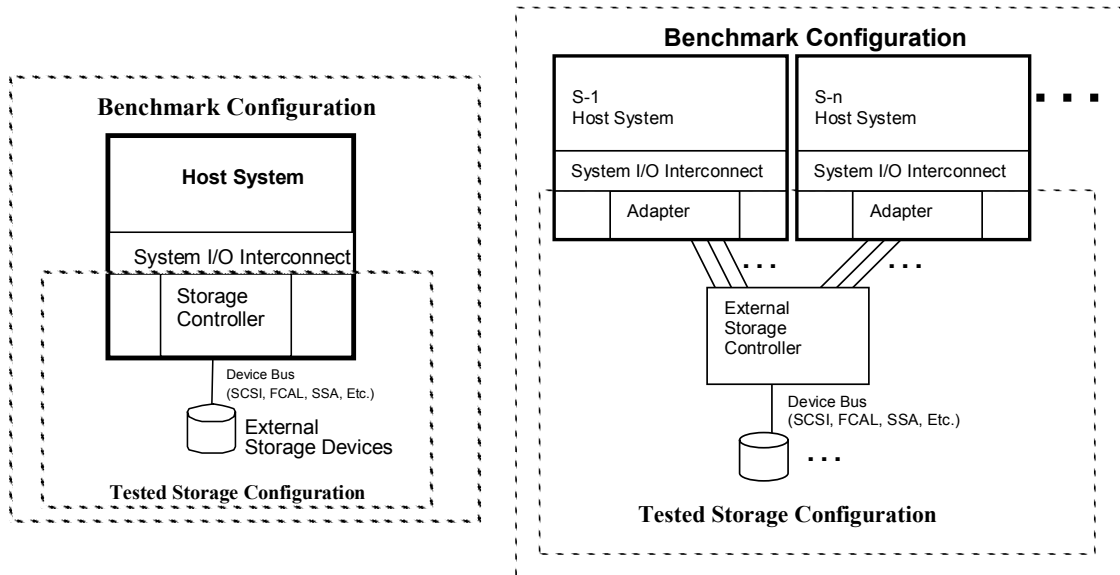
Clauses 4.5.3.1-4.5.3.3 describe and illustrate, in detail, several typical Tested Storage Configurations, including the boundary between the Host System and TSC (TSC Boundary). Those examples should not be considered the only valid Tested Storage Configurations.

A Test Sponsor may utilize a configuration that is different from the examples described and illustrated in Clauses 4.5.3.1-4.5.3.3. In such a case, the Test Sponsor is encouraged to contact the SPC prior to engaging in an Audit to ensure the proposed configuration will meet the SPC-1 benchmark requirements.

4.5.3.1 Embedded or External Storage Controller – External Storage Devices

Figure 4-3 illustrates two Benchmark Configurations (BCs). The first BC includes a Tested Storage Configuration (TSC) comprised of an embedded storage controller and external storage devices. The second BC includes a TSC comprised of an external storage controller and external storage devices

Figure 4-3: Embedded or External Controller – External Storage Devices



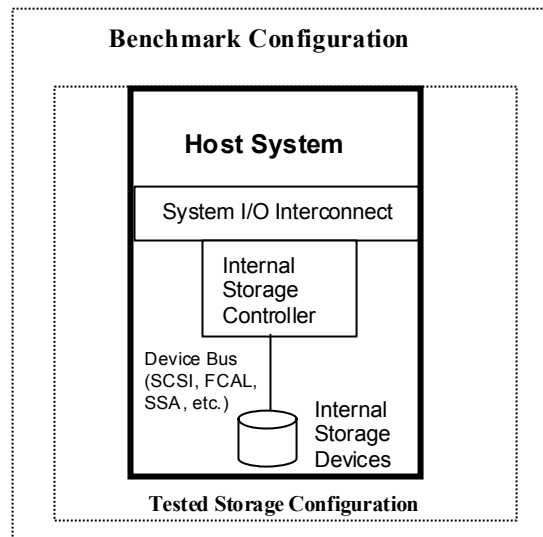
The components that comprise the TSC typically include:

1. A storage controller that plugs into a system I/O interconnect on the Host System
2. Batteries used to maintain power to cache/memory in the Storage Controller in the event of unexpected power failure.
3. Cabling between the Storage Controller and the Storage Devices used to implement the ASUs.
4. All cabinetry used to house components of the TSC (excluding the cabinetry, cooling, power, and monitoring systems required to house the Storage Controller embedded in the Host System cabinet).
5. Environmental monitoring systems and related cabling used to monitor the health of components of the TSC.
6. Fans used to cool components of the TSC.
7. Power supplies and related cabling used to power components of the TSC.
8. Power distribution systems and related cabling in cabinetry used to route power to the individual component power supplies in the TSC.
9. All management software necessary to present the ASUs to the Workload Generator.
10. Storage devices (e.g., disks) to provide the various levels of storage described in Clause 2: Data Repository.

4.5.3.2 Embedded Storage Controller – Embedded Storage Devices

A TSC that utilizes Host System components is illustrated in Figure 4-4.

Figure 4-4: Embedded Storage Controller – Embedded Storage Devices



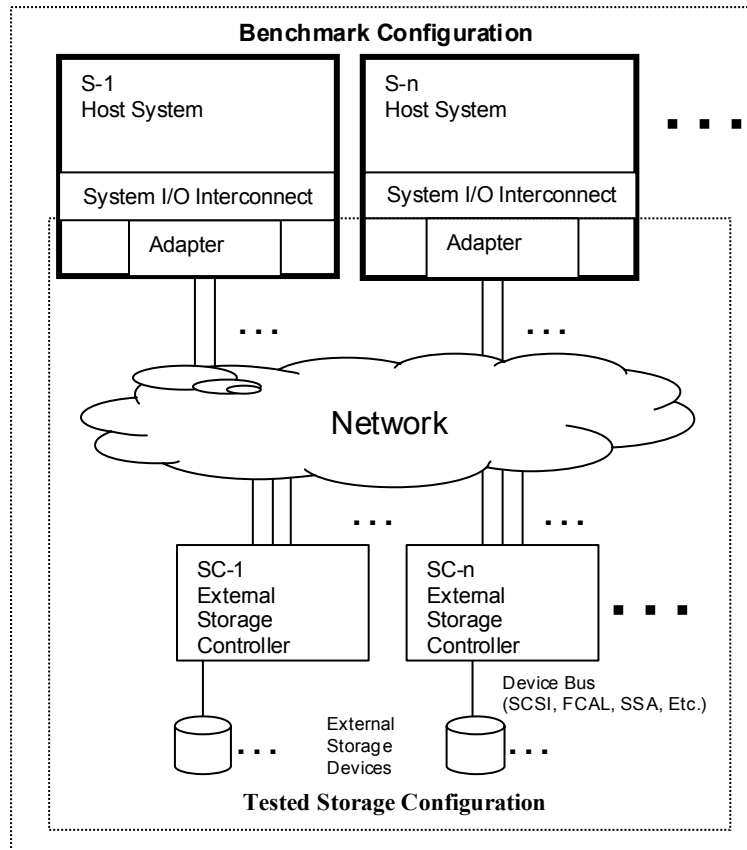
The components that comprise the TSC typically include:

1. A storage controller that either plugs into a system I/O interconnect on the Host System or is an integral Host System component.
2. Batteries used to maintain power to cache/memory in the storage controller in the event of unexpected power failure.
3. Storage devices (e.g., disks) to provide the various levels of storage described in Clause 2: Data Repository. The storage devices may either be connected externally to the Host System or connected internally as an integral Host System component.
4. Cabling between the storage controller and the storage devices used to implement the ASUs.
5. All cabinetry used to house components of the TSC.
6. Environmental monitoring systems and related cabling used to monitor the health of components of the TSC.
7. Fans used to cool components of the TSC.
8. Power supplies and related cabling used to power components of the TSC.
9. Power distribution systems and related cabling in cabinetry used to route power to the individual component power supplies in the TSC.
10. All management software necessary to present the ASUs to the SPC-2 Workload Generator.

4.5.3.3 Network Storage – External Storage Controller and External Storage Devices

A network storage TSC utilizing external storage controllers and external storage devices is illustrated in Figure 4-5.

Figure 4-5: Network Storage –External Storage Controller and Storage Devices



The TSC typically includes the following components:

1. One or more host bus adapters that connect the storage network into system I/O Interconnect(s) on Host System(s).
2. All network infrastructure including hubs, switches, bridges, routers, cables, connectors, as well as supporting cabinetry, cooling, power systems, and monitoring equipment/systems used to connect storage controllers the Host Systems
3. All software used to manage and maintain the network infrastructure.
4. External storage controllers or domain controllers including:
 - a) Batteries used to maintain power to write cache in the storage controller in the event of unexpected power failure.
 - b) Cabinetry used to house the storage controller.
 - c) Monitoring systems and related cabling used to monitor the health of the storage controller.

- d) Equipment used to cool the storage controller.
 - e) Power supplies and related cabling used to power the storage controller.
 - f) Power distribution systems and related cabling used to route power to the storage controllers.
 - g) All management software necessary to allow the storage controller(s) to present ASUs to the Workload generator.
5. Storage devices (e.g., disks) to provide the various levels of storage described in Clause 2: Data Repository.
 6. Cabling between the storage controller and the storage devices.
 7. Cabinetry used to house the storage devices.
 8. Monitoring systems and related cabling used to monitor the health of the storage devices.
 9. Equipment used to cool storage devices.
 10. Power supplies and related cabling used to power the storage devices.
 11. Power distribution systems and related cabling in storage device cabinetry used to route power to the individual storage device power supplies.
 12. All management software necessary to present and manage the ASUs to the Workload generator.

4.6 Tested Storage Product (TSP)

The Tested Storage Product (TSP) is a distinct, customer orderable product, which is the focal point of a SPC-1 result. Each SPC-1 result will be labeled with the formal name of the TSP (Clause 9.2.3, #3).

The composition of the Tested Storage Product will cause the SPC-1 result to be placed in one of the following two descriptive categories and listed as such in the Benchmark Results section of the SPC website.

4.6.1 Tested Storage Product (TSP) includes all Storage Devices

The Tested Storage Product is a distinct, customer orderable storage product, which includes all of the storage devices used in the benchmark. [Inclusion of all of the storage devices must be via one or more selectable option of the Tested Storage Product.](#) In that case, all of the storage devices, used in the Benchmark Configuration, are a part of both the Tested Storage Configuration and the Tested Storage Product.

4.6.2 Tested Storage Product (TSP) does not include all Storage Devices

A Tested Storage Product is a distinct, customer orderable product, such as software or a virtualization product, which does not include all of the storage devices used in the Benchmark Configuration. [The Tested Storage Product does not offer any selectable options to include all storage devices. The storage devices are ordered as products separate from the Tested Storage Product to complete the Tested Storage Configuration.](#) In that case, all of the storage devices, used in the Benchmark Configuration, are a part of the Tested Storage Configuration, but not the Tested Storage Product.

4.7 SPC-1 Workload Generator

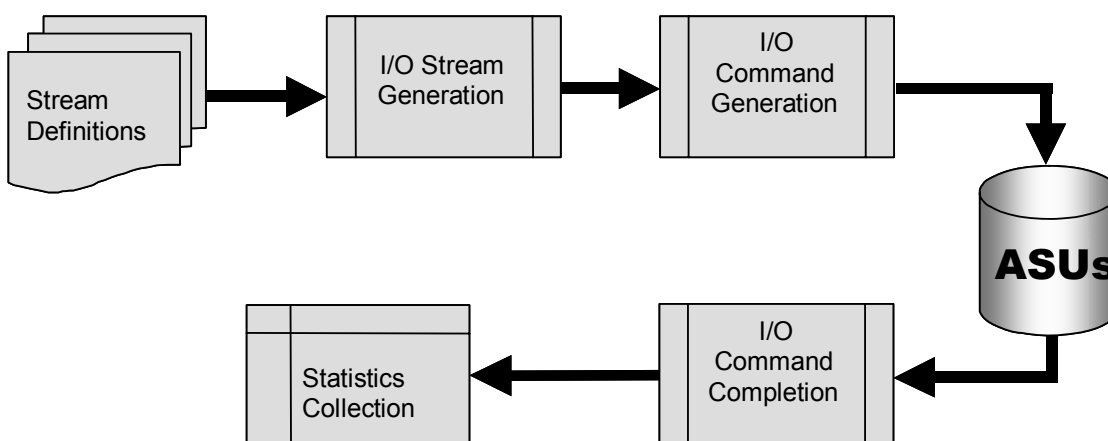
A SPC-1 result must be produced using the current SPC-1-Workload Generator kit. The current SPC-1 Workload Generator kit is available from the SPC to Test Sponsors in machine executable format.

The SPC-1 Workload Generator is instantiated by one or more processes running on one or more Host Systems that are part of the BC and implements the workload as described in Clause 3. The SPC-1 Workload Generator is supplied to Test Sponsors in machine executable format by the SPC.

As a user-space application, the SPC-1 Workload Generator shall reference the Addressable Storage Capacity in the Tested Storage Configuration (TSC). The SPC-1 Workload Generator is capable of randomly referencing any block within the Logical Address Space of any ASU.

The functional components of the SPC-1 Workload Generator are illustrated below in Figure 4-6.

Figure 4-6: Workload Generator Functional Components



Specific functions of the SPC-1 Workload Generator include:

- Generating parameters for I/O Requests to be issued to ASUs.
- Issuing I/O Requests to ASUs in the TSC.
- Receiving completed I/O Requests from ASUs on the TSC.
- Performing error checking and time stamping for I/O Requests.
- Computing statistics on completed I/O Requests and test runs.
- Generating test results for each test run within the benchmark.

The SPC-1 Workload Generator must be implemented as a general-purpose application program on a Host System intended to run application programs.

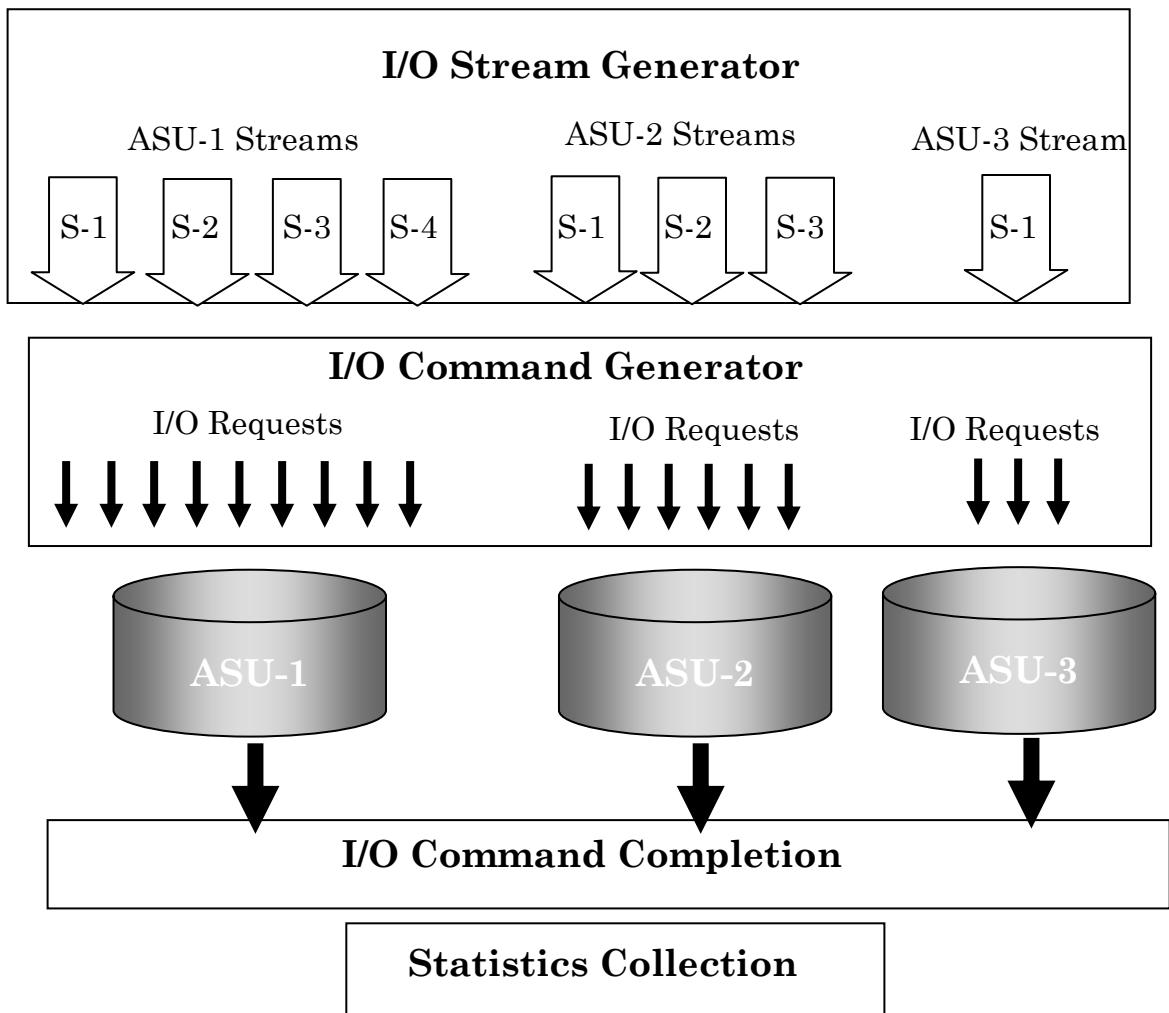
4.7.1 Workload Generator Description

Each I/O request of the SPC-1 workload is associated with a specific I/O Stream. The workload incorporates a number of distinct types of I/O Streams. The definitions of each stream type are presented in Clause 3.5.

Each I/O stream is made up of one or more concurrently executing instances that generate I/O commands for a specific ASU.

The relationships between the Workload Generator components, I/O streams and ASUs are illustrated in Figure 4-7.

Figure 4-7: Workload Generator Components, I/O Streams and ASUs



4.7.2 I/O Stream Generator Function

The I/O Stream Generator is responsible for generating a sequence of I/O requests for each instance of each ASU Stream as defined and described in Clauses 3.2.2, 3.2.3, and 3.5. As such, the I/O Stream Generator will compute the Transfer size, Transfer Address, type of I/O operation (Read or Write), and Transfer Alignment for each I/O request in each instance of each ASU I/O Stream.

The number of concurrently executing instances of each I/O Stream, in a given benchmark run, is given by the number of BSUs selected for that run.

4.7.3 I/O Command Generator Function

The I/O Command Generator is responsible for submitting I/O requests in the sequence defined by the I/O Stream Generator. Each I/O request is time stamped (and the time stamp is recorded) just prior to submission to the operating system for execution.

4.7.4 I/O Command Completion Module

The I/O Command completion module is responsible for:

- Receiving completed I/O Requests from System Software.
- Time stamping the completed I/O Requests.
- Recording any error conditions that may have occurred while executing the I/O Request.
- Forwarding key metrics to the Statistics collection module.

4.7.5 Statistics Collection and Data Reduction Module

The Statistics Collection Module exists to reduce the CPU overhead and storage requirements needed to support the Workload Generator by computing key on-the-fly statistics for a test run of the SPC-1 benchmark. This functional module of the Workload Generator is also responsible for writing a Results File for each test executed in the course of the benchmark. Results files are used by Test Sponsors to report results and by the SPC Audit Service to verify results authenticity. Appendix A contains an example Results File from an SPC-1 Test Run.

Results file will be produced in a human-readable format and will include data necessary for audit authentication.

The data collected in Results Files is selected to reduce Workload Generator related CPU overhead during an SPC-1 Test Run. As a result, a separate stand-alone program/tool exists to transform the “raw” performance data in Results Files into a format that can be directly used to generate a Full Disclosure Report (a Summary Results File). An example Summary Results File from an SPC-1 Test Run can be found in Appendix C.

4.7.6 Multi-Host Workload Generator Implementation Considerations

Test Sponsors may choose to configure multiple Host Systems and multiple independent Storage Subsystems in a Benchmark Configuration (BC). In this case:

1. In a multi-host BC running multiple Workload Generators, the work presented to each ASU from all Host Systems shall preserve the workload parameters as stipulated in clause 3.5. See Figure 4-8 and Figure 4-9 as illustrations of this requirement.
2. ASUs implemented across multiple Storage Subsystems in the TSC must preserve the requirements expressed in Clause 2 (Data Repository).

Comment: *It is the intent of this clause that multiple Workload Generators spread across multiple Host Systems effectively behave as a single Workload Generator relative to the workload offered to the TSC.*

Figure 4-8: ASU Relationship To Multiple Hosts

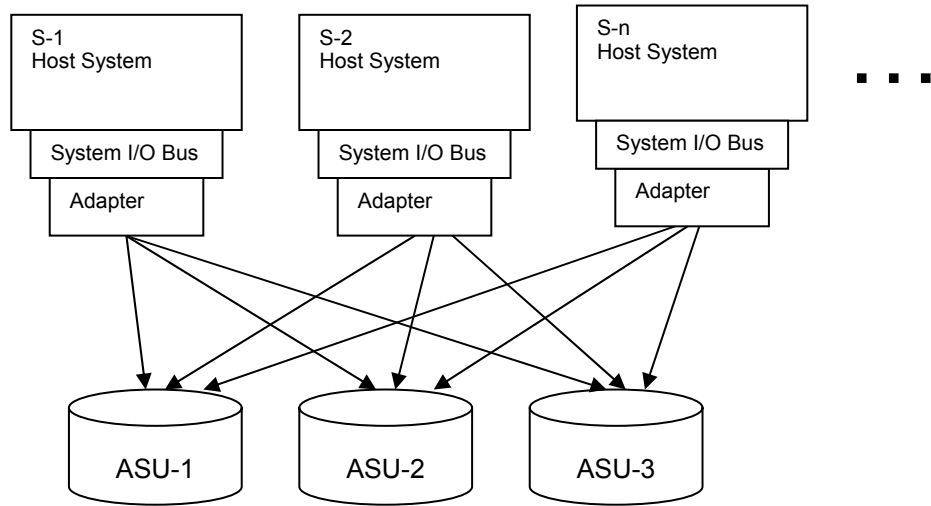
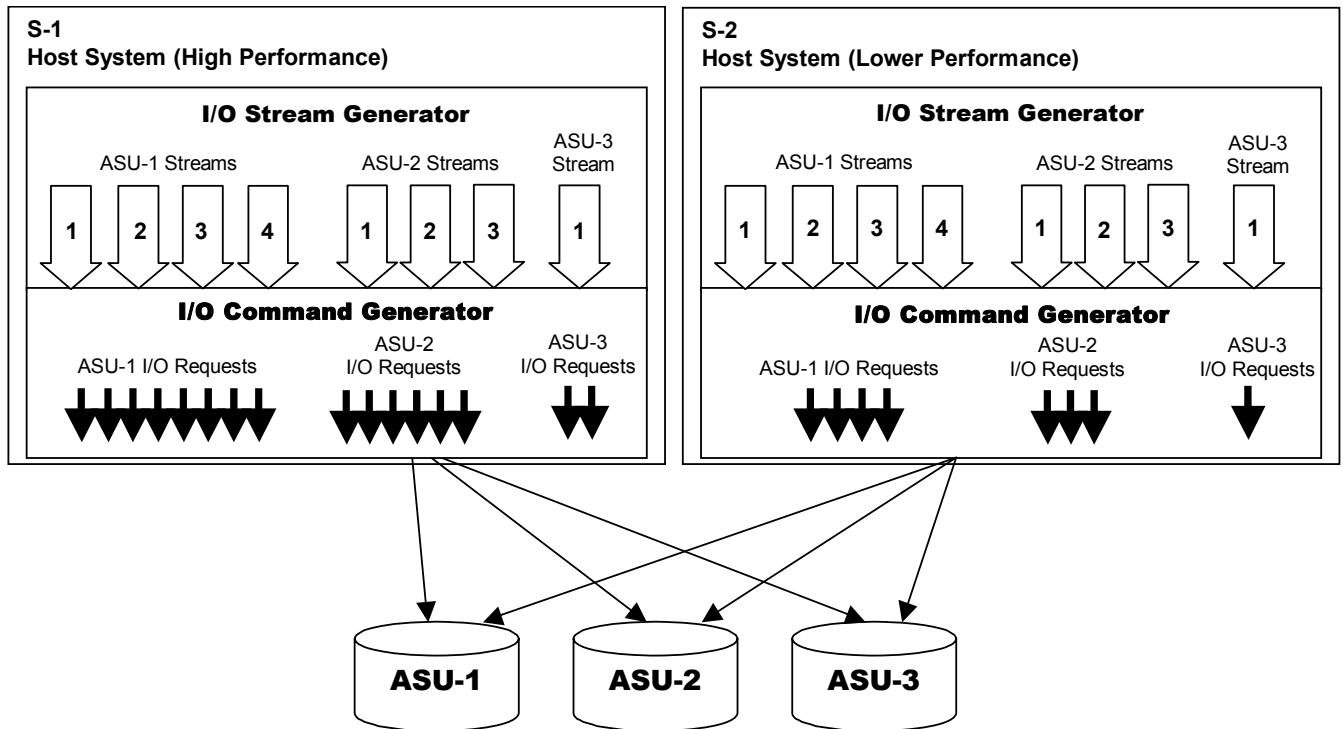


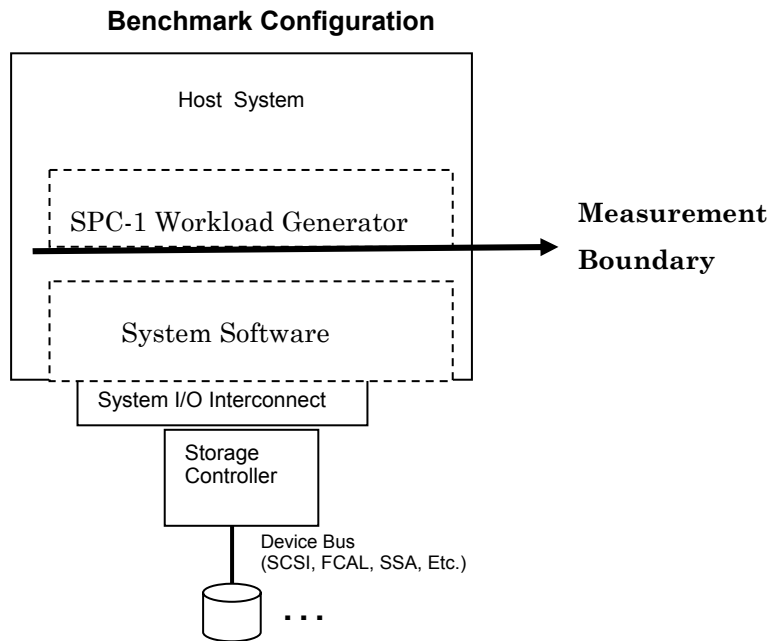
Figure 4-9: Multi-Host Workload Requirements



4.7.7 Measurement Boundary

The Measurement Boundary for computing SPC-1 results is primarily defined by the implementation of the SPC-1 Workload Generator as illustrated in Figure 4-10 and Figure 4-11. The Measurement Boundary occurs within the SPC-1 Workload Generator where start and completion times of I/O Requests are recorded.

Figure 4-10: Measurement Boundary

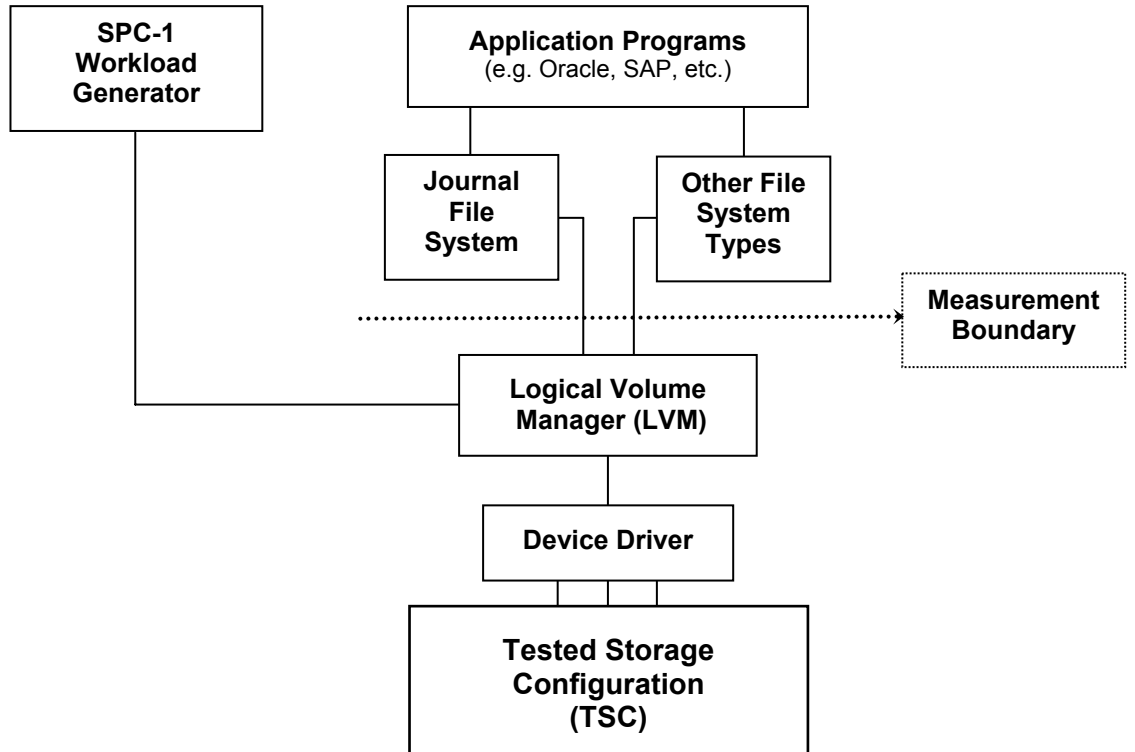


4.7.8 Application Storage Unit (ASU) Access

The SPC-1 Workload Generator is not allowed to utilize any file system functionality, such as caching or pre-fetching, provided by the Host System(s) when accessing an ASU. As an example, the UNIX implementations of the SPC-1 Workload Generator will issue I/O Requests via the raw, unblocked I/O interface. Figure 4-11 illustrates that example.

All other operating system implementations of the SPC-1 Workload Generator will utilize the operating system's mechanisms for performing I/O that matches as closely as possible the raw, unblocked I/O interface provided by UNIX.

Figure 4-11: Measurement Boundary in an UNIX System Implementation



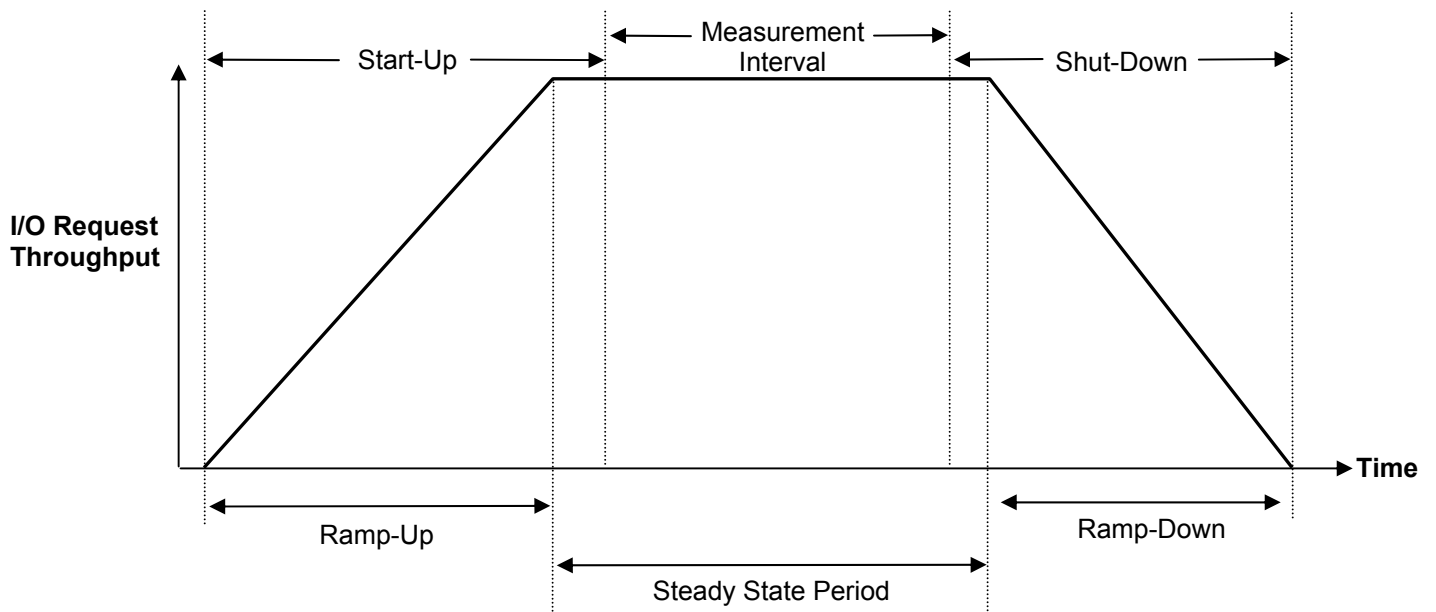
Clause 5: Test Measurement Requirements (Execution Rules)

5.1 Supporting Definitions

- 5.1.1 **Average Response Time:** The sum of the Response Times for all Measured I/O Requests divided by the total number of Measured I/O Requests.
- 5.1.2 **Completed I/O Request:** An I/O Request with a Start Time and a Completion Time (see Figure 5-2).
- 5.1.3 **Completion Time:** The time recorded by the Workload Generator when an I/O Request is satisfied by the TSC as signaled by System Software.
- 5.1.4 **Data Rate:** The data transferred in all Measured I/O Requests in an SPC-1 Test Run divided by the length of the Test Run in seconds.
- 5.1.5 **Expected I/O Count:** For any given I/O Stream and Test Phase, the product of 50 times the BSU level, the duration of the test phase in seconds, and the Intensity Multiplier for that I/O stream as given in Clause 3.5.
- 5.1.6 **Failed I/O Request:** Any I/O Request issued by the Workload Generator that could not be completed or was signaled as failed by System Software. A Failed I/O Request has no Completion Time (see Figure 5-2).
- 5.1.7 **I/O Request Throughput:** The total number of Measured I/O requests in an SPC-1 Test Run divided by the duration of the Measurement Interval in seconds.
- 5.1.8 **In-Flight I/O Request:** An I/O Request issued by the I/O Command Generator to the TSC that has a recorded Start Time, but does not complete within the Measurement Interval (see Figure 5-2).
- 5.1.9 **Measured I/O Request:** A Completed I/O Request with a Completion Time occurring within the Measurement Interval (see Figure 5-2).
- 5.1.10 **Measured Intensity Multiplier:** The percentage of all Measured I/O Requests that were issued by a given I/O stream.
- 5.1.11 **Measurement Interval:** The finite and contiguous time period, after the TSC has reached Steady State, when data is collected by a Test Sponsor to generate an SPC-1 test result or support an SPC-1 test result.
- 5.1.12 **Ramp-Up:** The time required for the Benchmark Configuration (BC) to produce Steady State throughput after the Workload Generator begins submitting I/O Requests to the TSC for execution.
- 5.1.13 **Ramp-Down:** The time required for the BC to complete all I/O Requests issued by the Workload Generator. The Ramp-Down period begins when the Workload Generator ceases to issue new I/O Requests to the TSC.
- 5.1.14 **Response Time:** The Response Time of a Measured I/O Request is its Completion Time minus its Start Time.

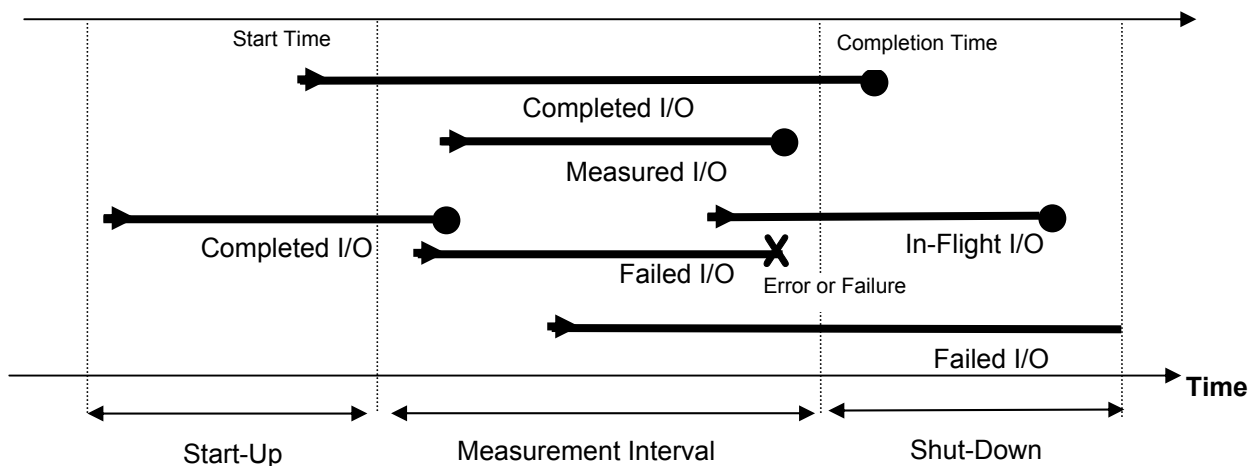
- 5.1.15 **Start Time:** The time recorded by the Workload Generator when an I/O Request is submitted, by the Workload Generator, to the System Software for execution on the Tested Storage Configuration (TSC).
- 5.1.16 **Start-Up:** The period that begins after the Workload Generator starts to submit I/O requests to the TSC and ends at the beginning of the Measurement Interval.
- 5.1.17 **Shut-Down:** The period between the end of the Measurement Interval and the time when all I/O Requests issued by the Workload Generator have completed or failed.
- 5.1.18 **Steady State:** The consistent and sustainable throughput of the TSC. During this period the load presented to the TSC by the Workload Generator is constant.
- Comment: Steady 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.*
- 5.1.19 **Test:** A collection of Test Phases and or Test Runs sharing a common objective.
- 5.1.20 **Test Run:** The execution of SPC-1 for the purpose of producing or supporting an SPC-1 test result. SPC-1 Test Runs may have a finite and measured Ramp-Up period, Start-Up period, Shut-Down period, and Ramp-Down period as illustrated in the Figure 5-1 below. All SPC-1 Test Runs shall have a Steady State period and a Measurement Interval.

Figure 5-1: Sample Test Run



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

Figure 5-2: I/O Completion Types



5.2 System Scaling

The SPC-1 benchmark synthesizes a community of users running against storage that is organized logically into the three SPC-1 Application Storage Units (ASUs). The test conditions of a given set of SPC-1 test results are characterized by the physical Benchmark Configuration (BC), the assigned storage capacity, and the size of the synthetic community of users executing against that storage capacity as reflected by the number of SPC-1 Business Scaling Units (BSUs).

5.2.1 Load Scaling (BSU)

In the synthetic framework of the SPC-1 benchmark, one SPC-1 BSU corresponds to a community of users who collectively generate up to 50 I/O's per second. The throughput of 50 I/O's per second for one SPC-1 BSU represents a best case, in which no significant contention occurs for storage resources. The actual throughput obtained for any given number of SPC-1 BSU's depends upon the unique characteristics of the Tested Storage Configuration (TSC). Thus, to obtain greater I/O Request Throughput the Test Sponsor will increase the number of BSU's presented by the Workload Generator to the TSC.

Each TSC must be measured at a series of load points. Its corresponding number of SPC-1 BSU's defines each load point.

5.2.2 Capacity Scaling (ASU)

The capacity selected by the Test Sponsor for Physical Storage Capacity, Configured Storage Capacity, Addressable Storage Capacity, and Application Unit Storage Capacity is at the discretion of the Test Sponsor subject to the requirements of Clause 2: Data Repository. Test Sponsors are encouraged to configure the maximum possible capacities for the TSC.

5.3 Requirements and Constraints

5.3.1 SPC Approved Workload Generator

All SPC-1 results must be produced using the current SPC-approved Workload Generator kit. The documentation included with the kit is to be considered an extension of this benchmark specification and will describe the appropriate use of the Workload Generator kit. The procedures, requirements, and constraints described in the kit documentation must be adhered to in order to produce a SPC-1 result.

5.3.2 Audit

A SPC-1 benchmark measurement must successfully complete an Audit as defined in Clause 10.6 before it can be submitted to the SPC and become a SPC-1 result.

5.3.3 Benchmark Configuration (BC) Consistency

The physical and logical configuration of the BC, as well as all configuration and tuning parameters, shall not be changed across Tests, Test Phases or Test Runs.

5.3.4 Start-Up Period

The Start-Up period for all SPC-1 Test Runs must be greater than or equal to three (3) minutes and ensure that the TSC has reached Steady State. The Start-Up periods, configurable by the Test Sponsor, must be disclosed.

5.3.5 Shut-Down Period

The Shut-Down period, configurable by the Test Sponsor, must be disclosed.

5.3.6 Measurement Resolution

The Measurement resolution for all reported Response Time results shall be 0.01 ms.

5.3.7 Failed I/O Requests

All I/O Requests initiated during any Test or Test Phase in the SPC-1 benchmark must complete. A Failed I/O Request shall result in an invalid SPC-1 test.

Comment: This requirement includes Start-Up and Shut-Down periods.

5.3.8 I/O Request Pre-generation

If the Workload Generator pre-generates I/O Requests to be issued to the TSC, the Test Sponsor shall not structure the execution or configuration of the BC to take advantage of the prior knowledge of the content of each pre-generated I/O request.

5.3.9 Repeatability and Reproducibility

Each reported SPC-1 performance metric must represent a level of performance that is repeatable and reproducible. It is the intent of this clause to allow any customer, consultant, or competitor to consistently reproduce an SPC-1 performance result.

5.3.10 Data Persistence

Data persistence properties and requirements as specified in Clause 6 will be maintained for all I/O requests.

5.3.11 No Warm-up

Other than booting/starting the host systems, bringing ASU's on-line for use by the Workload Generator, and starting the Workload Generator, no substantive work shall be performed on the BC prior to or in between SPC-1 Tests, Test Phases, or Test Runs.

Comment: It is the specific intent of this clause that Test Sponsors NOT be allowed to warm up caches or optimize automated tuning parameters between a Test, Test Phase, or Test Run

5.3.12 Interpolation or Rounding

Final reported metrics shall not be interpolated or averaged across Test Runs. Results shall not be rounded for computing results, reporting results, or making comparisons across between different results.

5.3.13 I/O Profile Preservation

5.3.13.1 Each execution of a measurement interval during a test phase must produce Measured I/O Requests that reflect the workload profiles that are defined in Clause 3.5.

5.3.13.2 For each I/O stream executed during a test phase, the Measured Intensity Multiplier must satisfy at least one of following conditions:

- a. The stream's Measured Intensity Multiplier may differ from the Intensity Multiplier defined for that stream by no more than 5% of the value provided in Clause 3.5;
- b. The number of Measured I/O Requests for that stream shall differ from the product of Intensity Multiplier (defined in Clause 5.1.10) and Measured I/O Requests (defined in Clause 5.1.9) by no more than 50 I/Os.

5.3.13.3 For each I/O stream executed during a test phase, the coefficient of variation for the Measured Intensity Multiplier may be no more than 0.2, when calculated from the Measured Intensity Multiplier reported at one minute intervals throughout the measurement interval of the test phase.

Coefficient of variation is defined to be:

$$V = \frac{StDev(C)}{Mean(C)}$$

where: V is the coefficient of variation
StDev(C) is the standard deviation of the Measured Intensity Multiplier
Mean(C) is the average of the Measured Intensity Multiplier

5.3.13.4 A benchmark execution that produces a Measured Intensity Multiplier that does not satisfy the requirements defined in Clauses 5.3.13.2 and 5.3.13.3 is not compliant with this specification.

5.4 SPC-1 Performance Tests

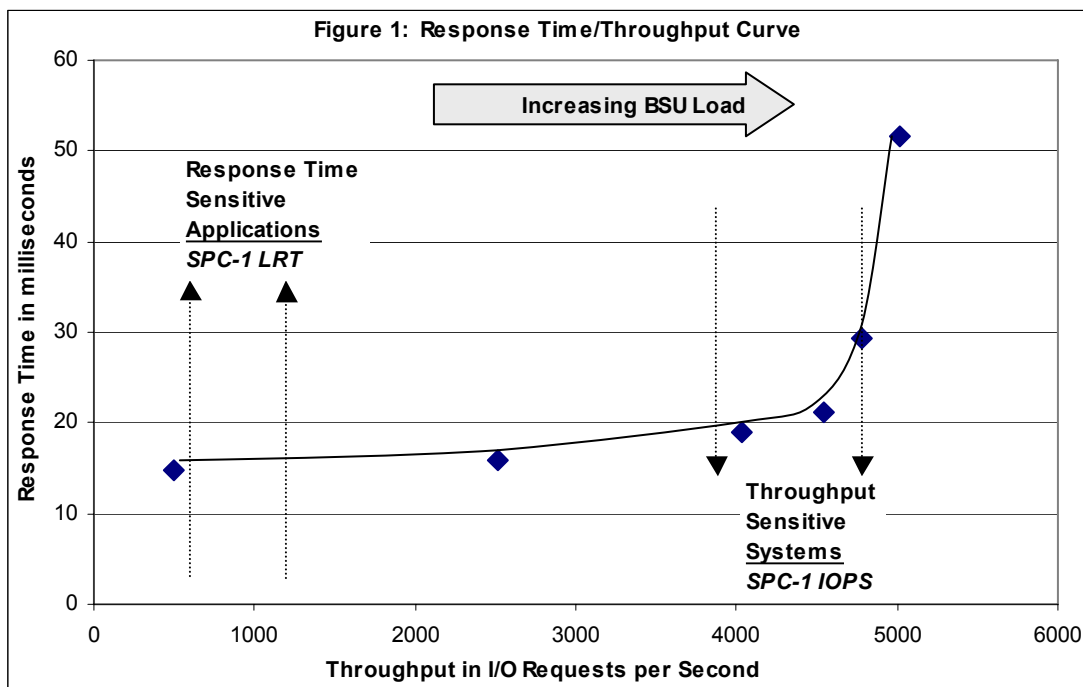
5.4.1 Introduction

SPC-1 tests and resulting metrics are designed with an understanding there are generally two classes of environments critically dependent on storage subsystem performance:

1. Systems which have many applications or many simultaneous application execution threads which can saturate the total I/O Request processing potential (i.e., throughput) of a storage subsystem. An example of such an environment would be an on-line transaction processing (OLTP) system handling airline reservations. In this case, the success of the system rests on the ability of the Storage System to process large numbers of I/O Requests while maintaining acceptable response time to the application(s) its supports. The maximum I/O Request Throughput capability of a storage subsystem in this environment is documented by the SPC-1 IOPS™ result as well as documented by a graph of Response Time versus Throughput at multiple benchmark load levels (i.e., a response time throughput curve).
2. Business critical Applications where success is dependent upon minimizing wall clock completion time but are required to issue thousands of synchronous I/O Requests (one after the completion of another) in order to complete. An example of such an environment would be a large database rebuild operation. In this case, the total I/O Request throughput on the storage subsystem is kept small in an effort to drive to bare minimum the time required to complete each I/O request and thus, achieve significantly reduced wall clock completion time for the application. The ultimate capabilities of a storage subsystem to provide minimum I/O request response times in this environment is documented by the SPC-1 LRT™ result.

Figure 5-3 illustrates the relationship of these two testing objectives via a response time throughput curve.

Figure 5-3: Key SPC-1 Test Objectives



5.4.2 An Overview of the SPC-1 Benchmark Tests

The SPC-1 benchmark includes the following three Tests:

- The Primary Metrics Test (Clause 5.4.4).
- The two Repeatability Tests, LRT and IOPS (Clause 5.4.5).
- The Data Persistence Test (Clause 6).

Each Test must be completed and reported for a SPC-1 benchmark result. Each Test may contain a number of Test Phases and associated Test Runs. Figure 5-4 summarizes in a convenient illustration the flow and time requirements of the SPC-1 Tests.

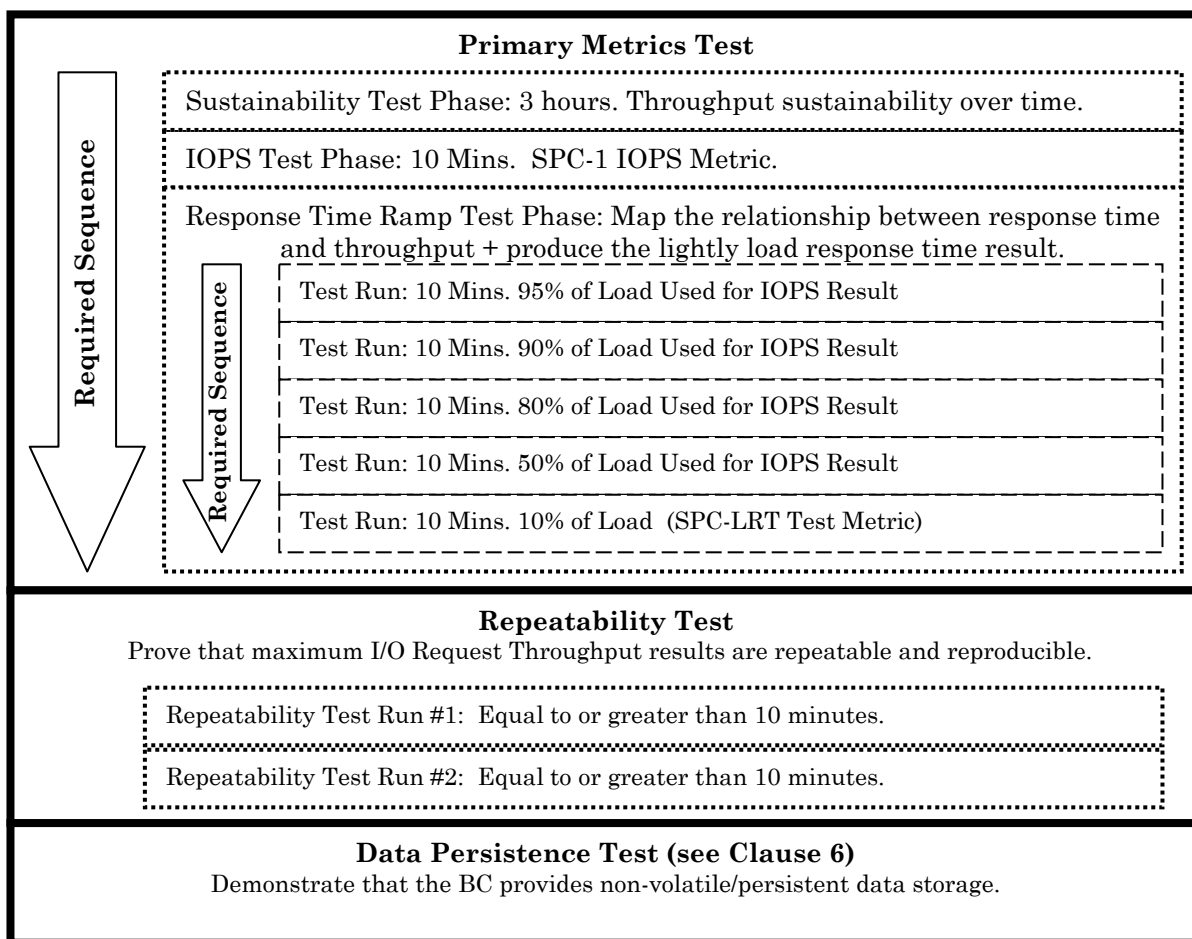
5.4.3 SPC-1 Benchmark Test Sequence

The Tests must be executed in the following sequence: Primary Metrics, Repeatability, and Data Persistence. That required sequence must be uninterrupted from the start of Primary Metrics to the completion of Persistence Test Run 1. Uninterrupted means the Benchmark Configuration shall not be power cycled, restarted, disturbed, altered, or adjusted during the above measurement sequence. If the required sequence is interrupted other than for the Host System/TSC power cycle between the two Persistence Test Runs, the measurement is invalid.

The Test Sponsor is not limited in the number of attempts to complete the required, uninterrupted sequence of SPC-1 Tests. Figure 5.4 illustrates the required sequence of SPC-1 Tests.

An exception may be made by the auditor to the above requirement for an uninterrupted sequence of SPC-1 Tests. If such an exception is made, it will be documented in the “Anomalies or Irregularities” section of the SPC-1 Full Disclosure Report as well as the “Audit Notes” portion of the Audit Certification Report.

Figure 5-4: Summary of SPC-1 Tests



5.4.4 Primary Metrics Test

The SPC-1 Primary Metrics Test uses the Workload Generator as described in Clause 4 to execute the Workload defined in Clause 3 against the Data Repository as defined in Clause 2.

The Primary Metrics Test has three Test Phases, which shall be executed in sequence:

1. Sustainability.
2. IOPS (I/Os Per Second)
3. Response Time Ramp.

The duration of the Start-Up and Shut-Down periods for each Test Run in the Primary Metrics Test shall be identical.

5.4.4.1 Sustainability Test Phase

5.4.4.1.1 The Sustainability Test Phase has exactly one Test Run and shall demonstrate the maximum sustainable I/O Request Throughput within at least a continuous three (3) hour Measurement Interval. This Test Phase also serves to insure that the TSC has reached steady state prior to reporting the final maximum I/O Request Throughput result (SPC-1™ IOPS).

Comment: It is the intent of this test that customers, consultants, or competitors be able to easily demonstrate that an IOPS result can be consistently maintained over long periods of time as would be expected in system environments with demanding long term I/O Request Throughput requirements.

5.4.4.1.2 The computed I/O Request Throughput of the Sustainability Test must be within 5% the reported SPC-1 IOPS™ result. Thus, the Sustainability Test Phase can constrain the reported IOPS result. The IOPS Test (that follows the Sustainability Test) must be run at the same BSU load level as the Sustainability Test.

5.4.4.1.3 The Measured Intensity Multiplier for each I/O stream in the Sustainability Test must satisfy the I/O mix requirements defined in Clause 5.3.13.

5.4.4.1.4 The Average Response Time, as defined in Clause 5.1.1, will be computed and reported for the Sustainability Test Run and cannot exceed 30 milliseconds. If the Average Response Time exceeds that 30-millisecond constraint, the measurement is invalid.

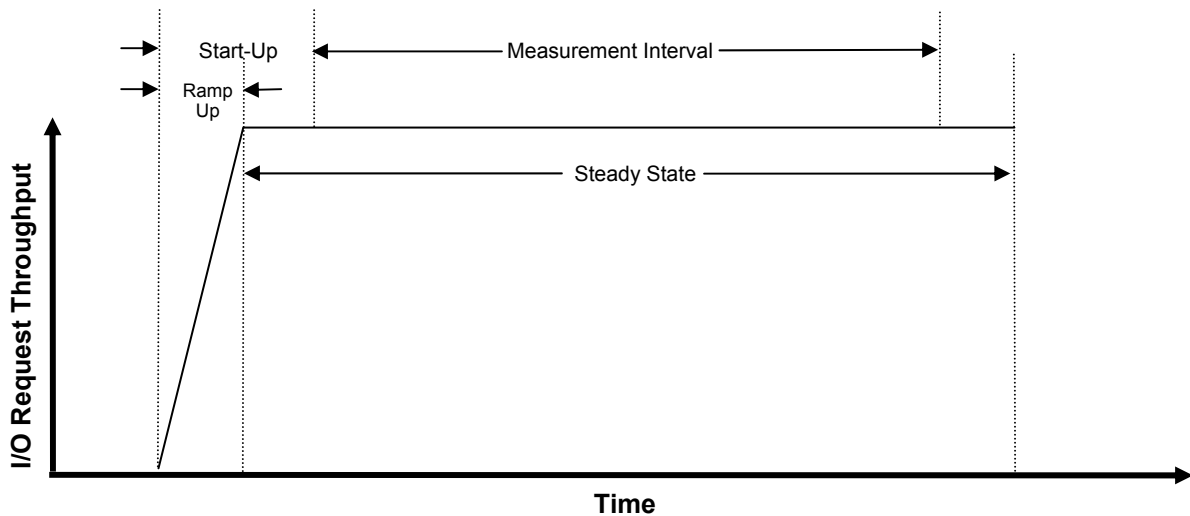
5.4.4.1.5 All Sustainability Test Phase results or data used to compute Sustainability Test Phase results shall be obtained from Workload Generator Results Files.

5.4.4.1.6 Workload Generator Results Files and Summary Results Files produced from Sustainability Test Phase shall be preserved and supplied to the SPC Audit Service. The format and distribution medium used to communicate this information to the SPC Audit Service shall be determined by the SPC Audit Service.

5.4.4.1.7 The Sustainability Test Phase will have a Start-Up, Ramp-Up, Steady State, Ramp Down, and Shut-Down period as well as a Measurement Interval.

5.4.4.1.8 Figure 5-5 illustrates the events and components of the Sustainability Test Phase.

Figure 5-5: Sustainability Test Phase



5.4.4.2 IOPS Test Phase

5.4.4.2.1 The IOPS Test Phase has one Test Run and is intended to rigorously document the maximum attainable I/O Request Throughput of the Tested Storage Configuration (TSC) after achieving sustainable and consistent I/O Request Throughput.

5.4.4.2.2 The reported metric resulting from the IOPS test is SPC-1 IOPS™, computed as the I/O Request Throughput for the Measurement Interval of the IOPS Test Run.

5.4.4.2.3 The Average Response Time, as defined in Clause 5.1.1, will be computed and reported for the IOPS Test Run and cannot exceed 30 milliseconds. If the Average Response Time exceeds that 30-millisecond constraint, the measurement is invalid.

5.4.4.2.4 See Figure 5-6 for an illustration of the events and components of the IOPS Test Phase and its relationship to other Test Phases. This illustration is not to scale.

5.4.4.2.5 The IOPS Test Phase immediately follows the Sustainability Test Phase.

***Comment:** It is the intent of this clause to insure that the BC and TSC have demonstrated Steady State in preparation for the reported IOPS result.*

5.4.4.2.6 The IOPS Test Phase is run at the same BSU load level as the Sustainability Test.

5.4.4.2.7 The IOPS Test Phase will have a Start-Up, Ramp-up, Steady State, Ramp-down, and Shutdown period as well as a Measurement Interval.

5.4.4.2.8 The Measured Intensity Multiplier for each I/O stream in the IOPS Test Run must satisfy the I/O mix requirements defined in Clause 5.3.13.

5.4.4.2.9 The BSU load presented by the Workload Generator to ASUs shall remain unchanged between the Sustainability Test Phase and IOPS Test Phase.

5.4.4.2.10 During the transition from the Sustainability Test Phase to IOPS Test Phase, the I/O Request Throughput shall not drop below 50% of the SPC-1 IOPS™ result. For example, if a Test Sponsor obtained an SPC-1 IOPS™ I/O Request Throughput result of 200, during the transition to the IOPS Test Phase, the I/O Request Throughput shall not have dropped below 100.

5.4.4.2.11 The duration of the Measurement Interval for the IOPS Test Phase is 10 minutes.

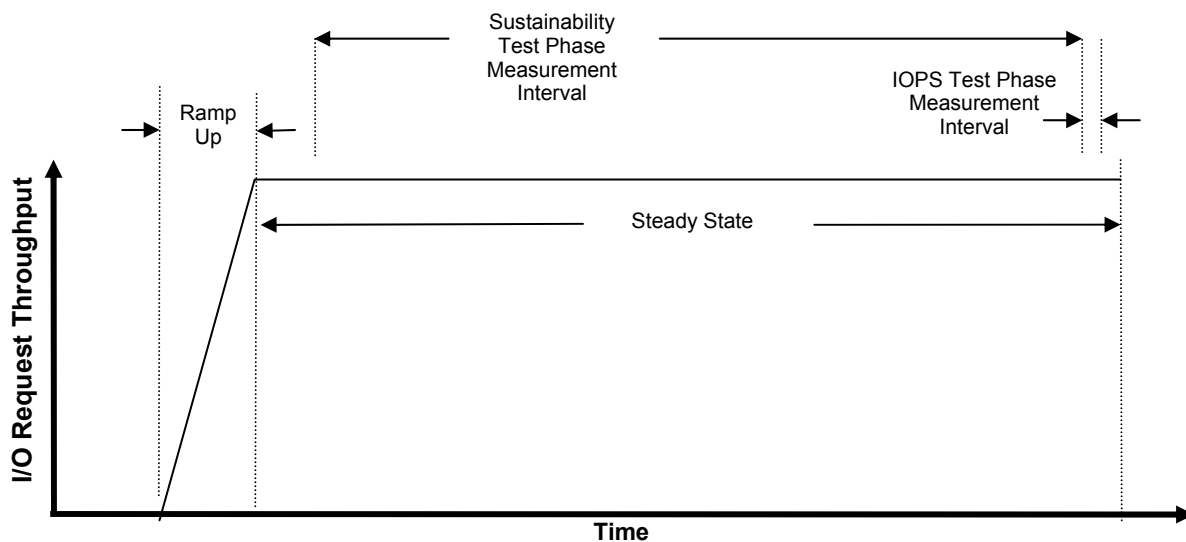
5.4.4.2.12 The Test Sponsor shall do nothing to impact the I/O Request Throughput between the end of the Sustainability Test Phase and the beginning of the IOPS Test Phase.

Comment: *The intent of Clauses 5.4.4.2.9, 5.4.4.2.10, and 5.4.4.2.12 is to ensure the load presented to the TSC during the transition between the two Test Phases remains under the control of the Workload Generator, without any intervention from the test sponsor, while constraining the variance in I/O Request Throughput during each Test Phase transition*

5.4.4.2.13 All IOPS Test Phase data used to compute IOPS Test Phase results shall be obtained from Workload Generator Results Files.

5.4.4.2.14 Workload Generator Results Files and Summary Results Files produced from the IOPS Test Phase shall be preserved and supplied to the SPC Audit Service. The format and distribution medium used to communicate this information to the SPC Audit Service shall be determined by the SPC Audit Service.

Figure 5-6: Sustainability & IOPS Test Phases



5.4.4.3 Response Time Ramp Test Phase

- 5.4.4.3.1 This test phase shall measure Average Response Time and I/O Request Throughput for BSU load levels at 10%, 50%, 80%, 90%, and 95% of the BSU load level used to report the IOPS test result. As such this Test Phase has exactly five Test Runs. The objectives of this Test Phase are to demonstrate:
- The relationship between Average Response Time and I/O Request Throughput for a Test Sponsor's TSC (i.e., complete a response time/throughput curve).
 - The (optimal) Average Response Time of a lightly loaded TSC (the SPC-1 LRT™ result).
- 5.4.4.3.2 The BSU level required at a given load level in this test phase shall be the integer value resulting from truncating the product of the BSU level used to report the IOPS test result and the load level percentage.
- 5.4.4.3.3 The duration for each Measurement Interval shall be equal to 10 minutes.
- 5.4.4.3.4 The sequence of Test Runs in this Test Phase shall be:
1. 95% BSU load level.
 2. 90% BSU load level.
 3. 80% BSU load level.
 4. 50% BSU load level.
 5. 10% BSU load level (SPC-1 LRT™ Metric)
- 5.4.4.3.5 Each Test Run in this Test Phase shall have a Start-Up, Ramp-Up, Steady State, Ramp-down, and Shutdown period as well as a Measurement Interval.
- 5.4.4.3.6 The Measured Intensity Multiplier for each I/O stream in each Test Run must satisfy the I/O mix requirements defined in Clause 5.3.13.
- 5.4.4.3.7 See Figure 5-7 for an illustration of the events and components of the Response Time Ramp Test Phase and its relationship to other Test Phases in this Test. This figure illustrates all measurement intervals associated with the Primary Metrics Test. The figure is not to scale.
- 5.4.4.3.8 The Response Time Ramp Test Phase immediately follows the IOPS Test Phase.
- 5.4.4.3.9 The BC or TSC may not be restarted between the IOPS Test Phase and the Response Time Ramp Test Phase. In addition, the Test Sponsor shall do nothing to impact the I/O Request Throughput between the end of the IOPS Test Phase and the beginning of the Response Time Ramp Test Phase.
- 5.4.4.3.10 The Test Sponsor shall do nothing to impact the I/O Request Throughput between Test Runs of this Test Phase.

5.4.4.3.11 During the transition from one BSU load level to the next of the Response Time Ramp Test Phase, the I/O Request Throughput shall not drop below 50% of the next reported I/O Request Throughput Result. For example, if a Test Sponsor obtained an I/O Request Throughput result of 180 at the 90% BSU load level, during the transition to the 80% Load Level, the I/O Request Throughput shall not drop below 80.

Comment: The intent of Clauses 5.4.4.3.7-5.4.4.3.10 is to ensure the load presented to the TSC during the transition between Test Runs remains under the control of the Workload Generator, without any intervention from the test sponsor, while constraining the variance in I/O Request Throughput during each Test Run transition.

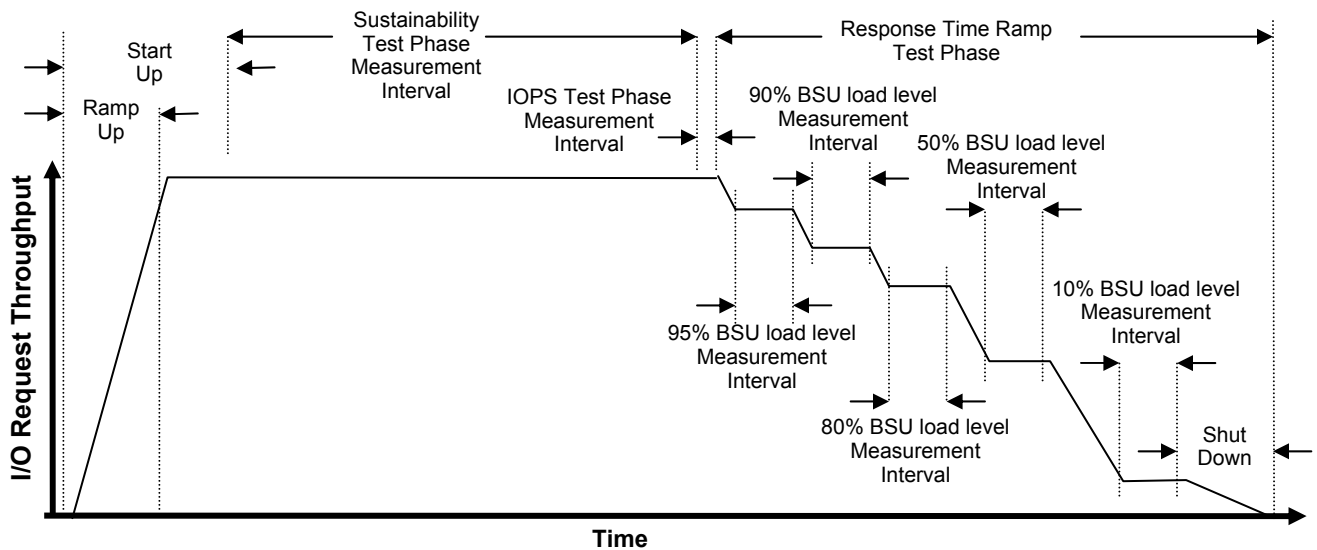
5.4.4.3.12 The final reported SPC-1 LRT™ Metric is computed as the Average Response Time of the 10% BSU load level Test Run.

5.4.4.3.13 I/O Request Throughput and Average Response Time will be computed for the Measurement Interval of each Test Run in the Response Time Ramp Test Phase.

5.4.4.3.14 All Response Time Ramp Test Phase results or data used to compute Response Test Ramp Test Phase results shall be obtained from Workload Generator Results Files.

5.4.4.3.15 Workload Generator Results Files and Summary Results Files produced for all Test Runs of the Response Time Ramp Test Phase shall be preserved and supplied to the SPC Audit Service. The format and distribution medium used to communicate this information to the SPC Audit Service shall be determined by the SPC Audit Service.

Figure 5-7: Primary Metrics Test



5.4.5 Repeatability Test

The Repeatability Test demonstrates the repeatability and reproducibility of the SPC-1 IOPS™ and SPC-1 LRT™. The test uses the Workload Generator as described in Clause 4 to execute the Workload defined in Clause 3 against the Data Repository as defined in Clause 2.

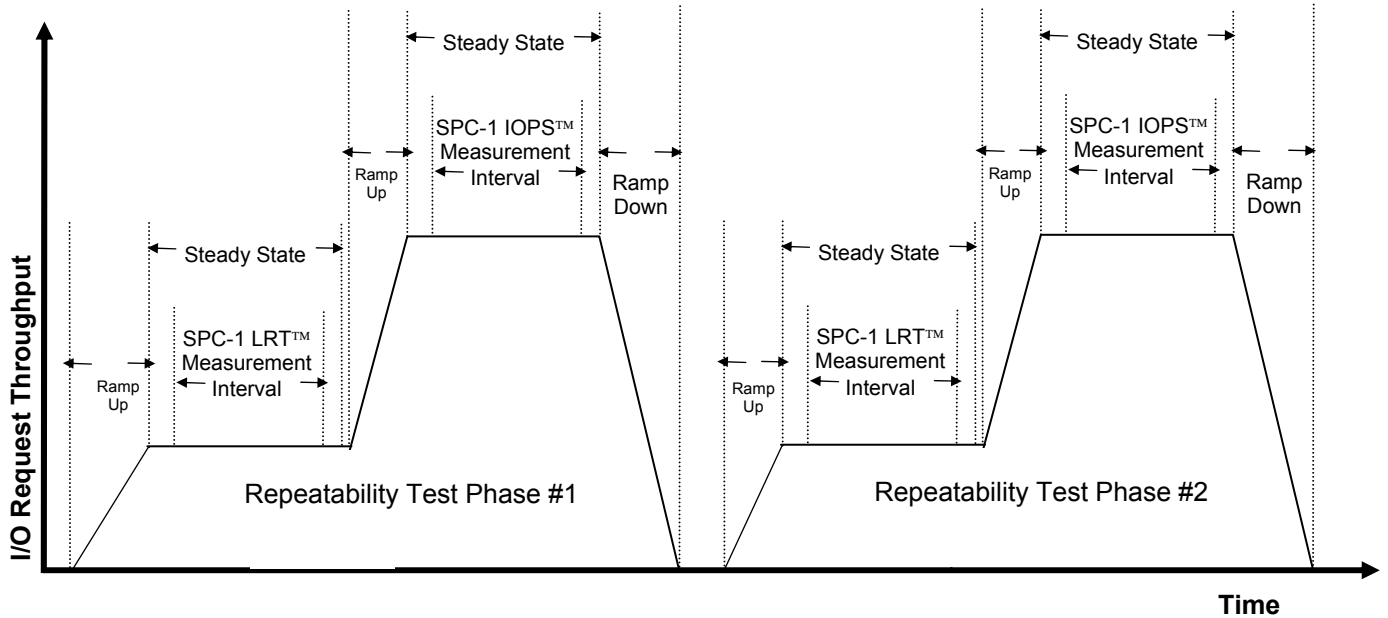
There are two identical Test Phases in the Repeatability Test. Each Test Phase contains two Test Runs. The first Test Run (SPC-1 LRT™ Repeatability Test Run) produces a SPC-1 LRT™ result. The second Test Run (SPC-1 IOPS™ Repeatability Test Run) produces a SPC-1 IOPS™ result. . If any Test Run in either of the two Test Phases is not compliant, both Test Phases must be repeated.

- 5.4.5.1 The Test Sponsor shall do nothing to impact the performance of the BC between Test Runs of the Repeatability Test.
- 5.4.5.2 Each Test Run in the Repeatability Test will contain a Start-Up, Ramp-Up, Steady State, Ramp-down, and Shut-down period as well as a Measurement Interval.
- 5.4.5.3 The Measured Intensity Multiplier for each I/O stream in the Repeatability Test must satisfy the I/O mix requirements defined in Clause 5.3.13.
- 5.4.5.4 The duration of the Start-Up, Shut-Down, and Measurement Interval will be identical for each Test Run in the Repeatability Test.
- 5.4.5.5 The Measurement Interval for each Repeatability Test Run shall be equal to or greater than 10 minutes.
- 5.4.5.6 Figure 5-8 illustrates the sequence of events and components of the Repeatability Test.
- 5.4.5.7 Steady State for the first Test Run in each Test Phase is attained at the same BSU load level used in the Primary Metrics Test to produce the final reported SPC-1 LRT™ metric.
- 5.4.5.8 Steady State for the first second Test Run in each Test Phase is attained at the same BSU load level used in the Primary Metrics Test to produce the final reported SPC-1 IOPS™ metric.
- 5.4.5.9 The final reported SPC-1 IOPS™ metric is deemed reproducible and repeatable if the I/O Request Throughput for each of the two SPC-1 IOPS™ Repeatability Test Runs is greater than the reported SPC-1 IOPS™ metric minus 5%. As such, the Repeatability Test will constrain the final reported SPC-1 IOPS™ metric.
- 5.4.5.10 The Average Response Time, as defined in Clause 5.1.1, will be computed and reported for each of the two SPC-1 IOPS™ Test Runs and cannot exceed 30 milliseconds. If the Average Response Time exceeds that 30-millisecond constraint, the measurement is invalid.
- 5.4.5.11 The final reported SPC-1 LRT™ metric is deemed reproducible and repeatable if the Average Response Time for each of the two SPC-1 LRT™ Repeatability Test Runs is less than the reported SPC-1 LRT™ metric plus 5%. As such, the LRT Repeatability Test will constrain the final reported SPC-1 LRT™ metric.
- 5.4.5.12 All Repeatability Test data used to compute Repeatability Test results shall be obtained from Workload Generator Results Files.

5.4.5.13 Workload Generator Results Files and Summary Results Files produced from each Test Run of the IOPS Repeatability Test shall be preserved and supplied to the SPC Audit Service. The format and distribution medium used to communicate this information to the SPC Audit Service shall be determined by the SPC Audit Service.

5.4.5.14 Each instance of the Repeatability Test shall be run with a statistically distinct sequence of I/O requests to assure that prior cache contents do not affect the results of the current test phase. The two Repeatability Test Phases may be run uninterrupted.

Figure 5-8: Repeatability Test



Clause 6: Data Persistence Requirements and Test

6.1 Introduction

Logical Volumes and related Application Storage Units (ASUs) must demonstrate the ability to preserve data across extended periods of power loss without corruption or loss. To provide this “Persistence” capability, the Tested Storage Configuration (TSC) must use Logical Volumes and related ASUs that:

- Are capable of maintaining data integrity across power cycles or outages.
- Ensure the transfer of data between Logical Volumes and host systems occurs without corruption or loss.

Data persistence does not guarantee data availability. Data loss may result from system component failure or unplanned catastrophe. The storage subsystem may, but need not, include mechanisms to protect against such failure modes. Testing or guaranteeing such failure modes and increased availability mechanisms in the test storage configuration are not within the mandate or the scope of this benchmark.

6.2 Persistence Test Validation

Validation that the SPC-1 Persistence Test completed successfully is provided by the SPC Audit Service, attesting to the fact that the test has been satisfactorily completed on the BC per the test requirements below.

6.3 SPC-1 Persistence Test Constraints

- 6.3.1 This test is performed in isolation from other SPC-1 Tests.
- 6.3.2 The SPC-1 Workload Generator shall be used to perform the SPC-1 Persistence Test.
- 6.3.3 The results of the SPC-1 Persistence Test must successfully complete Audit Certification as defined in Clause 10.2 before they can be reported or accepted as official SPC results.
- 6.3.4 Any TSC that fails a Persistence Test can be rerun until it passes.
- 6.3.5 The physical and logical configuration of the BC shall not be changed between the successful execution of the Persistence Test and any other SPC-1 Test.
- 6.3.6 No other work shall be performed on the BC between the successful execution of the Persistence Test and the execution of other SPC-1 Tests, Test Phases, or Test Runs.
- 6.3.7 A TSC must successfully complete the Persistence Test in order for SPC-1 results to be valid.
- 6.3.8 Success or failure of the Persistence Test shall be determined solely by information obtained from an SPC-1 Workload Generator Results File.
- 6.3.9 All I/O Requests initiated during any part of the Persistence Test in the SPC-1 benchmark must complete. A Failed I/O Request shall render a Persistence Test invalid.
- 6.3.10 No other work shall be performed on the BC during the execution of the Persistence Test Procedure.

6.4 Data Persistence Test Procedure

The following sequence of steps must be followed to complete the Persistence Test.

1. The SPC-1 Workload Generator contains a special module that will be configured to write 16 block I/O Requests at random over the total Addressable Storage Capacity of the TSC for 10 minutes at greater than or equal to 25% of the BSU level used to generate the reported SPC-1 IOPS™ rate. The SPC-1 Workload Generator shall at random select a pattern of bits to be written into the blocks of each I/O request written in this test phase. The address of each Logical Block written as well as the type of pattern written in each logical block shall be recorded in an encoded log file by the SPC-1 Workload Generator. This log file is to be preserved and provided to the SPC Audit Service as well as used later in this test sequence.
2. Shutdown and power off the Tested Storage Configuration (TSC). Any TSC caches employing battery backup must be flushed/emptied.
3. If the TSC includes the Host System(s), shutdown and power off the Host System(s). Any TSC caches on the Host System(s) employing battery backup must be flushed/emptied. If the TSC does not include the Host System(s), there is no requirement for the Host System configuration to be shutdown and power cycled.
4. Restart the TSC and if the Host System(s) were shutdown, restart the Host System(s).
5. Read and verify all Logical Blocks previously written in step #1 using the log file recorded in step #1. Verification is performed by the SPC-1 Workload Generator by reading each block written in step #1, and insuring that the pattern of bits written in step #1 is correct.
6. If the SPC-1 Workload Generator verifies that each block written in step #1 has been unaltered in content in the course of executing steps #2 through #4 the TSC passes the Persistence Test, else, the TSC fails.
7. The Workload Generator produces a Persistence Test Results File for each run of the Persistence Test. The format and distribution medium for these Results Files shall be determined by the SPC Audit Service. The Persistence Test Results File will be produced in a human-readable format and will include data necessary for audit authentication. An example Persistence Test Results File is provided in Appendix B.

Clause 7: Reported Metrics

7.1 SPC-1 Price-Performance

- 7.1.1 SPC-1 Price-Performance is defined as the ratio of the Total System Price as defined in 8.1.1.2, to the SPC-1 IOPS™, the I/O Request Throughput of the TSC as established by the IOPS Test Phase in Clause 5.4.4.2.
- 7.1.2 SPC-1 Price-Performance must be reported to a resolution of the smallest negotiable whole unit of the local currency in which Total System Price is reported, per Clause 8.2.1.5. For example, configurations priced in US dollars would report SPC-1 Price-Performance to a resolution of \$0.01.

7.2 Primary Metrics Requirements

- 7.2.1 The following primary metrics are required to be reported for each SPC-1 result.
1. **SPC-1 IOPS™** the I/O Request Throughput of the TSC as established by the IOPS Test Phase in Clause 5.4.4.2.
 2. **Total ASU Capacity** as defined in Clauses 2.6.6 and 2.6.7.
 3. **SPC-1 Price-Performance** as defined in Clause 7.1.
- 7.2.2 All external references to an SPC-1 IOPS results must be identified as “**SPC-1 IOPS™**”.
- 7.2.3 All external references to the Total ASU Capacity primary metric must be identified as “**Capacity of xxx GB**”.
- 7.2.4 All external references to SPC-1 Price-Performance must be identified as “**SPC-1 Price-Performance of xxx**” with the appropriate currency symbol for local pricing.
- 7.2.5 All external references to each of the primary metrics listed above must state the data protection level employed in the benchmark as defined in Clause 2.4.5.
- 7.2.6 All external references to the primary metrics listed above must also state the appropriate category, as defined in Clauses 4.6.1 and 4.6.2, which describes the Test Storage Product.
- 7.2.7 Test sponsors that publish or market an SPC-1 result must insure that:
1. The SPC-1 IOPS™ rate, ASU Capacity, and SPC-1 Price-Performance appear as a complete and coupled set of information using the same font style, font size, and text clarity.
 2. An appropriately and clearly labeled SPC-1 Audit Identifier appears with the SPC-1 IOPS™, ASU Capacity and SPC-1 Price-Performance results.
- 7.2.8 The SPC-1 IOPS™ rate, Total ASU Capacity, and SPC-1 Price-Performance must appear in the same paragraph and on the same page (or set of adjacent items in a single list) when externally communicating an SPC-1 performance result. In addition, SPC-1 IOPS™ rate, Total ASU Capacity, data protection level, SPC-1 Price-Performance, Tested Storage Product category, and SPC-1 Audit Identifier must be published in sequence per the following example.

Example: “Today XXXXX Corporation announces an industry leading SPC-1 benchmark result on the new YYYYYY storage system. The YYYYYY produced an **SPC-1 IOPS™** rate of NNNNN and an **SPC-1 Price-Performance** value of \$zz.zz at a **Capacity** of xxx GB. The YYYYYY [includes all the storage devices used in the benchmark configuration / does not include all storage devices used in the benchmark configuration, requiring storage devices to be added to the benchmark configuration]. These results used a data protection level of **PPPPP** and received SPC-1 Audit Identifier **ZZZ-N**. “

- 7.2.9 A given document, article, presentation, or publication may reference an individual benchmark result provided that the reference follows a paragraph which satisfies the requirements of 7.2.8.

***Note:** The bold formatting in Clauses 7.2.1-7.2.3 and the example in Clause 7.2.8 is added for editorial emphasis. That specific formatting is not required for the items that are reported.*

7.3 Additional Metrics Requirements

- 7.3.1 All external references to an SPC-1 LRT results must be identified as “**SPC-1 LRT™**”.

Clause 8: Pricing

This clause defines the components and methodology necessary to calculate required three-year pricing and the SPC-1 price-performance primary metric. The fundamental premise of this clause is that what is tested is priced and what is priced is tested.

8.1 **Priced Components**

The components to be priced include the hardware and software components present in the Tested Storage Configuration (TSC), any additional operational components required by the TSC, and three-year maintenance on all of the above components.

8.1.1 **Tested Storage Configuration (TSC)**

The TSC represents the physical configuration that is physically present during the benchmark measurement as defined in Clause 4.5. The TSC when used in pricing must represent a customer orderable configuration. To allow the use of a valid measurement configuration that may not represent a customer orderable configuration, this clause will distinguish between the TSC and Priced Storage Configuration.

8.1.1.1 **Priced Storage Configuration**

The Priced Storage Configuration represents a customer orderable configuration. If the TSC, without modification, is customer orderable, it is also the Priced Storage Configuration.

In cases where the TSC is a valid measurement configuration but not a customer orderable configuration, the TSC and Priced Storage Configuration will differ. In those cases, the Priced Storage Configuration will be comprised of the TSC with the appropriate components added or deleted to create a customer orderable configuration.

For example, consider a configuration in which a portion of the Physical Storage Capacity (Clause 2.2) is not physically connected to the TSC, and the TSC can be ordered without that unused storage. In this case, the Priced Storage Configuration would not include the unused storage.

A second example would be a configuration in which all of the Physical Storage Capacity is used in the benchmark, but that specific storage capacity is not orderable. The amount of storage included in the pricing would be adjusted to create an orderable configuration, again resulting in a Priced Storage Configuration that differs from the TSC.

In those cases where there is deletion or addition of components to create a customer orderable configuration, the Priced Storage Configuration must be capable of providing at least the same level of reported performance as the TSC. The intent of this requirement is to ensure that any component change to the TSC be performance-neutral.

8.1.1.2 **Calculation of TSC Pricing**

Calculation of the three-year pricing, known as Total System Price, includes:

- The cost of the Priced Storage Configuration as defined in Clause 8.1.1.1.
- The cost of additional hardware and/or software products as described in Clause 8.1.2.
- Maintenance as defined in Clause 8.1.3
- Host System(s) that are considered priced TSC components (Clause 4.5.1).

Specifically excluded from the pricing calculation are the following:

- Components necessary for the execution of the benchmark but do not provide any storage functionality and do not enhance the measured performance of the Tested Storage Configuration.
- System software, which is not a third-party product, that meets the exclusions listed in Clause 4.5.1.
- The cost of maintenance for HBA included in the Priced Storage Configuration.

8.1.2 Additional Operational Components

- 8.1.2.1 Additional products explicitly required for the operation, administration, or maintenance of the Priced Storage Configuration must be included. This includes all required third-party software and hardware products.
- 8.1.2.2 Copies of the software used by the Priced Storage Configuration, on appropriate media, and a software load device, if required for initial load or maintenance updates, must be included.
- 8.1.2.3 The price of all cables used to connect components of the Priced Storage Configuration must be included.

8.1.3 Maintenance

- 8.1.3.1 Hardware maintenance and software support, no matter what it is called by the vendor, provides the following:

- Acknowledgement of new and existing problems within four (4) hours.
- On-site presence of a qualified maintenance engineer or provision of a customer replaceable part within four (4) hours of the above acknowledgement for any hardware failure that results in an inoperative Priced Storage Configuration that can be remedied by the repair or replacement of a Priced Storage Configuration component. In either case, the remedy will result in resumption of operation.

Comment: Resumption of operation means the Priced Storage Configuration must be returned to the same state/configuration that was present before the failure.

- Commitment to fix software defects within a reasonable time.

- 8.1.3.2 The maintenance pricing must be independent of actual failure rates over the three-year period, no matter how many failures occur during that period. The use of Mean Time Between Failure (MTBF) data to directly compute the maintenance cost for this benchmark is precluded. The hardware maintenance pricing requirements cannot be met by pricing based on the cost to fix specific failures, even if the failure rate is calculated from MTBF data.

- 8.1.3.3 Hardware maintenance and software support must be configured using standard pricing which covers 7 days per week, 24 hours per day coverage, either on-site, or if available as standard offering, via a central support facility for a duration of at least three years (36 months).

8.2 Pricing Methodology

The pricing methodology must reflect the cost of operation of the Benchmark Configuration using packages and discounts commonly practiced and generally available products. This cost must be disclosed in a line item fashion using local pricing.

8.2.1 Packages and Discounts

Packaging and pricing that are generally available to customers are acceptable. Promotional and/or limited availability offerings are explicitly excluded. Revenue discounts based on total price are permissible. Any discount must be only for the configuration being priced and cannot be based on past or future purchases. Individually negotiated discounts are not permitted. Special customer discounts (e.g., GSA schedule, educational schedule) are not permitted. This is a one time, stand-alone purchase.

- 8.2.1.1 Generally available discounts for the priced configuration are allowed.
- 8.2.1.2 Generally available packaged pricing is allowed.
- 8.2.1.3 Assumptions of other purchases, other sites with similar systems, or any other assumption that relies on the principle that the customer has made any other purchase from the vendor are specifically prohibited.
- 8.2.1.4 Local retail pricing and discount structure shall be used in each country for which results are published.
- 8.2.1.5 Price shall be represented by the currency with which the customer would purchase the system.
- 8.2.1.6 For all hardware components used in the priced system, the cost must be the price of a new component (i.e., not reconditioned or previously owned).
- 8.2.1.7 For Test Sponsor(s) who have only indirect sales channels, pricing must be actual generally available pricing from indirect channels that meet all other requirements of Clause 8.
- 8.2.1.8 Maintenance may be bundled as a component of package pricing. In that case, the maintenance component of the package must be clearly identified in the description of the bundle/package. A Test Sponsor may also include a standard multi-year maintenance option as a separately priced component. In cases where there is not such a 'bundling' of maintenance or a standard multi-year maintenance options is not available, the three-year maintenance cost shall be computed as three times the one-year maintenance cost. If maintenance is priced in that manner, a discount based on pre-payment in excess of 12 months is prohibited.

8.2.2 Product Availability

- 8.2.2.1 The Priced Storage Configuration is the actual configuration the customer would purchase. However, vendors may announce new products and disclose benchmark results before new products have actually shipped. This is allowed, but any use of benchmark-special implementations is specifically disallowed (see Clause 0.2).
- 8.2.2.2 Clause 0.2 requirements must be fulfilled with respect to the set of possible customers (users) in the country where the BC is priced.
- 8.2.2.3 All hardware and software used in the calculations must be announced and generally orderable by customers.
- 8.2.2.4 Each product or collection of products that comprise the Priced Storage Configuration must have an Availability Date, which is a date such that it is committed that by that date all requirements of Clause 0.2 will be fulfilled for that product or collection, including delivery for general availability.
- 8.2.2.5 The Priced Storage Configuration Availability Date and an availability date for any product not already generally available must be disclosed.

8.2.2.6 The Priced Storage Configuration Availability Date must not exceed three months beyond the Full Disclosure Report submittal date.

***Comment:** The essence of the Priced Storage Configuration Availability Date is the ability to take physical delivery of an integrated configuration that is identical the priced configuration, achieves the tested performance, and demonstrates fulfillment of all the requirements of Clause 0.2.*

8.2.2.7 The Test Sponsor must disclose all effective date(s) of the reported prices

8.2.3 Third-Party Pricing

8.2.3.1 In the event that any hardware, software, or maintenance is provided by a third party not involved as a Test Sponsor of the benchmark, the pricing must satisfy all requirements for general availability, standard volume discounts, and full disclosure.

8.2.3.2 The Test Sponsor is required to clearly identify all the items, components and services that are not acquired from the Test Sponsor. Any third party supplier's items and prices, including discounts, are subject to the same disclosure requirements as those components supplied by the Test Sponsor. Discounts shall not be dependent on purchases from any other suppliers.

8.2.3.3 Any pricing that is not directly offered by the Test Sponsor and not derived from the third party supplier's generally available pricing and discounts must be guaranteed by the third party in a written price quotation. The quotation must be valid for a period not less than 60 days from the date the results are submitted.

8.2.3.4 Third party's written quotations must be included in the Full Disclosure Report and must state:

- That the quoted prices are generally available;
- The time period for which the prices are valid;
- The basis of all discounts;
- Any terms and conditions that apply to the quoted prices.

8.3 Required Reporting

8.3.1 Pricing Spreadsheet

8.3.1.1 The pricing spreadsheet details how the three-year cost of ownership is computed. It contains the prices, discounts, warranty information, and maintenance cost for all the hardware and software components in the Priced Storage Configuration. Price disclosure shall be presented in a structured fashion to enhance clarity and comparability between test results.

8.3.1.2 The **reference price** of a component or subsystem is defined as the price at which it could be ordered individually from the vendor or designated third-party supplier.

8.3.1.3 The pricing spreadsheet must be included in the Full Disclosure Report (see Clause 9.2.4.3.5) and must include the following items for each component in the Priced TSC:

- Part name or brief description
- Part number

- Source of the component, whether from a Test Sponsor or a third party (note: this can be an index into a list of component sources provided that list is included in the pricing spreadsheet)
- Reference price of the component (see Clause 8.3.1.2)
- Quantity of the component used in the priced configuration
- The extended price of the component, based on the reference price of the component, the quantity included in the priced configuration and any component-level discounting
- Three-year maintenance cost (including any discount for pre-payment, see Clause 8.2.1.8), or a notation that maintenance for the part is included in another maintenance charge.
- If the component is a bundle/package of parts, as allowed by Clause 8.2.1, the above items apply to the bundle but each item in the bundle/package must be clearly identified in the description of bundle/package.
- Components required to configure the Priced TSC that have an aggregate price less than 0.1% of the Priced TSC may be listed as a single line item with a description of the collection of components, e.g., "Miscellaneous Cables."

8.3.1.4 The total price of the Priced Storage Configuration and its associated three-year maintenance cost, rounded to the nearest whole dollar amount, must be included in the pricing spreadsheet.

8.3.1.5 The percentage, amount, and basis (including type and justification) of all discounts listed must be disclosed. A tabular summary may be employed to simplify the presentation.

Comment: *Thresholds for such discounts need not be disclosed.*

8.3.1.6 While package pricing is allowed, the level of discount obtained through such packages shall be disclosed by reporting the individual reference price for each component in the pricing spreadsheet (see Clause 8.3.1.2).

Comment: *This requirement does not apply to components that are not sold separately, other than as repair parts.*

8.3.2 Price Reporting

The total three-year price as described in Clause 8.3.1 will be reported with regard to pricing.

Clause 9: Full Disclosure

9.1 Supporting Definitions

9.1.1 **Response Time Frequency Distributions:** This consists of one graph and supporting table that clearly illustrates the frequency distribution of response times that occurred during an SPC-1 Test Run. The graph (see Figure 9-1) illustrates the number of occurrences for each Response Time range. Each Response Time Frequency Distribution graph and table shall have the format, content, and appearance illustrated in Figure 9-1 and Table 9-1. The intent of this graph is to supply reviewers with a consistent, clear, and powerful means for quickly assessing the response time results from a given Test Run. Data used to compute or construct the Response Time Frequency Distribution shall be obtained from Workload Generator Results Files.

Figure 9-1: Response Time Frequency Distribution (by occurrence)

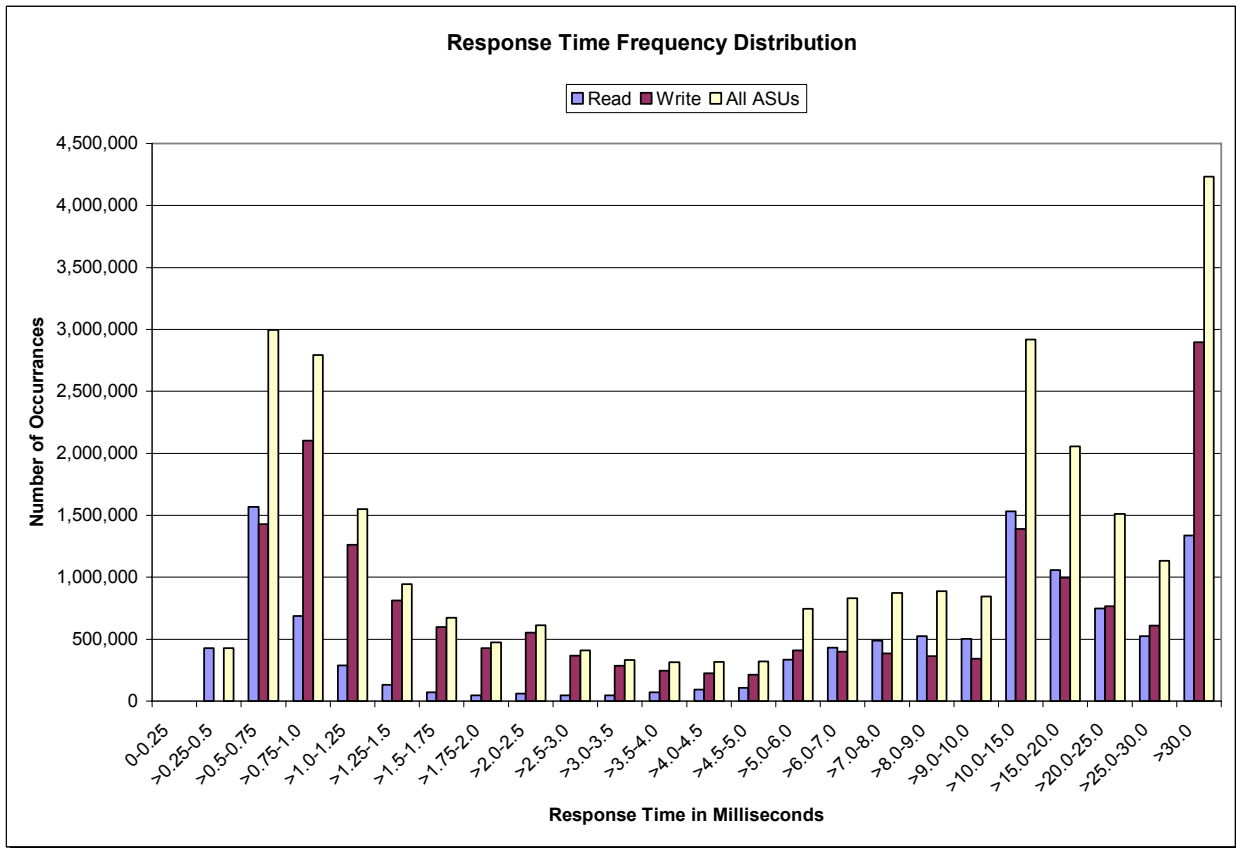


Table 9-1: Response Time Frequency Distribution

Response Time (ms)	0-0.25	>0.25-0.5	>0.5-0.75	>0.75-1.0	>1.0-1.25	>1.25-1.5	>1.5-1.75	>1.75-2.0
Read	-	427,684	1,568,848	688,322	289,759	133,147	72,296	45,788
Write	-	1,185	1,428,189	2,103,441	1,260,081	811,224	600,248	427,034
All ASUs	-	428,869	2,997,037	2,791,763	1,549,840	944,371	672,544	472,822
ASU1	-	348,613	2,169,264	1,796,157	878,643	480,369	310,003	225,586
ASU2	-	80,166	541,694	360,062	162,715	84,627	53,551	38,136
ASU3	-	90	286,079	635,544	508,482	379,375	308,990	209,100
Response Time (ms)	>2.0-2.5	>2.5-3.0	>3.0-3.5	>3.5-4.0	>4.0-4.5	>4.5-5.0	>5.0-6.0	>6.0-7.0
Read	60,251	44,812	47,992	70,566	93,029	106,316	333,996	431,023
Write	553,921	366,406	283,861	244,716	224,737	214,345	409,998	399,645
All ASUs	614,172	411,218	331,853	315,282	317,766	320,661	743,994	830,668
ASU1	326,223	241,203	203,061	201,899	210,710	216,050	538,024	620,768
ASU2	55,301	42,287	36,843	35,926	36,875	37,461	79,169	88,670
ASU3	232,648	127,728	91,949	77,457	70,181	67,150	126,801	121,230
Response Time (ms)	>7.0-8.0	>8.0-9.0	>9.0-10.0	>10.0-15.0	>15.0-20.0	>20.0-25.0	>25.0-30.0	>30.0
Read	488,549	521,991	502,486	1,531,647	1,056,940	746,630	523,564	1,335,023
Write	384,779	364,630	343,662	1,387,838	998,125	765,555	609,606	2,896,247
All ASUs	873,328	886,621	846,148	2,919,485	2,055,065	1,512,185	1,133,170	4,231,270
ASU1	652,790	663,143	627,639	2,038,331	1,338,412	868,850	579,604	1,269,839
ASU2	103,457	109,509	105,637	342,079	203,873	173,019	137,119	562,153
ASU3	117,081	113,969	112,872	539,075	512,780	470,316	416,447	2,399,278

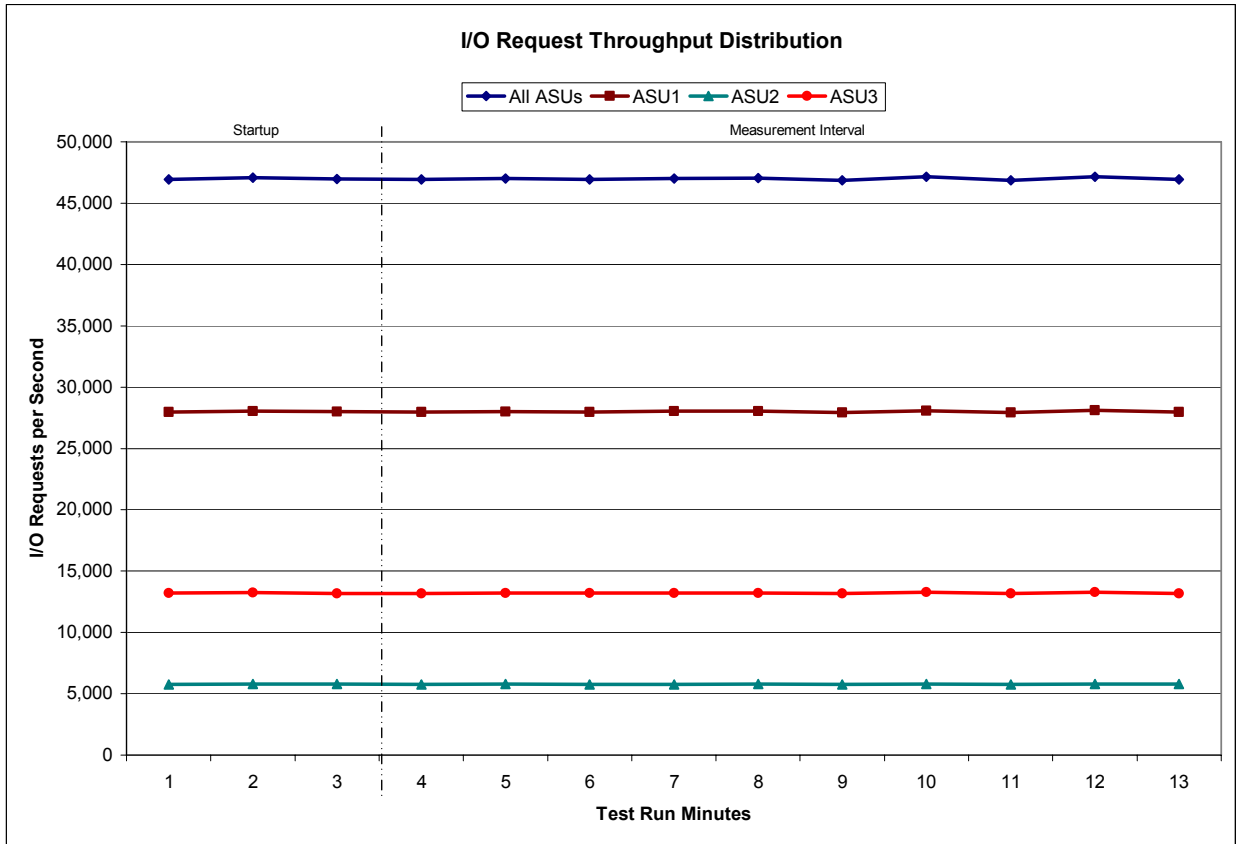
9.1.2 **I/O Request Throughput Distribution:** This consists of a graph and supporting table that clearly illustrates the I/O Request Throughput that occurred in each minute of an SPC-1 Test Run. Each I/O Request Throughput Distribution graph shall have the format, content, and appearance illustrated in Figure 9-2. The intent of this graph is to supply reviewers with a consistent, clear and powerful means for quickly assessing the I/O Request Throughput results from a given Test Run. Data used to compute or construct the I/O Request Throughput Distribution shall be obtained from Workload Generator Results Files.

A table containing the data used to generate the graph shall accompany each I/O Request Throughput Distribution graph. Each I/O Request Throughput Distribution table shall have the content and appearance illustrated in Table 9-2. Every whole minute in a Test Run shall have its data presented in the table and graph.

Table 9-2: I/O Request Throughput Distribution

940 BSUs	Start	Stop	Interval	Duration
<i>Start-Up/Ramp-Up</i>	13:08:12	13:11:13	0-2	0:03:01
<i>Measurement Interval</i>	13:11:13	13:21:26	3-12	0:10:13
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	46,952.37	27,959.13	5,769.45	13,223.78
1	47,089.50	28,054.62	5,779.40	13,255.48
2	46,971.02	28,008.15	5,782.18	13,180.68
3	46,933.32	27,975.72	5,765.35	13,192.25
4	46,996.52	28,006.45	5,782.48	13,207.58
5	46,929.67	27,965.10	5,764.03	13,200.53
6	47,009.80	28,032.75	5,775.95	13,201.10
7	47,036.07	28,040.30	5,778.10	13,217.67
8	46,884.67	27,948.15	5,767.78	13,168.73
9	47,141.68	28,066.75	5,809.87	13,265.07
10	46,870.37	27,945.45	5,756.85	13,168.07
11	47,159.78	28,105.17	5,788.82	13,265.80
12	46,941.17	27,978.97	5,783.75	13,178.45
Average	46,990.30	28,006.48	5,777.30	13,206.53

Figure 9-2: I/O Request Throughput Distribution



9.1.3 **Average Response Time Distribution:** This consists of a graph and supporting table that clearly illustrates the Average Response Time Distribution that occurred in each minute of an SPC-1 Test Run.

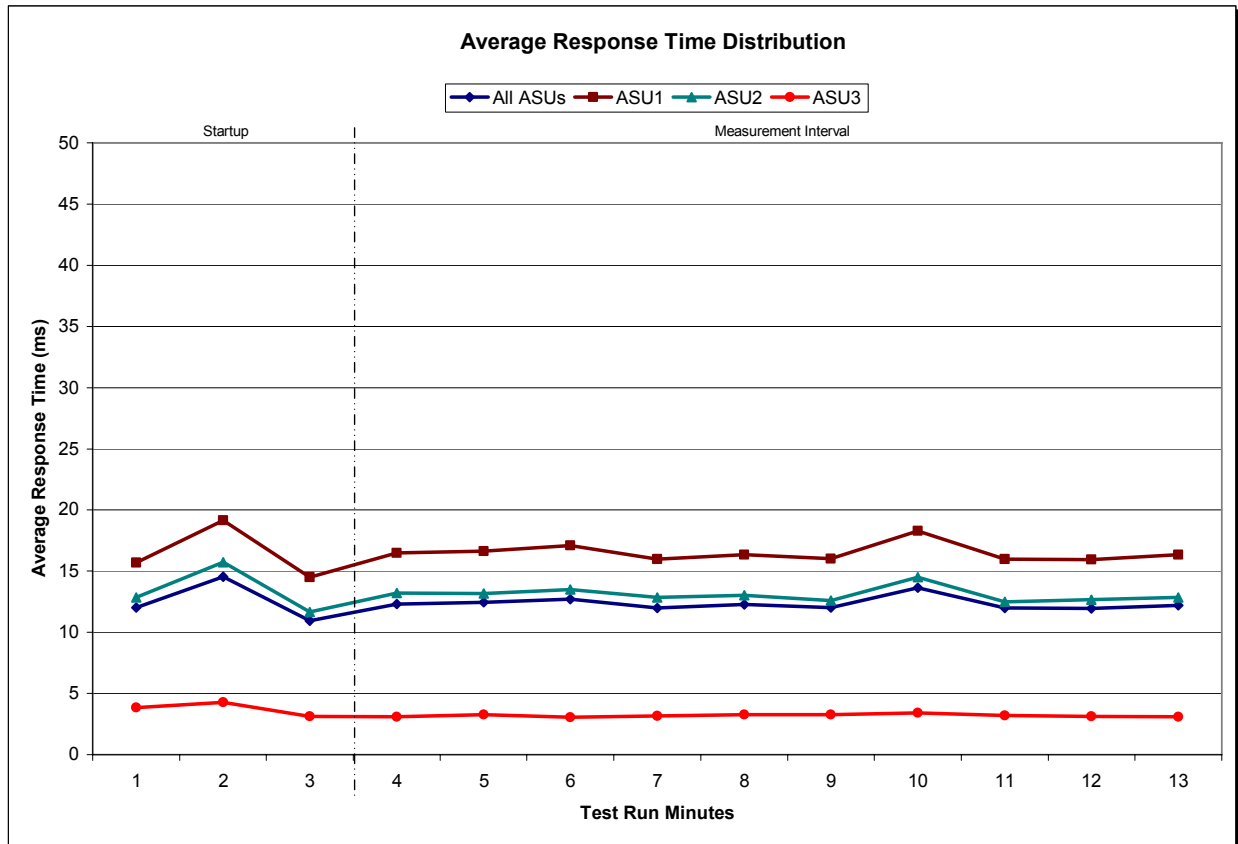
A table containing the data used to generate the graph shall accompany each Response Time Distribution graph. Each I/O Request Throughput Distribution table shall have the content and appearance illustrated in Table 9-3. Every whole minute in a Test Run shall have its data presented in the table and graph.

Each Average Response Time Distribution graph shall have the format, content, and appearance illustrated in Figure 9-3. The intent of this graph is to supply reviewers with a consistent, clear, and powerful means for quickly assessing the response time results from a given Test Run. Data used to compute or construct the Average Response Time Distribution shall be obtained from Workload Generator Results Files.

Table 9-3: Average Response Time Distribution

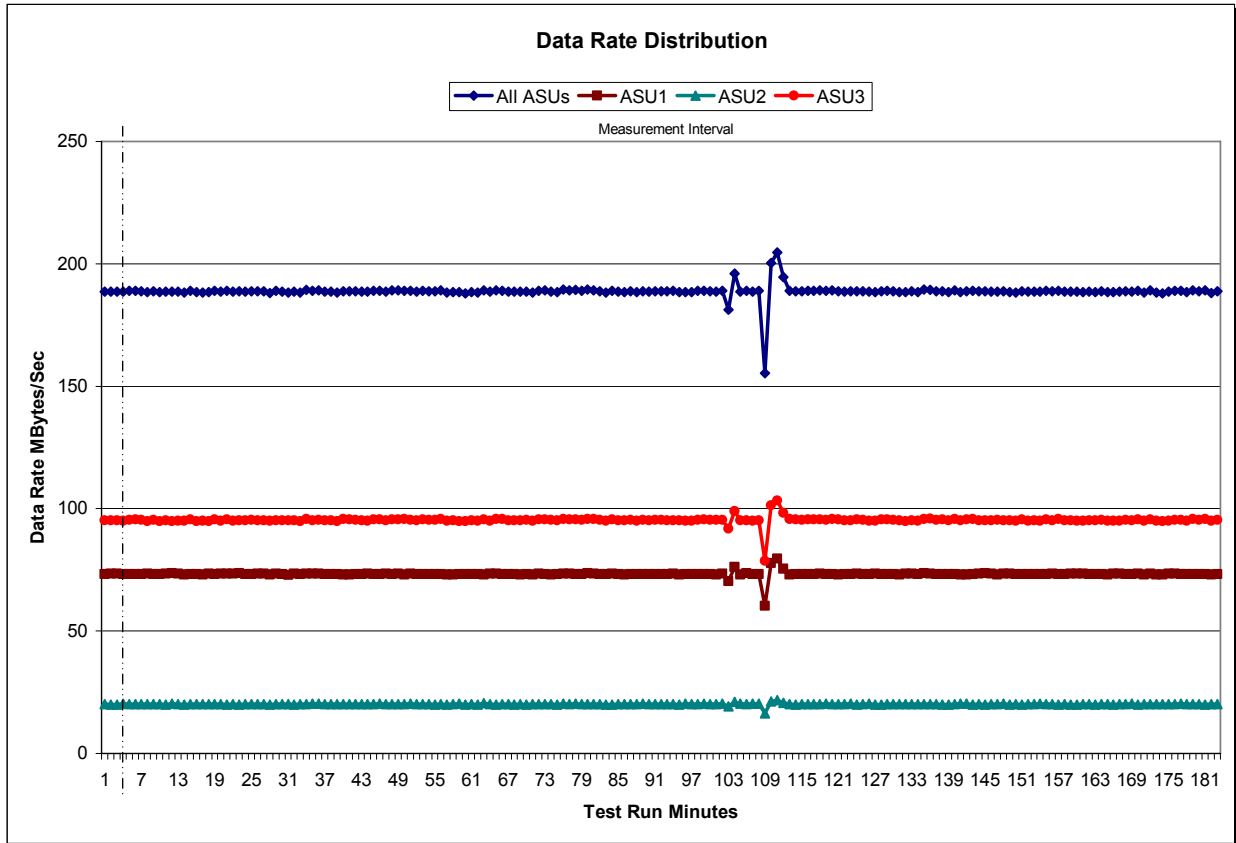
460 BSUs Start-Up/Ramp-Up Measurement Interval	Start	Stop	Interval	Duration
	12:35:45	12:38:46	0-2	0:03:01
	12:38:46	12:48:46	3-12	0:10:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	12.01	15.68	12.84	3.85
1	14.53	19.13	15.73	4.27
2	10.96	14.51	11.68	3.11
3	12.32	16.49	13.20	3.09
4	12.45	16.63	13.16	3.26
5	12.72	17.11	13.51	3.07
6	12.00	16.00	12.85	3.15
7	12.26	16.35	13.02	3.27
8	12.03	16.03	12.60	3.28
9	13.64	18.28	14.50	3.42
10	11.97	15.98	12.51	3.20
11	11.94	15.94	12.69	3.12
12	12.20	16.36	12.84	3.11
Average	12.35	16.52	13.09	3.20

Figure 9-3: Average Response Time Distribution



9.1.4 **Data Rate Distribution:** This consists of a graph and supporting table that clearly illustrates the Data Rate Distribution that occurred in each minute of an SPC-1 Test Run. Each Data Rate Distribution graph shall have the format, content, and appearance illustrated in Figure 9-4. The intent of this graph is to supply reviewers with a consistent, clear, and powerful means for quickly assessing Data Rate Throughput results from a given Test Run. Data used to compute or construct the Data Rate Distribution shall be obtained from Workload Generator Results Files.

Figure 9-4: Data Rate Distribution



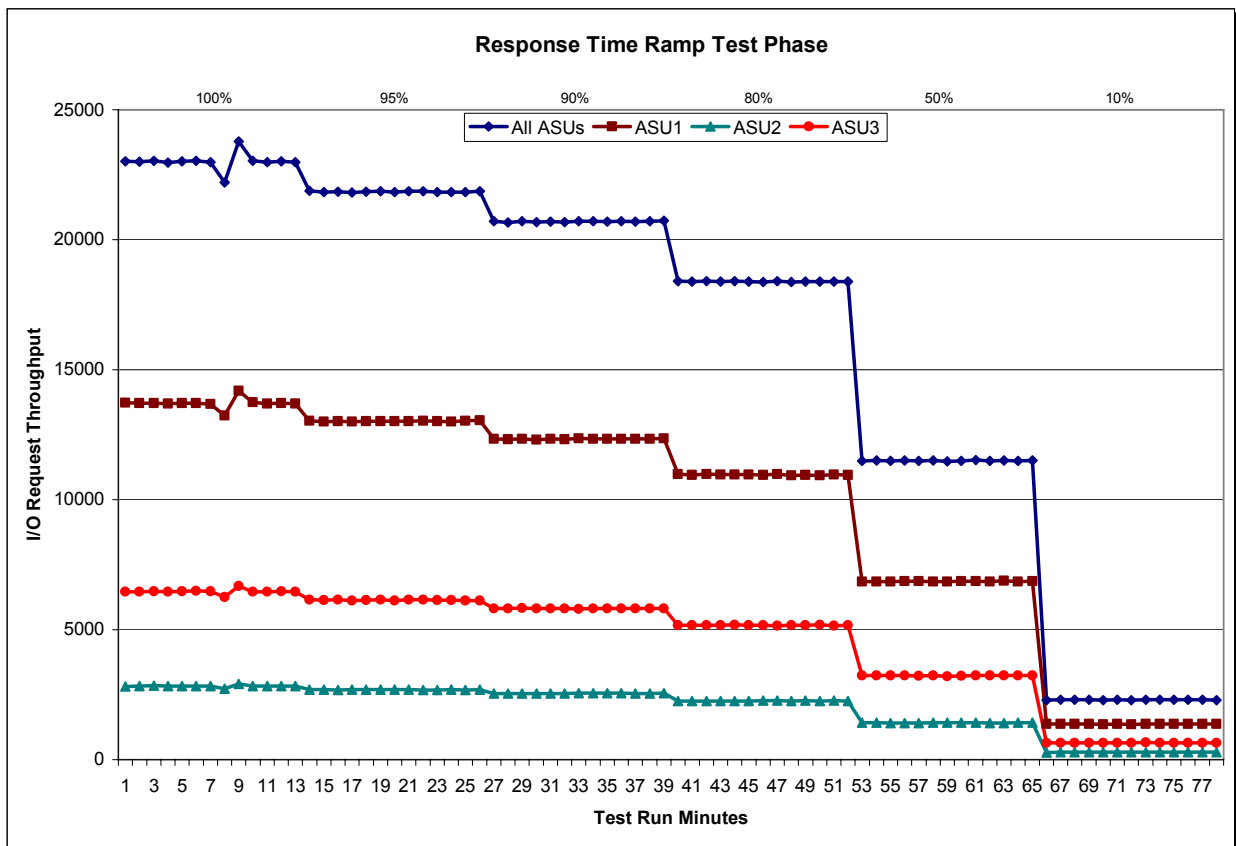
A table containing the data used to generate the graph shall accompany each Data Rate Distribution graph. Each Data Rate Distribution table shall have the content and appearance illustrated in Table 9-4. Every whole minute in a Test Run shall have its data presented in the table and graph.

Table 9-4: Data Rate Distribution

Ramp-Up/Start-Up Measurement Interval		Start	Stop	Interval	Duration															
		17:08:01	17:11:01	0-2	0:03:00															
		17:11:01	20:11:01	3-182	3:00:00															
Interval	All ASUs	ASU1	ASU2	ASU3	Interval	All ASUs	ASU1	ASU2	ASU3	Interval	All ASUs	ASU1	ASU2	ASU3						
0	188.65	73.34	20.15	95.16	60	188.49	73.17	20.13	95.19	120	188.86	73.05	20.20	95.61						
1	188.65	73.49	20.01	95.16	61	188.33	73.22	20.05	95.06	121	188.64	73.18	20.23	95.23						
2	188.71	73.36	20.07	95.28	62	189.14	73.10	20.45	95.59	122	188.81	73.23	20.39	95.19						
3	188.55	73.17	20.32	95.06	63	188.69	73.41	20.17	95.11	123	188.82	73.35	19.95	95.53						
4	188.94	73.26	20.20	95.48	64	189.19	73.35	20.05	95.79	124	188.87	73.31	20.15	95.41						
5	189.00	73.24	20.12	95.64	65	189.03	73.28	20.07	95.68	125	188.65	73.26	20.26	95.12						
6	188.79	73.27	20.10	95.42	66	188.65	73.24	20.17	95.24	126	188.45	73.41	20.02	95.02						
7	188.42	73.47	20.13	94.82	67	188.56	73.23	20.06	95.26	127	188.84	73.28	20.06	95.50						
8	188.82	73.34	20.07	95.40	68	188.57	73.16	20.20	95.21	128	188.95	73.19	20.20	95.56						
9	188.41	73.30	20.19	94.93	69	188.67	73.32	19.97	95.39	129	188.84	73.32	20.19	95.33						
10	188.64	73.40	20.06	95.18	70	188.26	73.07	20.15	95.04	130	188.53	73.08	20.18	95.27						
11	188.71	73.53	20.33	94.85	71	189.03	73.38	20.14	95.51	131	188.39	73.48	20.14	94.77						
12	188.59	73.39	20.16	95.03	72	189.18	73.34	20.19	95.66	132	188.82	73.48	20.11	95.23						
13	188.23	73.13	20.04	95.06	73	188.55	73.10	20.10	95.35	133	188.46	73.18	20.18	95.09						
14	188.92	73.28	20.15	95.49	74	188.48	73.22	20.03	95.23	134	189.61	73.62	20.23	95.76						
15	188.47	73.32	20.23	94.92	75	189.44	73.37	20.28	95.80	135	189.37	73.42	20.11	95.84						
16	188.25	73.13	20.17	94.95	76	189.24	73.40	20.25	95.59	136	188.82	73.24	20.21	95.37						
17	188.40	73.37	20.13	94.90	77	189.26	73.32	20.29	95.65	137	188.75	73.22	19.98	95.55						
18	189.05	73.23	20.23	95.60	78	188.90	73.24	20.22	95.45	138	188.42	73.22	20.07	95.14						
19	188.55	73.38	20.12	95.04	79	189.44	73.56	20.20	95.68	139	189.20	73.26	20.20	95.74						
20	188.94	73.40	19.99	95.55	80	189.23	73.37	20.19	95.68	140	188.48	73.10	20.25	95.13						
21	188.60	73.38	20.18	95.03	81	188.87	73.27	20.22	95.38	141	188.84	72.99	20.28	95.57						
22	188.84	73.55	20.04	95.25	82	188.23	73.19	20.05	94.99	142	189.01	73.26	20.02	95.74						
23	188.60	73.31	20.09	95.21	83	189.02	73.46	20.03	95.53	143	188.80	73.39	20.14	95.28						
24	188.89	73.28	20.18	95.43	84	188.71	73.34	20.16	95.21	144	188.77	73.59	20.01	95.17						
25	188.78	73.41	20.15	95.22	85	188.53	73.04	20.23	95.26	145	188.70	73.37	20.11	95.21						
26	188.75	73.49	20.11	95.15	86	188.74	73.33	20.09	95.33	146	188.62	73.02	20.18	95.42						
27	188.16	73.07	20.03	95.05	87	188.39	73.27	20.13	94.99	147	188.86	73.40	20.27	95.19						
28	188.90	73.48	20.13	95.29	88	188.81	73.17	20.29	95.35	148	188.53	73.40	20.00	95.12						
29	188.63	73.30	20.08	95.25	89	188.69	73.27	20.24	95.19	149	188.31	73.21	20.07	95.02						
30	188.34	72.97	20.18	95.19	90	188.85	73.30	20.24	95.31	150	188.89	73.18	20.06	95.65						
31	188.60	73.38	20.02	95.20	91	188.75	73.17	20.24	95.34	151	188.57	73.31	20.17	95.08						
32	188.25	73.26	20.19	94.80	92	188.77	73.26	20.22	95.29	152	188.60	73.19	20.14	95.28						
33	189.29	73.44	20.08	95.77	93	188.94	73.42	20.25	95.27	153	188.65	73.32	20.27	95.06						
34	188.92	73.37	20.28	95.27	94	188.43	73.14	20.01	95.28	154	188.91	73.18	20.07	95.65						
35	189.08	73.44	20.30	95.33	95	188.53	73.26	20.25	95.02	155	188.78	73.36	20.17	95.25						
36	188.61	73.23	20.21	95.17	96	188.46	73.26	20.19	95.01	156	189.06	73.25	19.99	95.82						
37	188.62	73.19	20.13	95.30	97	188.92	73.34	20.22	95.36	157	188.61	73.23	20.22	95.16						
38	188.31	73.20	20.18	94.93	98	189.06	73.18	20.28	95.59	158	188.69	73.37	20.06	95.26						
39	188.84	73.02	20.11	95.71	99	188.84	73.31	20.19	95.34	159	188.62	73.45	20.06	95.11						
40	188.85	73.14	20.17	95.55	100	188.67	73.14	20.10	95.43	160	188.52	73.42	20.08	95.01						
41	188.89	73.31	20.15	95.42	101	189.07	73.36	20.38	95.32	161	188.71	73.22	20.21	95.28						
42	188.60	73.27	20.13	95.20	102	181.33	70.39	19.20	91.75	162	188.47	73.17	20.04	95.26						
43	188.59	73.35	20.18	95.07	103	196.09	76.16	21.01	98.92	163	188.85	73.27	20.21	95.37						
44	189.05	73.31	20.14	95.59	104	188.58	73.16	20.25	95.17	164	188.43	73.11	20.23	95.09						
45	189.01	73.24	20.26	95.52	105	189.03	73.55	20.25	95.24	165	188.45	73.38	20.05	95.02						
46	188.67	73.35	20.14	95.18	106	188.60	73.34	20.25	95.01	166	188.65	73.41	20.21	95.03						
47	189.10	73.32	20.15	95.64	107	188.93	73.32	20.41	95.20	167	188.77	73.24	20.11	95.42						
48	189.13	73.40	20.18	95.56	108	155.29	60.29	16.43	78.58	168	188.71	73.17	20.27	95.26						
49	189.03	73.11	20.24	95.69	109	200.37	77.73	21.28	101.36	169	189.04	73.40	20.01	95.64						
50	188.97	73.37	20.28	95.33	110	204.62	79.56	21.76	103.30	170	188.20	73.11	20.11	94.98						
51	188.67	73.32	20.08	95.28	111	194.48	75.42	20.73	98.33	171	189.19	73.46	20.10	95.63						
52	188.92	73.22	20.21	95.49	112	188.96	73.12	20.17	95.68	172	188.26	73.08	20.09	95.09						
53	188.74	73.24	20.12	95.38	113	188.82	73.33	20.00	95.49	173	187.97	73.01	20.14	94.83						
54	188.77	73.32	20.06	95.39	114	188.87	73.26	20.18	95.42	174	188.69	73.36	20.21	95.12						
55	189.23	73.30	20.24	95.69	115	188.90	73.26	20.15	95.49	175	188.98	73.35	20.22	95.42						
56	188.30	73.14	20.05	95.11	116	188.94	73.26	20.12	95.56	176	189.05	73.32	20.28	95.45						
57	188.44	73.07	20.09	95.27	117	189.17	73.48	20.19	95.50	177	188.43	73.26	20.15	95.02						
58	188.38	73.22	20.32	94.83	118	188.92	73.25	20.32	95.35	178	189.21	73.34	20.17	95.70						
59	187.95	73.17	19.98	94.80	119	189.09	73.18	20.20	95.72	179	188.72	73.33	20.08	95.31						
										180	189.18	73.29	20.05	95.84						
										181	188.15	73.07	20.10	94.98						
										182	188.73	73.27	20.12	95.33						

9.1.5 **Response Time Ramp Distribution:** This consists of a graph that clearly illustrates the I/O Request Throughput that occurred in each minute of the Measurement Intervals during the SPC-1 Response Time Ramp Test Phase. Each Response Time Ramp Distribution graph shall have the format, content, and appearance illustrated in Figure 9-5. The intent of this graph is to supply reviewers with a consistent, clear, and powerful means for quickly assessing results. Data used to compute or construct the Response Time Ramp Distribution shall be obtained from Workload Generator Results Files.

Figure 9-5: Response Time Ramp Distribution



9.1.6 **Response Time/Throughput Functions:** Graphs and supporting table that clearly illustrate the relationship of Response Time to I/O Request Throughput during an SPC-1 Response Time Ramp Test Phase and IOPS Test shall be provided in the Full Disclosure Report. The graphs shall have the format, content, and appearance illustrated in Figure 9-6 and Figure 9-7. The intent of this graph is to supply reviewers with a consistent, clear, and powerful means for quickly assessing results. Data used to compute or construct the Response Time/Throughput Function shall be obtained from Workload Generator Results Files.

Figure 9-6: Response Time/Throughput Function

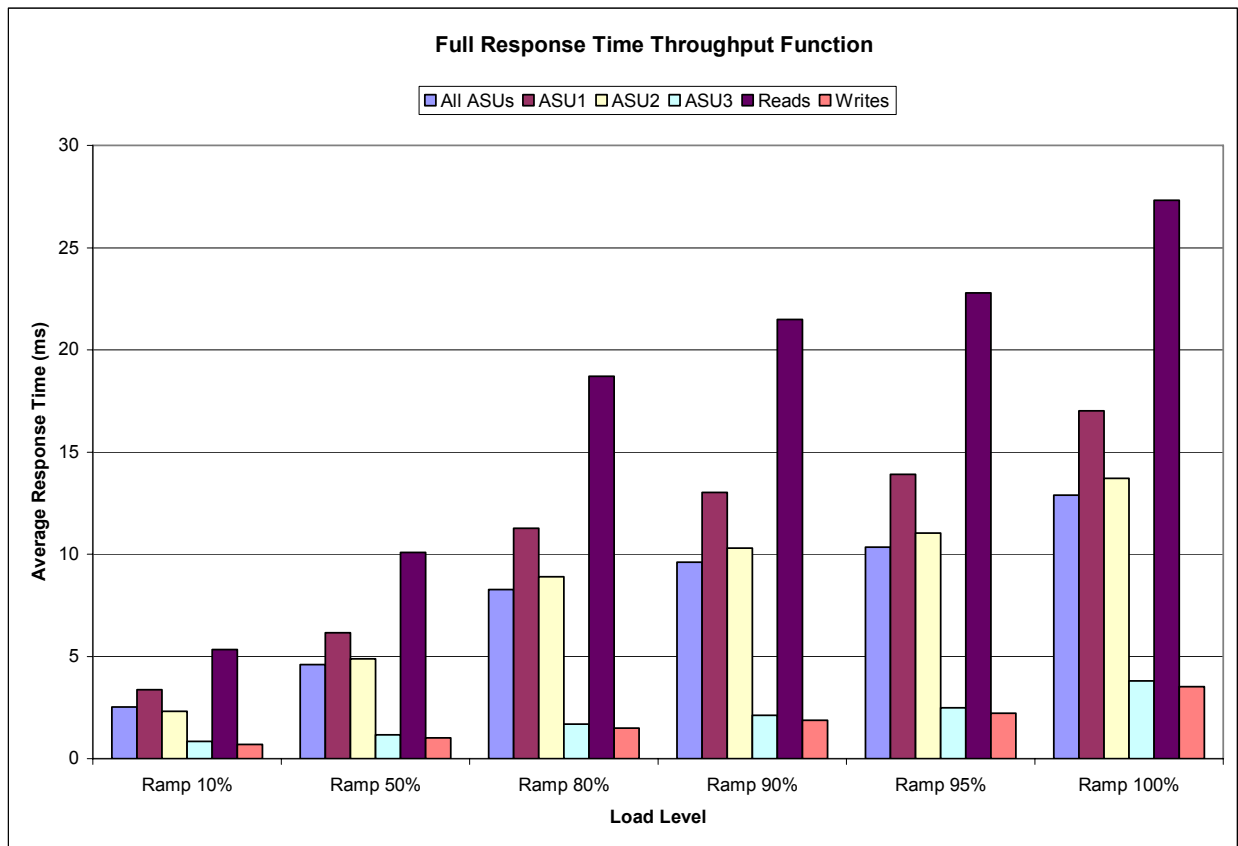
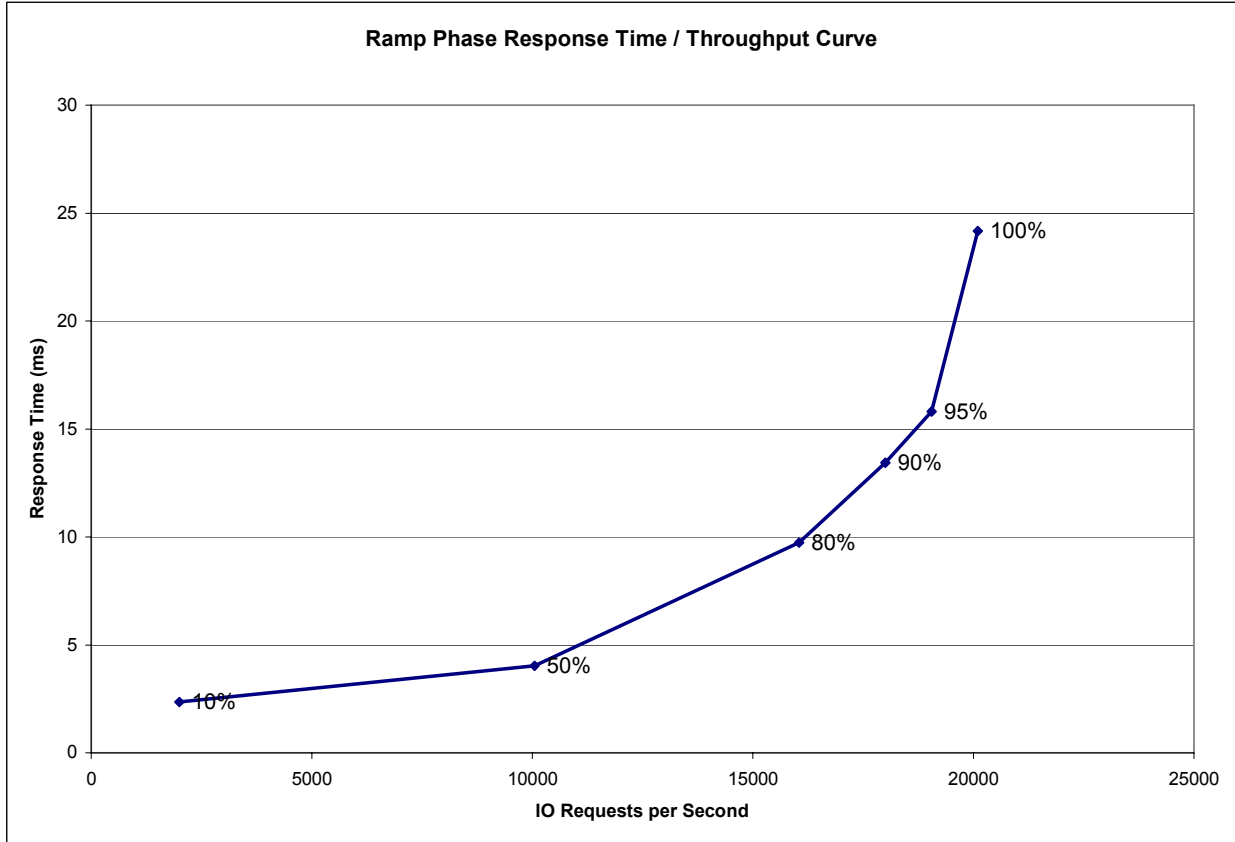


Figure 9-7: Simple Response Time Throughput Curve



A table containing the data used to generate the graphs shall accompany each Response Time/Throughput Function. Each table shall have the content and appearance illustrated in Table 9-5.

Table 9-5: Response Time Ramp Distribution

	10% Load	50% Load	80% Load	90% Load	95% Load	100% Load
I/O Request Throughput	1,998.06	10,051.11	16,050.13	18,003.36	19,054.29	20,096.97
Average Response Time (ms):						
All ASUs	2.36	4.03	9.73	13.43	15.81	24.18
ASU-1	3.12	5.35	11.05	14.72	17.60	27.04
ASU-2	3.12	5.12	10.11	13.05	14.41	18.78
ASU-3	0.41	0.74	6.77	10.89	12.63	20.46
Reads	5.43	9.10	13.63	16.17	18.69	26.67
Writes	0.36	0.73	7.20	11.65	13.94	22.55

9.1.7 **Full Disclosure Report (FDR):** A report submitted by a Test Sponsor to the SPC Administrator documenting the results, procedures, configuration, and equipment used for one execution of the SPC-1 benchmark on a single TSC.

9.2 Full Disclosure Report (FDR) Requirements

A Full Disclosure Report (FDR), submitted to the SPC Administrator, is required for each SPC-1 benchmark result. This clause includes a list of requirements for the Full Disclosure Report.

Comment: The intent of this disclosure is for a customer to be able to replicate the results of this benchmark given appropriate documentation and products.

9.2.1 Electronic Format

The FDR shall be submitted electronically as an Adobe PDF file.

9.2.2 Document Format

The FDR will contain a Table of Contents following the Title page that identifies the location of each 1st level and 2nd level heading in the document. Each page in the FDR shall be numbered. The FDR shall be written in the English Language. Pages of the FDR will be formatted with 3/4 inch margins. Graphs, tables, and illustrations shall use a minimum of an 8-point sans serif font such as Arial. It is recommended that the remainder of the FDR use a minimum 10-point serif font such as Century Schoolbook.

9.2.3 Title Page

The Title Page of the FDR shall only contain the following information:

1. Title Page Title: "SPC-1 Benchmark™ Results".
2. Test Sponsor Name, web site URL (if available), and Company Logo (optional).
3. The formal Tested Storage Product (TSP) name.
4. Date that the results were submitted to the SPC.

9.2.4 FDR Headings and Subheadings

The following content shall appear after the Table of Contents in each FDR. The hierarchy of sub clauses contained in this clause shall appear as an equivalent hierarchy of headings in the FDR.

9.2.4.1 Audit Certification

This section of the FDR shall contain a copy of the certification letter issued by the SPC Audit Service to the Test Sponsor for this execution of the SPC-1 Benchmark.

If the FDR is a revision to an existing FDR and contains changes to the original Priced Storage Configuration, the revised FDR shall contain an amended certification letter that includes auditor review and approval of those changes.

9.2.4.2 Letter of Good Faith

This section of the FDR shall contain a copy of the Letter of Good Faith issued by the Test Sponsor to the SPC Audit Service for this execution of the SPC-1 Benchmark. The Letter of Good Faith is required to be identical in format and content to the template in Appendix D with the appropriate changes specific to the benchmark submission (Test Sponsor name, TSC name, date, etc.). Any other changes in content and format must be approved by the SPC Compliance Review Committee (CRC) prior to the benchmark submission.

9.2.4.3 Executive Summary

The following content shall appear in the Executive Summary per the sequence below.

9.2.4.3.1 Test Sponsor and Contact Information

The executive summary shall contain a table of contact information for the Test Sponsor as well as key entities and individuals responsible for the published result. The content, appearance, and format of this table are specified in Table 9-6.

Table 9-6: Test Sponsor and Contact Information

Test Sponsor and Contact Information	
Test Sponsor Primary Contact (1)	Company, Company Web Address, Individual Name, Postal Address, Phone, FAX, Email Address.
Test Sponsor Alternate Contact (2)	Company, Company Web Address, Individual Name, Postal Address, Phone, FAX, Email Address.
Co Sponsor #1 (3)	Company, Company Web Address, Individual Name, Postal Address, Phone, FAX, Email Address.
Co Sponsor #2 (4)	Company, Company Web Address, Individual Name, Postal Address, Phone, FAX, Email Address.
Co Sponsor #N (5)	Company, Company Web Address, Individual Name, Postal Address, Phone, FAX, Email Address.
Auditor (6)	Company, Company Web Address, Individual Name, Postal Address, Phone, FAX, Email Address.

Footnotes to Table 9-6:

1. *The primary entity and first contact responsible for the submitted FDR. Entity will be the first point of contact in administrating results through the SPC Review Process.*
2. *The primary entity and alternate contact responsible for the submitted FDR. The Alternate contact will be contacted only if the Primary contact is not available.*
3. *Other independent entities that participated in producing the SPC-1 results.*
4. *Other independent entities that participated in producing the SPC-1 results.*
5. *All other independent entities that participated in producing the SPC-1 results.*
6. *Contact information for the Auditor used to certify the SPC-1 results.*

9.2.4.3.2 Revision Information and Key Dates

The executive summary shall contain a table of key dates and revision numbers associated with the published result. The content, appearance, and format of this table are specified in Table 9-7.

Table 9-7: Revision Information and Key Dates

Revision Information and Key Dates	
SPC-1 Specification revision number (1)	NN.NN.NN
SPC-1 Workload Generator revision number (2)	MM.MM.MM
Date Results were first used publicly (3)	DD/MM/YYYY
Date FDR was submitted to the SPC (4)	DD/MM/YYYY
Date revised FDR was submitted to the SPC (5) Current revision text: Revision History: dd/mm/yyyy – revision text dd/mm/yyyy – revision text	DD/MM/YYYY
Date the TSC is/was available for shipment to customers (6)	DD/MM/YYYY
Date the TSC completed audit certification (7)	DD/MM/YYYY

Footnotes to Table 9-7:

1. The revision number of the SPC-1 Specification used to produce the results reported in this FDR.
2. The revision number of the Workload Generator used to produce the results reported in this FDR.
3. The calendar date that the results reported in this FDR were made public (i.e., used outside the Test Sponsors and Co-Sponsors companies).
4. The calendar date that the results reported in this FDR were submitted to the SPC.
5. The calendar date that a revised FDR was submitted to the SPC. The Revision History is a brief description of each revision.
6. The calendar date that the TSC used to produce the results reported in this FDR is/was first available to be shipped to a customer.
7. The date the TSC completed audit certification per the requirements in Clause 10. This is the date that the Audit Certification Letter was issued to the Test Sponsor.

9.2.4.3.3 Tested Storage Product (TSP) Description

The executive summary shall contain a brief description of the Tested Storage Product (TSP). The description should include information that is consistent with the TSP categorization defined in Clause 4.6.

Features used in the benchmark by the TSP may be included in the description. For example, if the TSP is a software product that provides virtualization functionality used in the benchmark but does not include Storage Devices, the description should contain that information.

Features available in the TSP, but not used in the benchmark cannot be included in the description.

The description may include a website link to official product information available from the Test Sponsor.

9.2.4.3.3.2.4.3.4 Summary of Results

The executive summary shall contain a table of key results reported by the Test Sponsor. The content, appearance, and format of this table is specified in Table 9-8.

Table 9-8: Summary of Results

SPC-1 Results	
Tested Storage Product: AAAAAAAAAAAAAAAAAA (1)	
Metric	Reported Result
SPC-1 IOPS™ (2)	NNNNNN
SPC-1 Price-Performance (3)	\$XX.XX/SPC-1 IOPS™
Total ASU Capacity (4)	XX,XXX GB
Data Protection Level (5)	PPPPP
Price (6)	\$XXX,YYY,ZZZ
TSP Category (7)	TSP [includes / does not include] all Storage Devices

Footnotes to Table 9-8:

1. The formal name of the Tested Storage Product as defined in Clause 4.6..
2. Computed per Clause 5.4.4.2.2
3. Computed per Clause 7.1.
4. Computed per Clauses 2.6.6, and 2.6.7 (Total ASU Capacity).
Must be stated in gigabytes (GB) as a truncated integer or a truncated value with three significant digits, using the method that produces the more precise value.
5. The Data Protection Level that was selected per Clause 2.4.5. If **Other Protection Level** is used a brief description of the data protection must be included.
6. Computed per Clause 8.1.1.2
7. The TSC category as defined in Clauses 4.6.1 and 4.6.2.

9.2.4.3.49.2.4.3.5 Storage Capacities and Relationship Diagram

The Executive Summary will contain a copy of Figure 9-10, which documents and illustrates the various SPC-1 storage capacities and relationships.

9.2.4.3.59.2.4.3.6 Pricing Spreadsheet

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

9.2.4.3.69.2.4.3.7 Tested Storage Configuration (TSC) and Priced Storage Configuration Differences

The Executive Summary shall contain a list of all differences between the Tested Storage Configuration (TSC) and Priced Storage Configuration (PSC) must be included. See Clause 8.1.1 for definitions of TSC and PSC.

9.2.4.3.79.2.4.3.8 Priced Storage Configuration Component Changes in a Revised Executive Summary

A revised Executive Summary will contain a list of all Priced Storage Configuration component changes that are included in the revision (see Clause 9.4). The list will contain the line item information of the original component, the line item information of the new component, and a brief description of the difference(s) between the two components.

9.2.4.3.89.2.4.3.9 Response Time/Throughput Curve

The Executive Summary shall contain a Response Time/Throughput curve (see Figure 9-7) as well as a table (see Table 9-5) containing the data used to generate the Response Time/Throughput curve.

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

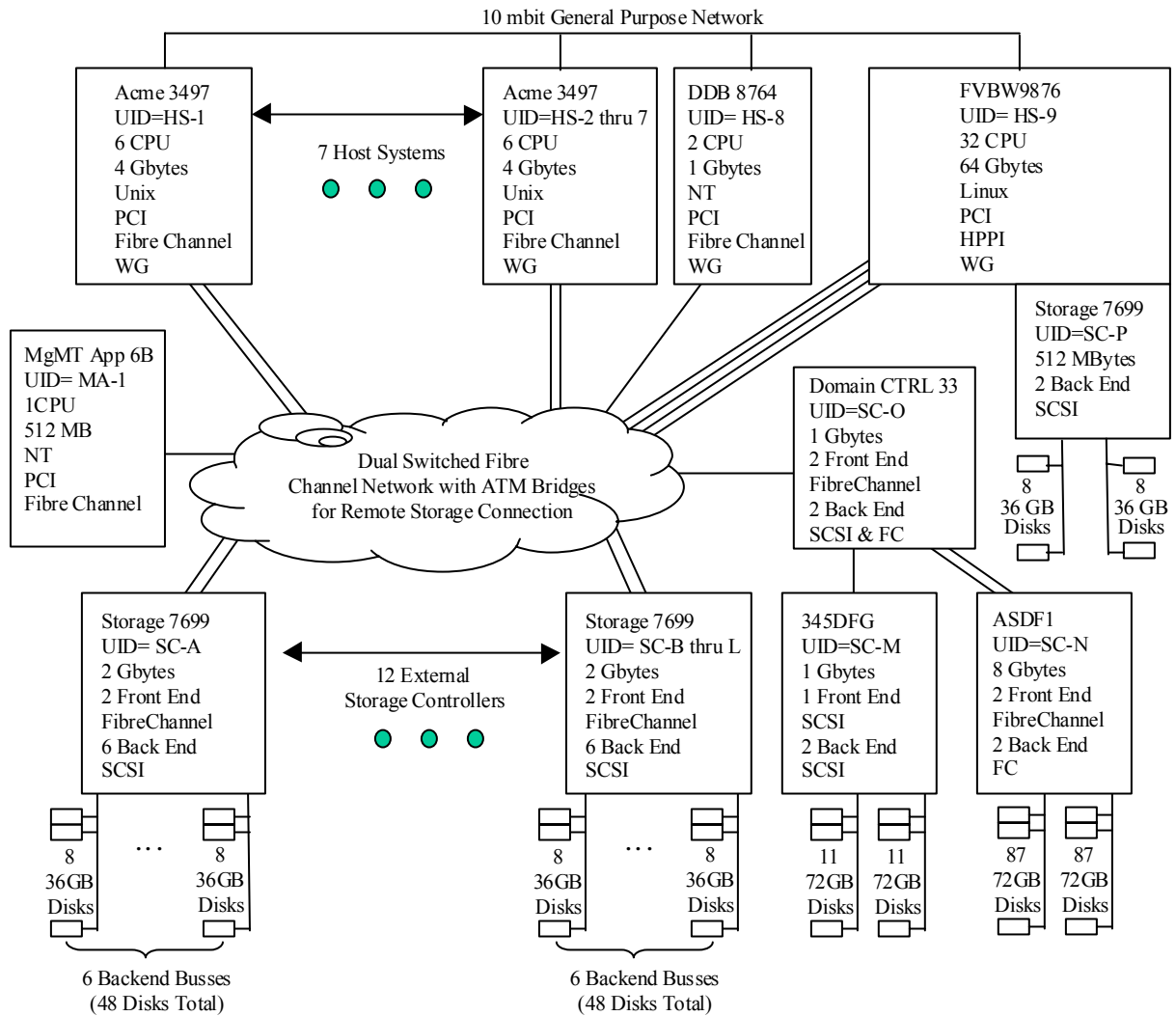
9.2.4.4.1 BC/TSC Configuration Diagram

A one page BC/TSC Configuration Diagram (see example in Figure 9-8) shall be included in the Executive Summary and illustrate the following information:

1. All Host Systems and Management Appliances in the BC. Each Host System shall designate (in sequence):
 - The model or name of the product.
 - A Unique Identifier (UID) for use in this FDR. This should be a simple name beginning with the prefix “HS-“ for Host Systems or beginning with the prefix “MA-“ for Management Appliances.
 - The number of CPUs or processors.
 - The amount of main memory in the system.
 - The type of System Software (i.e., operating system) running on the O.S.
 - The type of System I/O Interconnect.
 - The type of physical connections between Adapters (connected to the System I/O Interconnect) and any Storage Controllers or Storage Devices.
 - If the Host System runs the Workload Generator (designated by “WG”).
2. All Storage Controllers or Domain Controllers in the TSC. Each Controller shall designate (in sequence):
 - The model or name.
 - A Unique Identifier (UID) for use in this FDR. This should be a simple name that begins with the prefix “SC-“
 - The amount of memory and cache.
 - The number of Front-end physical interconnects (unless there are none).
 - The type of Front-end interconnects (unless there are none).
 - The number of Back-end physical interconnects.
 - The type of Back-end physical interconnects.
 - The type of physical connections between Adapters (connected to the System I/O Interconnect) and any Storage Controllers or Storage Devices.
3. The number of Storage Device as well as their capacities.
4. An illustration and description of the networks used to implement the BC.
5. If the TSC contains network storage, the diagram will include the network configuration. If a single diagram is not sufficient to illustrate both the Benchmark Configuration and network configuration in sufficient detail, the Benchmark Configuration diagram will include a high-level network illustration as shown in Figure 9-8. In that case, a separate, detailed network configuration diagram will also be included as described in Clause 9.2.4.4.2.

The content, appearance, and format of this diagram are specified in Figure 9-8.

Figure 9-8: BC/TSC Configuration Diagram



Comment: Detailed diagrams for system configurations and architectures can widely vary, and it is impossible to provide exact guidelines suitable for all implementations. The intent here is to describe the system components and connections in sufficient detail to allow independent reconstruction of the BC environment.

9.2.4.4.2 Storage Network Configuration

If a storage network was configured as a part of the Tested Storage Configuration and the Benchmark Configuration diagram described in Clause 9.2.4.4.1 contains a high-level illustration of the network configuration, the Executive Summary will contain a one page topology diagram of the storage network as illustrated in Figure 9-9.

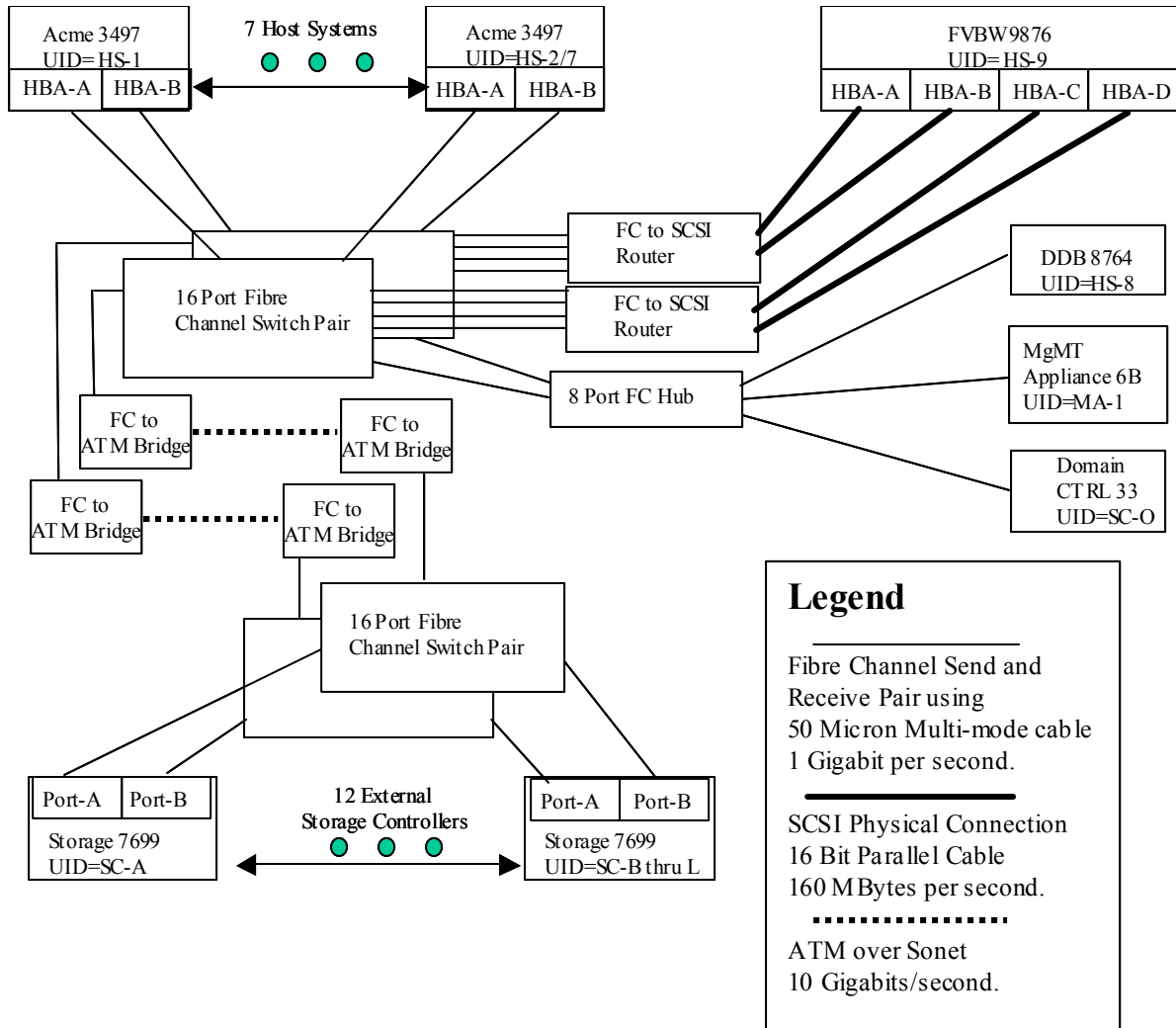
1. Storage Controllers and Domain Controllers (see Clause 9.2.4.4.1)
2. Host Systems (see Clause 9.2.4.4.1)
3. Routers and Bridges
4. Hubs and Switches
5. HBAs to Host Systems and Front End Port to Storage Controllers.

Additionally the diagram shall:

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

Comment: *The intent of this clause is that anyone should be able to recreate the benchmark environment and obtain the results published by the Test Sponsor.*

Figure 9-9: Storage Network Configuration Diagram



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

9.2.4.4.3 Host System Configuration

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

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

9.2.4.4.4 Republished Configuration Differences

If a new SPC-1 benchmark result republishes an existing SPC-1 benchmark result, all hardware and/or software differences between the original and new Priced Tested Storage Configurations must be listed. In addition, the performance impact of each difference must be listed. See Clause 10.6 for the requirements for audit reuse.

9.2.4.5 Benchmark Configuration (BC) Description

The intent of this clause is to require disclosure of information necessary to recreate the complete Benchmark Configuration (BC) and obtain the results published by the Test Sponsor.

9.2.4.5.1 Customer Tuning Parameters and Options

All Benchmark Configuration (BC) components with customer tunable parameters 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.

Examples of customer tunable parameters and options include:

- Options for each component used in a network used to connect Storage to Host Systems.
- HBA Options.
- Array Controller options.
- Operating system, run time environment, and application configuration parameters.
- Compilation and linkage options and run-time optimizations used to create/install any applications or the OS used on the BC.

9.2.4.5.2 Tested Storage Configuration Description

The FDR must include sufficient information to recreate the logical representation of the TSC. In addition to customer tunable parameters and options (Clause 4.2.4.5.3), that information must include, at a minimum:

- A diagram and/or description of the following:
 - All physical components that comprise the TSC. Those components are also illustrated in the BC Configuration Diagram in Clause 9.2.4.4.1 and/or the Storage Network Configuration Diagram in Clause 9.2.4.4.2.
 - The logical representation of the TSC, configured from the above components that will be presented to the Workload Generator.
- Listings of scripts used to create the logical representation of the TSC.
- If scripts were not used, a description of the process used with sufficient detail to recreate the logical representation of the TSC.

9.2.4.5.3 SPC-1 Workload Generator Storage Configuration

The FDR must include all SPC-1 Workload Generator storage configuration commands and parameters. That information is typically contained in the 'SPC1.cfg' file.

9.2.4.6 Data Repository

9.2.4.6.1 SPC-1 Storage Capacities and Relationships

Two tables and an illustration documenting the storage capacities and relationships of the SPC-1 Storage Hierarchy (Clause 2.1) shall be included in the FDR. The content, appearance, and format of the tables are specified in Table 9-9 and Table 9-10. The content, appearance, and format of the illustration are specified in Figure 9-10.

Table 9-9: SPC-1 Storage Capacities

SPC-1 Storage Capacities		
Storage Hierarchy Component	Units	Capacity
Total ASU Capacity (1)	GB	nnn,nnn
Addressable Storage Capacity (2)	GB	n,nnn,nnn
Configured Storage Capacity (3)	GB	n,nnn,nnn
Physical Storage Capacity (4)	GB	n,nnn,nnn
Parity – RAID5 or Other Protection Level (5)	GB	nnn,nnn
User Data Copy – Mirroring or Other Protection Level (5)	GB	nnn,nnn
Required Storage (6)	GB	nn
Global Storage Overhead (7)	GB	nn
Total Unused Storage (8)	GB	nn

Footnotes to Table 9-9.

- 1. Defined in Clause 2.6*
- 2. Defined in Clause 2.4*
- 3. Defined in Clause 2.3*
- 4. Defined in Clause 2.2*
- 5. Defined in Clause 2.4.5*
- 6. Defined in Clause 2.3.2*
- 7. Defined in Clause 2.2.3*
- 8. Sum of capacities defined in Clauses 2.2.4, 0, and 2.4.3*

Capacities must be stated in gigabytes (GB) as a truncated integer or a truncated value with three significant digits, using the method that produces the more precise value.

Figure 9-10: SPC-1 Storage Capacities and Relationships

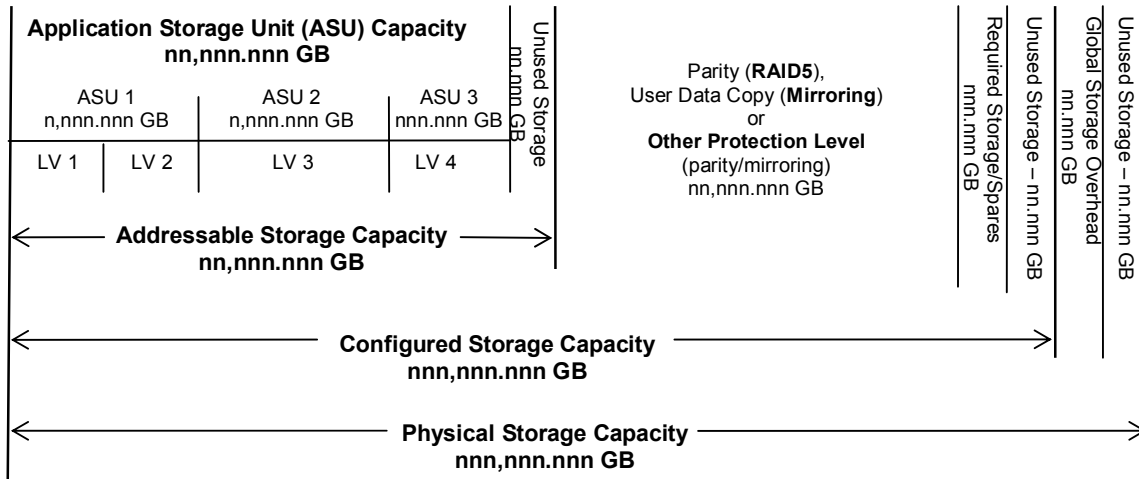


Table 9-10: SPC-1 Storage Hierarchy Ratios

	Addressable Storage Capacity	Configured Storage Capacity	Physical Storage Capacity
Total ASU Capacity	(1)	(2)	(3)
Parity (RAID5 or Other Protection Level)		(4)	(5)
User Data Copy (Mirroring or Other Protection Level)		(6)	(7)
Addressable Storage Capacity		(8)	(9)
Required Storage		(10)	(11)
Configured Storage Capacity			(12)
Global Storage Overhead			(13)
Unused Storage	(14)	(15)	(16)

Footnotes to Table 9-10.

The values calculated below are to be represented as a percentage with two significant digits, truncating after the second significant digit.

1. Total ASU Capacity ÷ Addressable Storage Capacity
2. Total ASU Capacity ÷ Configured Storage Capacity
3. Total ASU Capacity ÷ Physical Storage Capacity
4. Parity ÷ Configured Storage Capacity
5. Parity ÷ Physical Storage Capacity
6. User Data Copy ÷ Configured Storage Capacity

7. *User Data Copy ÷ Physical Storage Capacity*
8. *Addressable Storage Capacity ÷ Configured Storage Capacity*
9. *Addressable Storage Capacity ÷ Physical Storage Capacity*
10. *Required Storage ÷ Configured Storage Capacity*
11. *Required Storage ÷ Physical Storage Capacity*
12. *Configured Storage Capacity ÷ Physical Storage Capacity*
13. *Global Storage Overhead ÷ Physical Storage Capacity*
14. *Unused Storage (contained in Addressable Storage Capacity) ÷ Addressable Storage Capacity*
15. *Unused Storage (contained in Configured Storage Capacity) ÷ Configured Storage Capacity*
16. *Unused Storage (total) ÷ Physical Storage Capacity*

9.2.4.6.2 Logical Volume Capacity and ASU Mapping

A table illustrating the capacity of each ASU and the mapping of Logical Volumes to ASUs shall be provided in the FDR. Capacity must be stated in gigabytes (GB) as a truncated integer or a truncated value with three significant digits, using the method that produces the more precise value. Logical Volumes shall be sequenced in the table from top to bottom per its position in the contiguous address space of each ASU. The capacity of each Logical Volume shall be stated. Each Logical Volume identifier in the table shall be unique within the BC. The content, appearance, and format of this table are specified in Table 9-11. In conjunction with this table, the Test Sponsor shall provide a complete description of the type of data protection (see Clause 2.4.5) used on each Logical Volume.

Table 9-11: Logical Volume Capacity and ASU Mapping

Logical Volume Capacity and Mapping		
ASU-1 (nnn,nnn GB)	ASU-2 (nnn,nnn GB)	ASU-3 (nnnGB)
Volume 1 (nnn GB)	Volume 5 (nnn GB)	Volume 7 (nnn GB)
Volume 2 (nnn GB)	Volume 6 (nnn GB)	Volume 8 (nnn GB)
Volume 3 (nnn GB)		Volume 9 (nnn GB)
Volume 4 (nnn GB)		

9.2.4.7 SPC-1 Test Execution Results

9.2.4.7.1 Sustainability Test Phase

For the Sustainability Test Phase the FDR shall contain:

1. A Data Rate Distribution graph and data table (Clause 9.1.4).
2. I/O Request Throughput Distribution graph and data table (Clause 9.1.2).
3. A Response Time Frequency Distribution graph and table (Clause 9.1.1).
4. An Average Response Time Distribution graph and table (Clause 9.1.4).
5. The human readable Test Run Results File produced by the Workload Generator (*may be included in an appendix*).
6. A listing or screen image of all input parameters supplied to the Workload Generator (*may be included in an appendix*).
7. The Measured Intensity Multiplier for each I/O Stream.
8. The variability of the Measured Intensity Multiplier, as defined in Clause 5.3.13.3.

9.2.4.7.2 IOPS Test Phase

For the IOPS Test Phase the FDR shall contain:

1. I/O Request Throughput Distribution graph and table (Clause 9.1.2).
2. A Response Time Frequency Distribution graph and table (Clause 9.1.1).
3. An Average Response Time Distribution graph and table (Clause 9.1.4).
4. The human readable Test Run Results File produced by the Workload Generator (*may be included in an appendix*).
5. A listing or screen image of all input parameters supplied to the Workload Generator (*may be included in an appendix*).
6. The total number of I/O Requests completed in the measurement interval as well as the number of I/O Request with a Response Time less than or equal to 30.00 milliseconds and the number of I/O Requests with a Response Time greater than 30.00 milliseconds.

9.2.4.7.3 Response Time Ramp Test Phase

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

1. A Response Time Ramp Distribution graph (Clause 9.1.5).
2. The human readable Test Run Results File produced by the Workload Generator for each Test Run within the Response Time Ramp Test Phase (*may be included in an appendix*).
3. For the 10% BSU Load Level Test Run (*the SPC-1 LRT™ metric*) an Average Response Time Distribution graph and table (Clause 9.1.4).
4. A listing or screen image of all input parameters supplied to the Workload Generator (*may be included in an appendix*).

9.2.4.7.4 Repeatability Test

The following content shall appear in the FDR for each Test Run in the IOPS Repeatability Test:

1. A table containing the results of the Repeatability Test. The content, appearance, and format of the table are specified in Table 9-12.
2. I/O Request Throughput Distribution graph and table (Clause 9.1.2).
3. An Average Response Time Distribution graph and table (Clause 9.1.4).
4. The human readable Test Run Results File produced by the Workload Generator (*may be included in an appendix*).
5. A listing or screen image of all input parameters supplied to the Workload Generator (*may be included in an appendix*).

Table 9-12: Repeatability Test Results

	IOPS	LRT
Reported Metrics	<i>n,nnn.nn</i>	<i>n.nn</i>
Repeatability Test Phase 1	n,nnn.nn	n.nn
Repeatability Test Phase 2	n,nnn.nn	n.nn

9.2.4.8 Data Persistence Test Results

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

1. A listing or screen image of all input parameters supplied to the Workload Generator (may be optionally referenced in an appendix).
2. For the successful Data Persistence Test Run, a table illustrating key results. The content, appearance, and format of this table are specified in Table 9-13. Information displayed in this table shall be obtained from the Test Run Results File referenced below in #3.
3. For the successful Data Persistence Test Run, the human readable Test Run Results File produced by the Workload Generator (*may be contained in an appendix*).

Table 9-13: Data Persistence Test Results

Data Persistence Test Results	
Data Persistence Test Run Number: N (1)	
Total Number of Logical Blocks Written (2)	XXX,XXX
Total Number of Logical Blocks Verified (3)	YYY,YYY
Total Number of Logical Blocks that Failed Verification (4)	ZZ
Time Duration for Writing Test Logical Blocks (5)	MM:SS
Size in Bytes of each Logical Block (6)	ZZ,ZZZ,ZZZ
Number of Failed I/O Requests in the process of the Test (7)	R
Shutdown and power cycled Host System(s)? (8)	Yes/No

Footnotes to Table 9-13:

1. *Within the set of Data Persistence Test Runs executed to pass the Data Persistence Requirement, the Test Run Number. Tables in this section of the FDR shall be presented in the same sequence as the Test Runs performed by the Test Sponsor. Test Run Number shall be integer values beginning with the number one (1).*
2. *The total number of Logical Blocks written for this Test Run in step #1 of Clause 6.4.*
3. *The total number of Logical Blocks that passed verification in step #5 of Clause 6.4.*
4. *The total number of Logical Blocks that failed verification in step #5 of Clause 6.4.*
5. *Wall clock time in minutes and seconds required to complete step #1 of Clause 6.4.*
6. *The number of bytes per logical block in the TSC.*
7. *For all I/O Requests issued during the course of the Persistence Test the number of Failed I/O Requests per the definition in Clause 5.1.6.*
8. *If the Host System(s) were shutdown and power cycled enter 'Yes'. If the Host System(s) were not shutdown and power cycled, per Clause 6.4 #3, enter 'No'.*

9.2.4.9 Priced Storage Configuration Availability Date

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

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

9.2.4.10 Anomalies or Irregularities in Obtaining SPC-1 Results

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

9.2.4.11 Pricing Information

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

9.2.4.11.2 Clause 8.3 describes all pricing information that is required for the FDR.

9.2.4.11.3 A list of all differences between the Tested Storage Configuration (TSC) and Priced Storage Configuration must be included. See Clause 8.1 for definitions of TSC and Priced Storage Configuration.

9.3 Availability of the Full Disclosure Report

The Full Disclosure Report must be readily available to the public at a reasonable charge, similar to charges for similar documents by that Test Sponsor. The report must be made available when results are made public. In order to use the phrase "SPC Benchmark™," the Full Disclosure Report must have been submitted to the SPC Administrator as along with written permission to distribute the report.

9.4 Revisions to a Previously Submitted FDR

Revisions to a previously submitted FDR can only occur under the following conditions:

- Fully documented price changes to the Priced Storage Configuration.
- A change in Availability Date.
- As directed by the SPC Policies or Steering Committee recommendation.

9.4.1 Pricing Change Revisions

The SPC-1 pricing information for an existing SPC-1 result may be revised based on fully documented price changes in the Priced Storage Configuration. The price changes may be either decreases or increases.

If price changes in the Priced Storage Configuration result in a new SPC-1 Price-Performance that is greater than the existing SPC-1 Price-Performance by 5% or more, the Test Sponsor must submit a revised FDR within 30 days of the effective date of the pricing changes to remain compliant. Price changes in the Priced Storage Configuration below the 5% increase threshold are submitted at the discretion of the Test Sponsor.

The benchmark measurement need not be rerun to remain compliant if there are no component changes in the Priced Storage Configuration resulting from the revised pricing. If the revised pricing results in component changes to the Priced Storage Configuration, the requirements in Clause 10.8 must be met in order to submit the revised FDR.

***Comment:** The intent of this clause is that published SPC-1 Price-Performance reflects actual current SPC-1 Price-Performance.*

9.4.2 Availability Date Revisions

A previously submitted FDR may be revised as the result of a change in the Availability Date contained in the FDR. The revised Availability Date is subject to the requirements of Clause 8.x. The benchmark measurement need not be rerun to remain compliant if there are no components changes in the Priced Storage Configuration resulting from the revised Availability Date. If the revised Availability Date results in component changes to the Priced Storage Configuration, the requirements in Clause 10.8 must be met in order to submit the revised FDR.

9.4.3 SPC Policies and Steering Committee Directed Revisions

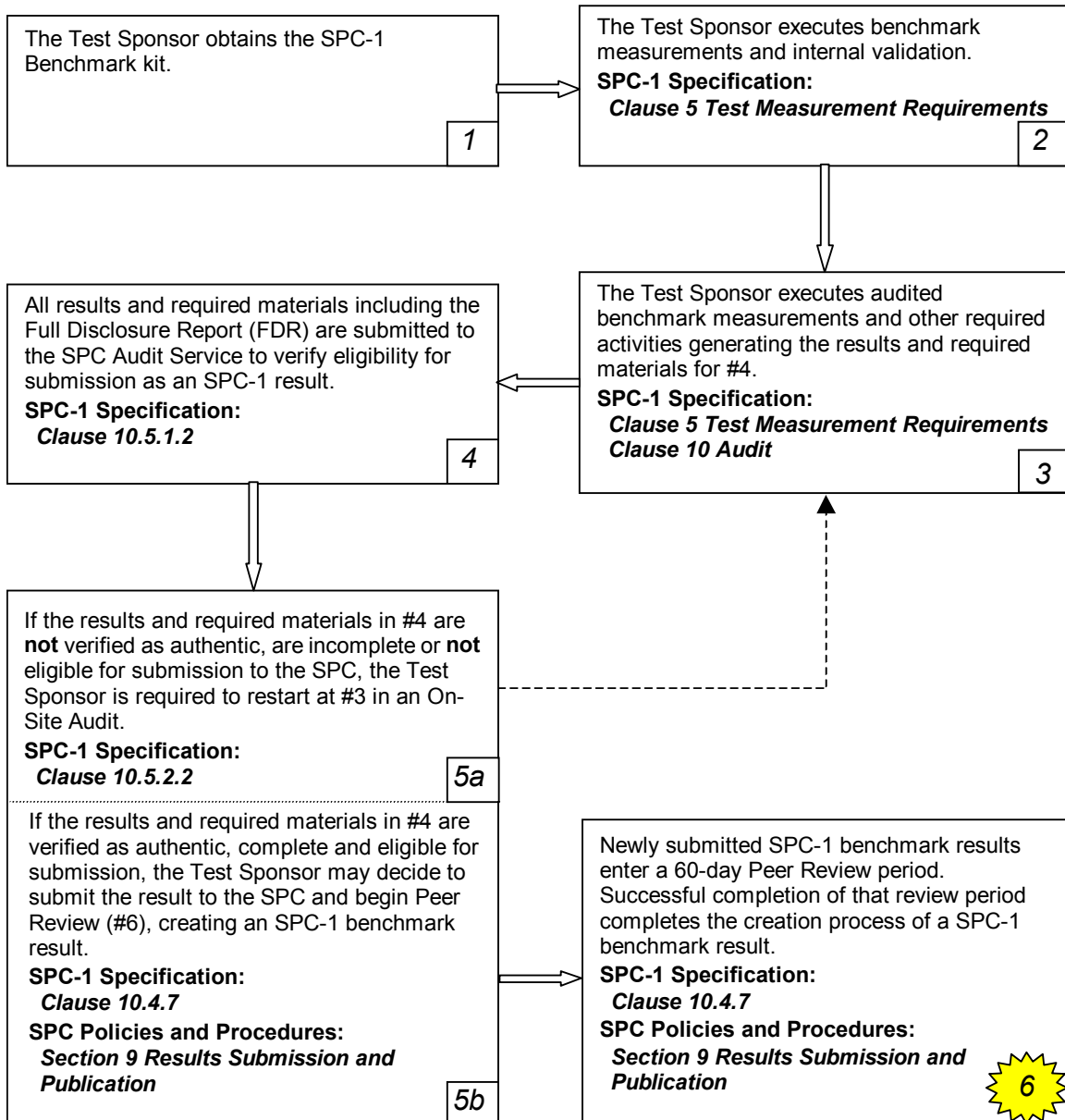
The SPC Policies may direct an existing FDR to be revised such as in the case of a compliance issue that requires revisions to the FDR to remain compliant. A FDR revision may also result from a Steering Committee recommendation such as the case of a member company corporate name change.

Clause 10: Audit & Results Submission

10.1 Introduction

The required audit of a SPC-1 benchmark is one component in a process that creates an SPC-1 benchmark result. That process, its components, and relevant documentation are illustrated below in Figure 10-1.

Figure 10-1: Creation and Submission of SPC-1 Results



10.2 SPC-1 Result Validation

10.2.1 Benchmark results using the SPC-1 benchmark specification must successfully complete the SPC-1 Result Validation process before they become SPC-1 benchmark results.

10.2.2 SPC-1 Result Validation is intended to certify:

- The Full Disclosure Report (FDR) is **complete** (Clause 9.2)
- Information contained in the FDR is **authentic**. For example, ensure that results files produced by the Workload Generator are unaltered and represent the actual execution of the Workload Generator.
- Information contained in the FDR is **accurate** and meets the appropriate requirements of this specification.

While it is not possible to preclude the possibility of an erroneous result, the validation process is designed to minimize the possibility that an audited result could lead the consumer of a benchmark result to an erroneous or misleading conclusion about the Tested Storage Configuration.

10.2.3 The SPC-1 Result Validation is composed of two required stages: Audit and Peer Review.

10.3 Peer Review

Peer Review of a new SPC-1 result begins when the Test Sponsor completes the benchmark result submission process that is described in Clause 10.4.7. Peer Review of a new SPC-1 result will encompass all aspects of the benchmark submission.

Peer Review of revisions to an existing SPC-1 result begins when the revised Full Disclosure Report (FDR) is submitted to the SPC. Peer Review, in this case, is limited to the revisions of the existing FDR, which include any component changes in the Priced Storage Configuration.

Peer Review is the sole mechanism for certifying the benchmark result compliance with this specification. Peer Review is described in the SPC Policies and Procedures.

10.4 Audit

10.4.1 Audit is defined as the execution of the procedures defined in Clause 10.6 using one of the audit methods defined in Clause 10.5.

10.4.2 The purpose of the Audit is to verify a benchmark result is eligible for submission. This verification would include:

- The Full Disclosure Report (FDR) is complete (Clause 9.2)
- Information contained in the FDR is authentic. For example, verify that results files produced by the Workload Generator are unaltered and represent the actual execution of the Workload Generator.
- Information contained in the FDR is accurate.
- Information contained in the FDR adheres to the requirements of the specification.

10.4.3 An Audit does not provide certification that a benchmark result is compliant with the specification. Certification that a benchmark result is compliant with the specification is a function of the Peer Review.

10.4.4 SPC Audit Service

The SPC Audit Service will provide an Auditor who is responsible for the execution of the Audit.

10.4.5 Auditor

- 10.4.5.1 The Auditor will, in the course of the Audit, determine if the benchmark result is eligible for submission to the SPC.
- 10.4.5.2 If the Auditor determines the benchmark result is eligible for submission, the Auditor will produce an Audit Report attesting to the successful completion of the Audit.
- 10.4.5.3 The Audit Report is issued to the Test Sponsor. The Test Sponsor may then submit the benchmark result to the SPC to establish a new SPC-1 benchmark result and begin the Peer Review (see Clause 10.4.7).
- 10.4.5.4 If the Auditor determines the benchmark result is not eligible for submission, the Test Sponsor may request an Audit Report that documents the eligibility issues of the benchmark result. In addition, the Audit Report will include recommendations to address the eligibility issues.
- 10.4.5.5 If the Test Sponsor disagrees with the Auditor's determination of eligibility, the Test Sponsor may submit an appeal to the Compliance Review Committee.

10.4.6 Audit Report

The Audit Report will document execution of the Audit procedures defined in Clause 10.6. The Audit Report of a successful Audit will contain any anomalous or inconsistent element encountered during the Audit. While those elements did not prevent successful completion of the Audit, their presence warranted documentation.

10.4.7 Benchmark Result Submission

- 10.4.7.1 A Test Sponsor may submit to the SPC a benchmark result that has successfully completed Audit.
- 10.4.7.2 Benchmark result submission to the SPC consists of:
- A PDF version of the Full Disclosure Report (FDR) and Executive Summary submitted to and received by the SPC.
 - Payment to the SPC of all Audit costs and SPC benchmark result filing fee.
 - A release, on file with the SPC, allowing public disclosure of the benchmark result and FDR.
- 10.4.7.3 When the submission is complete:
- A unique Submission Identifier is created for the submitted benchmark result.
 - The benchmark result becomes an SPC-1 benchmark result that is in "Submitted For Review" status.
 - A copy of both the FDR and Executive Summary are placed on the SPC website.
 - A notification email is sent to the SPC membership announcing the new SPC-1 result.
 - The 60-day Peer Review begins.

10.4.8 Submission Identifier

A Submission Identifier shall take the following format: **ZZZ-N**. Where:

- **ZZZ** is a unique code assigned by the SPC that identifies an original SPC-1 benchmark result and Audit.
- **-N** is the identifier for a republished SPC-1 result and Audit. The identifier will be omitted in the case of the original SPC-1 result and Audit (Submission Identifier = **ZZZ**). The first reuse of an Submission Identifier will set the value of N to 1 (Submission Identifier = **ZZZ-1**). Each subsequent reuse will increment the value of N by 1.

10.5 Audit Methods

10.5.1 Remote Audit

- 10.5.1.1 An SPC-1 benchmark execution may satisfy Audit requirements without an On-Site Audit subject to the limitations detailed below. This is referred to as a Remote Audit.
- 10.5.1.2 A Remote Audit requires submission of all Results Files produced by the SPC-1 benchmark execution, along with other materials, to the SPC Audit Service (see Clause 5).
- 10.5.1.3 In order to be eligible for an Remote Audit, the Benchmark Configuration (BC) to be audited and the Test Sponsor must satisfy the following criteria:
1. The Host Systems being benchmarked must be supported by the SPC-1 Workload Generator.
 2. The SPC Workload Generator version that will be used in the Remote Audit has been validated in an On-Site Audit or via some other SPC Audit Service approved method.
- 10.5.1.4 A Test Sponsor who cannot satisfy the requirements of Clause 10.5.1.3 must complete an On-Site Audit. Additionally, if there are questions concerning completeness and/or authenticity of the results, the SPC Audit Service may require an On-Site Audit. The costs of an On-Site Audit are the responsibility of the Test Sponsor.

10.5.2 On-Site Audit

- 10.5.2.1 A Test Sponsor may elect to satisfy the SPC-1 audit requirements by means of an On-Site Audit (Test Sponsors will be also be required to pay the costs for an On-Site Audit).
- Comment:** It is the intent of this option to allow Test Sponsors to add credibility to their results by requesting an On-Site Audit.*
- 10.5.2.2 A Test Sponsor that fails a Remote Audit or submits a SPC-1 benchmark result that has been found non-compliant, as defined in the SPC Policies and Procedures, will be required to use an On-Site Audit for their next benchmark result submission. Additionally, a Test Sponsor may be required to undertake an On-Site Audit at the discretion of the SPC Auditing Service. (Test Sponsors are required to pay the costs for an On-Site Audit). While this requirement will not be imposed unreasonably, it may be imposed at the sole discretion of the SPC Auditing Service.
- 10.5.2.3 The protocol and results of an On-Site Audit must be summarized in an audit report prepared by the SPC Audit Service and submitted Test Sponsor as part of the Audit.

10.6 Audit Procedures

10.6.1 Clause 0: Introduction Related Items

Obtain a Letter of Good Faith from the Test Sponsor signed by an appropriate senior executive. The Letter of Good Faith is required to appear on company letterhead. The document must be identical in format and content to the template in Appendix D with the appropriate changes specific to the benchmark submission (Test Sponsor name, TSC name, date, etc.). Any other changes in content and format must be approved by the SPC Compliance Review Committee (CRC) prior to the benchmark submission.

10.6.2 Clause 1: Workload Environment Related Items

None

10.6.3 Clause 2: Data Repository Related Items

1. Verify the Physical Storage Capacity and requirements stated in Clause 2.2.
2. Verify the Configured Storage Capacity and requirements stated in Clause 2.3.
3. Verify the Addressable Storage Capacity and requirements stated in Clause 2.4.
4. Verify the capacity of each Logical Volume and requirements stated in Clause 2.5.
5. Verify the capacity of each Application Storage Unit (ASU) and requirements stated in Clause 2.6.

10.6.3.1 Remote Audit Related Items

Verification of the above capacities is done using one of the following methods:

- A review of appropriate listings provided by the Test Sponsor.
- Remote access to the Tested Storage Configuration.
- A combination of listings and remote access.

Remote access is optionally supplied by the Test Sponsor and is not a requirement for a Remote Audit.

10.6.3.2 On-site Audit Related Items

Verification of the above capacities is done using one of the following methods:

- A review of appropriate listings provided by the Test Sponsor.
- Physical and remote access to the Tested Storage Configuration.
- A combination of listings and physical access.

10.6.4 Clause 3: Workload and I/O Operation Profile Related Items

None

10.6.5 Clause 4: Benchmark Configuration (BC), Tested Storage Configuration (TSC), and Workload Generator Related Items

1. Obtain a copy of Figure 9-8 (BC/TSC Configuration Diagram). If a storage network is employed in the BC/TSC, obtain a copy of Figure 9-9 (Storage Network Configuration Diagram). Confirm the components illustrated in the two figures.

2. Obtain a listing of all customer tunable parameters and options that have been altered from their default values. The listing must contain the name of each component with an altered parameter/option, the name of the parameter/option, and the altered value. .
3. Obtain information that is sufficient to recreate the logical representation of the TSC (Clause 9.2.4.5.2). That information must include, at a minimum, a diagram and/or description of the following
 - All physical components that comprise the TSC.
 - The logical representation of the TSC, configured from the above components, that was presented to the Workload Generator.
4. Verify the required configuration information for each Host System (Clause 9.2.4.4.3).
5. Verify the presence and version number of each Workload Generator on each Host System in the BC.
6. Verify the Tested Storage Configuration boundary within each Host System of the BC as documented in Clause 4.5 and as illustrated in Figure 4-3, Figure 4-4, and Figure 4-5.
7. In a multi-host configuration, verify compliance with Clause 4.7.6 #1 and #2.
8. In a multi-host configuration, verify that the execution of multiple Workload Generators on multiple Host Systems are synchronized in time and therefore support the requirements of Clause 4.7.6 #1.

Verification of items #6 and #7 may be done using the appropriate Test Results files.

10.6.5.1 Remote Audit Related Items

Verification of items #1-#5 is done using one of the following methods:

- A review of appropriate listings provided by the Test Sponsor.
- Remote access to the Tested Storage Configuration.
- A combination of listings and remote access.

Remote access is optionally supplied by the Test Sponsor and is not a requirement for a Remote Audit.

10.6.5.2 On-Site Audit Related Items

Verification of items #1-#5 is done using the following methods:

- A review of appropriate listings provided by the Test Sponsor.
- Physical access to the Tested Storage Configuration.

10.6.6 Clause 5: Test Measurement Requirements (Execution Rules) Related Items

10.6.6.1 Remote Audit Related Items

1. Obtain Results Files and Summary Results Files for each Test Run.
2. Authenticate the Results Files and Summary Results Files obtained in #1.
3. Inspect each Summary Results File to determine compliance with all the constraints and requirements of Clause 4 and Clause 5.

10.6.6.2 On-Site Audit Related Items

1. Observe the execution of each Test, Test Phase, and Test Run and determine compliance with the requirements and constraints of Clause 5.
2. Obtain Results Files and Summary Results Files for each Test Run.
3. Authenticate the Results Files and Summary Results Files obtained in #2.
4. Inspect each Summary Results File to determine compliance with all the constraints and requirements of Clause 4 and Clause 5.

10.6.7 Clause 6: Data Persistence Requirements and Test Related Items

If the Test Sponsor did not shutdown and power cycle the Host System(s), based on Clause 6.4 #3, the auditor may require additional information to ensure the submitted Persistence Test results are compliant. If, after reviewing all available information, compliance of the submitted Persistence Test results remains in question, the Test Sponsor will be required to re-run the Persistence Test and include the Host System(s) shutdown and power cycle step.

10.6.7.1 Remote Audit Related Items

1. Obtain the successful Persistence Test Results file.
2. Authenticate the successful Persistence Test Results File obtained in #1.
3. Inspect the Persistence Test Results File to determine compliance or non-compliance with all the constraints and requirements of Clause 6.

10.6.7.2 On-Site Audit Related Items

1. Observe the successful Persistence Test and determine its compliance with the requirements and constraints of Clause 6.
2. Obtain the Persistence Test Results File from each Test Run.
3. Authenticate the successful Persistence Test Results File obtained in #1.
4. Inspect the Persistence Test Results File to determine compliance or non-compliance with all the constraints and requirements of Clause 6.
5. Optional: Observe all runs (success or failure) or the Persistence Test.

10.6.8 Clause 7: Reported Metrics Related Items

None

10.6.9 Clause 8: Pricing Related Items

1. If the Tested Storage Configuration and Priced Storage Configuration are not identical, verify that the differences between the two configurations are disclosed and that the Priced Storage Configuration would be capable of providing at least the same level of reported performance as the TSC.
2. Review a preliminary copy of the pricing spreadsheet, described in Clause 8.3.1, and verify that it meets all the requirements and constraints of Clause 8. It is not required to review the final pricing prior to issuing the audit certification letter.

10.6.10 Clause 9: Full Disclosure Related Items

For both On-Site and Remote Audits ensure the Full Disclosure Report (FDR) submitted is complete and accurate based on the requirements in Clause 9.

10.7 Republishing An SPC-1 Benchmark Result

10.7.1 An existing SPC-1 benchmark result may be republished as a new result for a Tested Storage Configuration (TSC) other than the original TSC under following conditions:

- a) The hardware and software products that comprise the Priced Storage Configuration (8.1.1.1) in the new SPC-1 benchmark result are materially the same as those used in the original result.
- b) Any hardware and/or software differences between the original and new Priced Storage Configurations do not impact the performance-related primary metrics.
- c) All performance data disclosed in the new Full Disclosure Report is identical to that which is contained in the original FDR.

***Comment:** The intent of this clause is to allow a reseller of equipment from a given supplier to publish a result naming their particular brand or model number without requiring any additional performance testing.*

10.7.2 A SPC-1 benchmark result that republishes an existing result must identify the Test Sponsor and submission date of the original result in its Executive Summary (Clause 9.2.4.3).

10.7.3 All differences in hardware and software products that comprise the original and new Priced Storage Configuration must be listed in the Full Disclosure Report (Clause 9.2.4.4.2).

10.7.4 In the event that all conditions listed in Clause 10.7.1 are met, the audit may not follow the complete audit protocol defined in Clause 10.5.

10.8 Component Substitution in a revised FDR

If a revision to an existing SPC-1 Full Disclosure Report (FDR) would result in a change to the Priced Storage Configuration documented in the existing FDR, the Test Sponsor must submit to the auditor for review, a list of components that would be changed. The auditor may require additional information and/or specific tests to be executed to ensure the new Priced Storage Configuration is capable of successfully completing the Persistence Test, as well as, providing at least the same level of reported performance as stated in the current FDR.

Examples of component substitutions include:

- Replacement of an obsolete component that was included in the existing Priced Storage Configuration.
- Replacement of a component when a change in the component's availability would extend the SPC-1 Availability Date beyond the period allowed by the specification (Clause 8.x).

If the Priced Storage Configuration component changes are approved by the auditor, an amended Audit Report will be issued to the Test Sponsor for inclusion in the revised FDR. If the auditor does not approve the component changes, the Test Sponsor may appeal that decision to the Compliance Review Committee (CRC).

Appendix A: Example Results File

Below is an example Results File produced by the Workload Generator. The Results File must be produced, processed, and verified to provide the required information contained in a Full Disclosure Report, which is required to submit a SPC-1 benchmark result. A Results File may contain encoded information to support results verification activities.

Test Key	dkjd89sjk
Workload Generator Version	x.xx.xx
ASU Configuration	
<i>Logical Volumes in ASU-1</i>	<i>Capacity Mbytes</i>
DUA902839	
DUA29873837	
DUB278292	
DUB3837373	
for all Logical Volumes in ASU-1	
<i>Logical Volumes in ASU-2</i>	<i>Capacity Mbytes</i>
DUA902839	
DUA29873837	
DUB278292	
DUB3837373	
for all Logical Volumes in ASU-2	
<i>Logical Volumes in ASU-3</i>	<i>Capacity Mbytes</i>
DUA902839	
DUA29873837	
DUB278292	
DUB3837373	
for all Logical Volumes in ASU-3	

Overall Test Run Results		
Test Run Components	Start Time	Stop Time
Ramp-Up Period	hh:mm:ss	hh:mm:ss
Start-Up Period	hh:mm:ss	hh:mm:ss
Steady State Period	hh:mm:ss	hh:mm:ss
Measurement Interval Period	hh:mm:ss	hh:mm:ss
Shut Down Period	hh:mm:ss	hh:mm:ss
Ramp Down Period	hh:mm:ss	hh:mm:ss

Measured I/Os Completed	Result	Measured I/O	
		Data Transferred	Result
ASU-1, Stream-1 Reads	9433	ASU-1, Stream-1 Reads	36
ASU-1, Stream-1 Writes	9268	ASU-1, Stream-1 Writes	36
ASU-1, Stream-2 Reads	76116	ASU-1, Stream-2 Reads	297
ASU-1, Stream-2 Writes	75133	ASU-1, Stream-2 Writes	293
ASU-1, Stream-3 Reads	37654	ASU-1, Stream-3 Reads	147
ASU-1, Stream-3 Writes	0	ASU-1, Stream-3 Writes	0
ASU-1, Stream-4 Reads	56781	ASU-1, Stream-4 Reads	221
ASU-1, Stream-4 Writes	56714	ASU-1, Stream-4 Writes	221
ASU-2, Stream-1 Reads	2894	ASU-2, Stream-1 Reads	22
ASU-2, Stream-1 Writes	6935	ASU-2, Stream-1 Writes	54
ASU-2, Stream-2 Reads	11306	ASU-2, Stream-2 Reads	88
ASU-2, Stream-2 Writes	26372	ASU-2, Stream-2 Writes	206
ASU-2, Stream-3 Reads	18731	ASU-2, Stream-3 Reads	146
ASU-2, Stream-3 Writes	0	ASU-2, Stream-3 Writes	0
ASU-3, Stream-1 Reads	0	ASU-3, Stream-1 Reads	0
ASU-3, Stream-1 Writes	151786	ASU-3, Stream-1 Writes	406

Failed I/O Requests	Result
ASU-1, Stream-1 Total	0
ASU-1, Stream-2 Total	0
ASU-1, Stream-3 Total	0
ASU-1, Stream-4 Total	0
ASU-2, Stream-1 Total	0
ASU-2, Stream-2 Total	0
ASU-2, Stream-3 Total	0
ASU-3, Stream-1 Total	0

Transfer Size (KBytes)	Min	Max	Avg.
ASU-1, Stream-1	4,096	4,096	4096
ASU-1, Stream-2	4,096	4,096	4096
ASU-1, Stream-3	4,096	4,096	4096
ASU-1, Stream-4	4,096	4,096	4096
ASU-2, Stream-1	8,192	8,192	8192
ASU-2, Stream-2	8,192	8,192	8192
ASU-2, Stream-3	8,192	8,192	8192
ASU-3, Stream-1	512	8,192	2811

Measured I/Os					
Total Response Time (ms)	Sum	Min	Max	Avg.	Std. Dev
ASU-1, Stream-1 Reads	9,433	1	74.05	8	10.07
ASU-1, Stream-1 Writes	9,268	2	142.81	11	9.22
ASU-1, Stream-2 Reads	76,116	1	109.37	11	11.86
ASU-1, Stream-2 Writes	75,133	2	120.28	14	11.23
ASU-1, Stream-3 Reads	37,654	1	47.24	2	1.77
ASU-1, Stream-3 Writes	0	0	0	0	0
ASU-1, Stream-4 Reads	56,781	1	66.94	7	6.99
ASU-1, Stream-4 Writes	56,714	3	252.07	10	6.46
ASU-2, Stream-1 Reads	2,894	1	24.34	5	3.97
ASU-2, Stream-1 Writes	6,935	3	33.63	7	2.85
ASU-2, Stream-2 Reads	11,306	1	36.57	6	4.31
ASU-2, Stream-2 Writes	26,372	3	247.52	8	3.71
ASU-2, Stream-3 Reads	18,731	1	38.27	2	2.23
ASU-2, Stream-3 Writes	0	0	0	0	0
ASU-3, Stream-1 Reads	0	0	0	0	0
ASU-3, Stream-1 Writes	151,786	2	247.05	22	20.3
SUMMARY Reads	212,915	1	109.37	7	9.18
SUMMARY Writes	326,208	2	252.07	16	16.22
SUMMARY Total	539,123	1	252.07	13	14.56

Response Time Frequency (ms)	0-.25	>.25-.5	>.5-.75	>.75-1	>1-1.25	>1.25-1.5	>1.5-1.75	>1.75-2	>2-2.5	>2.5-3	>3-3.5	>3.5-4
ASU-1, Stream-1 Reads	0	0	0	89	1694	2314	173	77	141	145	112	142
ASU-1, Stream-1 Writes	0	0	0	0	0	0	0	0	2	145	282	360
ASU-1, Stream-2 Reads	0	0	0	1485	14332	3942	858	604	1139	837	873	1130
ASU-1, Stream-2 Writes	0	0	0	0	0	0	0	0	66	1665	2166	2149
ASU-1, Stream-3 Reads	0	0	0	33	7303	25210	1324	307	590	496	150	125
ASU-1, Stream-3 Writes	0	0	0	0	0	0	0	0	0	0	0	0
ASU-1, Stream-4 Reads	0	0	0	13	7962	11374	972	500	964	1500	1231	1263
ASU-1, Stream-4 Writes	0	0	0	0	0	0	0	0	0	791	2126	2081
ASU-2, Stream-1 Reads	0	0	0	0	35	1262	77	15	16	17	65	85
ASU-2, Stream-1 Writes	0	0	0	0	0	0	0	0	0	97	355	355
ASU-2, Stream-2 Reads	0	0	0	0	297	2616	177	56	41	39	307	419
ASU-2, Stream-2 Writes	0	0	0	0	0	0	0	0	0	541	1174	1210
ASU-2, Stream-3 Reads	0	0	0	1	198	15144	894	150	202	68	92	127
ASU-2, Stream-3 Writes	0	0	0	0	0	0	0	0	0	0	0	0
ASU-3, Stream-1 Reads	0	0	0	0	0	0	0	0	0	0	0	0
ASU-3, Stream-1 Writes	0	0	0	0	0	0	0	0	1640	2734	3048	3370

Response Time Frequency (ms)	>4-4.5	>4.5-5	>5-6	>6-7	>7-8	>8-9	>9-10	>10-15	>15-20	>20-25	>25-30	>30
ASU-1, Stream-1 Reads	137	153	334	335	323	336	343	1044	568	341	219	413
ASU-1, Stream-1 Writes	353	361	796	832	784	815	854	1897	688	400	248	451
ASU-1, Stream-2 Reads	1236	1411	2865	2941	3133	3116	3330	12201	7072	4569	3069	5973
ASU-1, Stream-2 Writes	2249	2388	4896	5099	5401	5645	6162	15084	7771	4636	3034	6722
ASU-1, Stream-3 Reads	131	122	295	236	253	272	288	442	76	0	0	1
ASU-1, Stream-3 Writes	0	0	0	0	0	0	0	0	0	0	0	0
ASU-1, Stream-4 Reads	1241	1326	2735	2815	2796	2870	2964	7743	3560	1545	677	730
ASU-1, Stream-4 Writes	2175	2315	4772	5131	5082	5158	5477	12727	4830	2100	923	1026
ASU-2, Stream-1 Reads	64	66	186	165	172	150	172	300	40	7	0	0
ASU-2, Stream-1 Writes	421	430	775	773	742	844	823	1228	77	12	2	1
ASU-2, Stream-2 Reads	381	392	899	860	825	891	955	1740	344	55	11	1
ASU-2, Stream-2 Writes	1409	1362	2905	2861	2788	3205	2912	5009	806	147	28	15
ASU-2, Stream-3 Reads	94	123	246	239	218	264	221	404	43	2	0	1
ASU-2, Stream-3 Writes	0	0	0	0	0	0	0	0	0	0	0	0
ASU-3, Stream-1 Reads	0	0	0	0	0	0	0	0	0	0	0	0
ASU-3, Stream-1 Writes	3608	3645	7217	7821	8657	8636	9513	23671	14507	9523	6803	37393

Test Run Interval Statistics									
<i>Minutes of Test Run</i>		<i>BSU Load Level</i>							
1									
2									
3									
4									
5									
6									
7									
8									
9									
↓									
<i>Final Test Run Minute</i>									
<i>I/O Requests Completed</i>		<i>ASU 1, Stream 1</i>	<i>ASU-1, Stream 1</i>	<i>ASU-1, Stream 2</i>	<i>ASU-1, Stream 2</i>	<i>ASU-1, Stream 3</i>	<i>ASU-1, Stream 3</i>	<i>ASU-1, Stream 4</i>	<i>ASU-1, Stream 4</i>
		<i>Reads</i>	<i>Writes</i>	<i>Reads</i>	<i>Writes</i>	<i>Reads</i>	<i>Writes</i>	<i>Reads</i>	<i>Writes</i>
<i>Minutes of Test Run</i>									
1		66	45	425	412	209	0	308	305
2		64	51	422	380	197	0	300	315
3		45	45	392	440	230	0	349	315
4		63	52	435	398	194	0	334	323
5		23	13	152	128	63	0	102	95
6		123	111	879	831	416	0	610	605
7		116	99	837	873	432	0	667	654
8		106	98	846	807	447	0	635	635
9		98	105	786	838	408	0	651	606
↓									
<i>Final Test Run Minute</i>									
<i>I/O Requests Completed</i>		<i>ASU 2, Stream 1</i>	<i>ASU-2, Stream 1</i>	<i>ASU-2, Stream 2</i>	<i>ASU-2, Stream 2</i>	<i>ASU-2, Stream 3</i>	<i>ASU-2, Stream 3</i>	<i>ASU-3, Stream 1</i>	<i>ASU-3, Stream 1</i>
		<i>Reads</i>	<i>Writes</i>	<i>Reads</i>	<i>Writes</i>	<i>Reads</i>	<i>Writes</i>	<i>Reads</i>	<i>Writes</i>
<i>Minutes of Test Run</i>									
1		14	30	55	115	99	0	0	886
2		22	40	56	133	100	0	0	815
3		13	34	60	171	104	0	0	857
4		17	42	55	148	94	0	0	862
5		12	11	27	51	46	0	0	291
6		32	85	142	291	204	0	0	1660
7		37	72	115	301	209	0	0	1694
8		28	74	128	276	211	0	0	1711
9		29	97	131	298	204	0	0	1692
↓									
<i>Final Test Run Minute</i>									

Total Response Time (ms)	ASU 1, Stream 1	ASU-1, Stream 1	ASU-1, Stream 2	ASU-1, Stream 2	ASU-1, Stream 3	ASU-1, Stream 3	ASU-1, Stream 4	ASU-1, Stream 4
	Reads	Writes	Reads	Writes	Reads	Writes	Reads	Writes
Minutes of Test Run								
1	334	336	2263	2924	343	0	1172	2251
2	290	356	2102	2776	303	0	1327	2301
3	232	361	2262	3140	343	0	1434	2328
4	281	334	2359	2941	311	0	1465	2286
5	111	100	688	897	107	0	422	693
6	515	840	5246	6600	717	0	2786	4618
7	585	752	5032	6959	715	0	3168	5153
8	407	738	5023	6282	748	0	2602	4687
9	498	886	4414	6481	701	0	2953	4570
↓								
Final Test Run Minute								

Total Response Time (ms)	ASU 2, Stream 1	ASU-2, Stream 1	ASU-2, Stream 2	ASU-2, Stream 2	ASU-2, Stream 3	ASU-2, Stream 3	ASU-3, Stream 1	ASU-3, Stream 1
	Reads	Writes	Reads	Writes	Reads	Writes	Reads	Writes
Minutes of Test Run								
1	52	191	318	828	195	0	0	6064
2	107	285	283	937	197	0	0	5632
3	62	242	360	1223	213	0	0	6075
4	50	293	345	1038	206	0	0	6093
5	42	87	118	367	113	0	0	2042
6	133	628	793	2118	420	0	0	12843
7	163	511	715	2172	399	0	0	13225
8	129	486	675	2050	384	0	0	13094
9	120	677	744	2163	383	0	0	13034
↓								
Final Test Run Minute								

Data Transferred (MBytes)	ASU 1, Stream 1	ASU-1, Stream 1	ASU-1, Stream 2	ASU-1, Stream 2	ASU-1, Stream 3	ASU-1, Stream 3	ASU-1, Stream 4	ASU-1, Stream 4
	Reads	Writes	Reads	Writes	Reads	Writes	Reads	Writes
Minutes of Test Run								
1	0	0	2	2	1	0	1	1
2	0	0	2	1	1	0	1	1
3	0	0	2	2	1	0	1	1
4	0	0	2	2	1	0	1	1
5	0	0	1	1	0	0	0	0
6	0	0	3	3	2	0	2	2
7	0	0	3	3	2	0	3	3
8	0	0	3	3	2	0	2	2
9	0	0	3	3	2	0	3	2
↓								
Final Test Run Minute								

Data Transferred (MBytes)	ASU 2, Stream 1	ASU-2, Stream 1	ASU-2, Stream 2	ASU-2, Stream 2	ASU-2, Stream 3	ASU-2, Stream 3	ASU-3, Stream 1	ASU-3, Stream 1
	Reads	Writes	Reads	Writes	Reads	Writes	Reads	Writes
Minutes of Test Run								
1	0	0	0	1	1	0	0	2
2	0	0	0	1	1	0	0	2
3	0	0	0	1	1	0	0	2
4	0	0	0	1	1	0	0	3
5	0	0	0	0	0	0	0	1
6	0	1	1	2	2	0	0	4
7	0	1	1	2	2	0	0	4
8	0	1	1	2	2	0	0	5
9	0	1	1	2	2	0	0	5
↓								
Final Test Run Minute								

Appendix B: Example Persistence Test Results File

The Persistence Test Results File may contain encoded information to support results verification activities.

Test Key	dkjd89sjk
Workload Generator Version	2.02.83
Summary Test Run Results	
Time to Write Test Blocks	hh:mm:ss
Blocks Written by Logical Volume	Result
DUA902839	3849
DUA29873837	3849
DUB278292	3849
DUB3837373	3849
for all Logical Volumes	
Blocks Verified by Logical Volume	Result
DUA902839	3849
DUA29873837	3849
DUB278292	3848
DUB3837373	3849
for all Logical Volumes	
Failed I/O Request by Logical Volume	Result
DUA902839	0
DUA29873837	0
DUB278292	1
DUB3837373	0
for all Logical Volumes	

Appendix C: Example Summary Results File

The Summary Results File may contain encoded information to support results verification activities.

Test Key	dkjd89sjk
Workload Generator Version	2.02.83
ASU Configuration	
Logical Volumes in ASU-1	Capacity Mbytes
DUA902839	38373890
DUA29873837	34243424
DUB278292	22342423
DUB3837373	23423423
for all Logical Volumes in ASU-1	
Logical Volumes in ASU-2	Capacity Mbytes
DUA902839	38373890
DUA29873837	34243424
DUB278292	22342423
DUB3837373	23423423
for all Logical Volumes in ASU-2	
Logical Volumes in ASU-3	Capacity Mbytes
DUA902839	38373890
DUA29873837	34243424
DUB278292	22342423
DUB3837373	23423423
for all Logical Volumes in ASU-3	

Overall Test Run Results		
Test Run Components	Start Time	Stop Time
Ramp-Up Period	hh:mm:ss	hh:mm:ss
Start-Up Period	hh:mm:ss	hh:mm:ss
Steady State Period	hh:mm:ss	hh:mm:ss
Measurement Interval Period	hh:mm:ss	hh:mm:ss
Shut Down Period	hh:mm:ss	hh:mm:ss
Ramp Down Period	hh:mm:ss	hh:mm:ss
Measured I/Os Completed	Result	
ASU-1, Stream-1 Reads	38393	
ASU-1, Stream-1 Writes	39491	
ASU-1, Stream-1 Total	77884	
ASU-1, Stream-2 Reads	41440	
ASU-1, Stream-2 Writes	42483	
ASU-1, Stream-2 Total	83923	
ASU-1, Stream-3 Reads	44108	
ASU-1, Stream-3 Writes	46168	
ASU-1, Stream-3 Total	90277	
ASU-1, Stream-4 Reads	48406	
ASU-1, Stream-4 Writes	49229	
ASU-1, Stream-4 Total	97635	
ASU-1 Total	349718	
ASU-2, Stream-1 Reads	51354	
ASU-2, Stream-1 Writes	52269	
ASU-2, Stream-1 Total	103624	
ASU-2, Stream-2 Reads	54155	
ASU-2, Stream-2 Writes	54715	
ASU-2, Stream-2 Total	108870	
ASU-2, Stream-3 Reads	57402	
ASU-2, Stream-3 Writes	58393	
ASU-2, Stream-3 Total	115795	
ASU-2 Total	328289	
ASU-3, Stream-1 Reads	59590	
ASU-3, Stream-1 Writes	59786	
ASU-3, Stream-1 Total	119376	
ASU-3 Total	119376	
GRAND TOTAL	797384	

I/O Request Throughput		Measured I/O, Total Resp. Time (ms)		Average Response Time (ms)	
	Result		Result		Result
ASU-1, Stream-1 Reads	234	ASU-1, Stream-1 Reads	2334.76	ASU-1, Stream-1 Reads	23.57
ASU-1, Stream-1 Writes	238	ASU-1, Stream-1 Writes	2388.67	ASU-1, Stream-1 Writes	24.53
ASU-1, Stream-1 Total	472	ASU-1, Stream-1 Total	4723.43	ASU-1, Stream-1	24.05
ASU-1, Stream-2 Reads	245	ASU-1, Stream-2 Reads	2468.98	ASU-1, Stream-2 Reads	25.65
ASU-1, Stream-2 Writes	248	ASU-1, Stream-2 Writes	2560.92	ASU-1, Stream-2 Writes	26.65
ASU-1, Stream-2 Total	493	ASU-1, Stream-2 Total	5029.90	ASU-1, Stream-2	26.15
ASU-1, Stream-3 Reads	260	ASU-1, Stream-3 Reads	2650.48	ASU-1, Stream-3 Reads	26.69
ASU-1, Stream-3 Writes	266	ASU-1, Stream-3 Writes	2759.17	ASU-1, Stream-3 Writes	27.69
ASU-1, Stream-3 Total	525	ASU-1, Stream-3 Total	5409.65	ASU-1, Stream-3	27.19
ASU-1, Stream-4 Reads	278	ASU-1, Stream-4 Reads	2854.10	ASU-1, Stream-4 Reads	27.88
ASU-1, Stream-4 Writes	290	ASU-1, Stream-4 Writes	2945.12	ASU-1, Stream-4 Writes	28.16
ASU-1, Stream-4 Total	568	ASU-1, Stream-4 Total	5799.23	ASU-1, Stream-4	28.02
ASU-1	2058	ASU-1 Total	20962.21	ASU-1	26.35
ASU-2, Stream-1 Reads	303	ASU-2, Stream-1 Reads	3066.07	ASU-2, Stream-1 Reads	28.41
ASU-2, Stream-1 Writes	307	ASU-2, Stream-1 Writes	3217.64	ASU-2, Stream-1 Writes	29.08
ASU-2, Stream-1 Total	610	ASU-2, Stream-1 Total	6283.71	ASU-2, Stream-1	28.75
ASU-2, Stream-2 Reads	308	ASU-2, Stream-2 Reads	3269.09	ASU-2, Stream-2 Reads	29.77
ASU-2, Stream-2 Writes	313	ASU-2, Stream-2 Writes	3408.02	ASU-2, Stream-2 Writes	30.83
ASU-2, Stream-2 Total	621	ASU-2, Stream-2 Total	6677.11	ASU-2, Stream-2	30.30
ASU-2, Stream-3 Reads	321	ASU-2, Stream-3 Reads	3488.95	ASU-2, Stream-3 Reads	32.31
ASU-2, Stream-3 Writes	325	ASU-2, Stream-3 Writes	3576.13	ASU-2, Stream-3 Writes	33.01
ASU-2, Stream-3 Total	646	ASU-2, Stream-3 Total	7065.08	ASU-2, Stream-3	32.66
ASU-2	1876	ASU-2 Total	20025.90	ASU-2	30.57
ASU-3, Stream-1 Reads	329	ASU-3, Stream-1 Reads	3595.15	ASU-3, Stream-1 Reads	34.31
ASU-3, Stream-1 Writes	341	ASU-3, Stream-1 Writes	3766.41	ASU-3, Stream-1 Writes	35.35
ASU-3, Stream-1 Total	670	ASU-3, Stream-1 Total	7361.56	ASU-3, Stream-1	34.83
ASU-3	670	ASU-3 Total	7361.56	ASU-3	34.83
All ASUs	4604	GRAND TOTAL	48349.66	ALL ASUs	30.58

Measured I/O, Data transferred (MBytes)		Data Rate (MBytes/Sec)	
	Result		Result
ASU-1, Stream-1 Reads	39847	ASU-1, Stream-1 Reads	12.23
ASU-1, Stream-1 Writes	41337	ASU-1, Stream-1 Writes	12.36
ASU-1, Stream-1 Total	81184	ASU-1, Stream-1	12.30
ASU-1, Stream-2 Reads	42755	ASU-1, Stream-2 Reads	12.66
ASU-1, Stream-2 Writes	42841	ASU-1, Stream-2 Writes	13.10
ASU-1, Stream-2 Total	85596	ASU-1, Stream-2	12.88
ASU-1, Stream-3 Reads	43194	ASU-1, Stream-3 Reads	13.32
ASU-1, Stream-3 Writes	44321	ASU-1, Stream-3 Writes	13.56
ASU-1, Stream-3 Total	87515	ASU-1, Stream-3	13.44
ASU-1, Stream-4 Reads	45307	ASU-1, Stream-4 Reads	13.89
ASU-1, Stream-4 Writes	46396	ASU-1, Stream-4 Writes	14.46
ASU-1, Stream-4 Total	91703	ASU-1, Stream-4	14.18
ASU-1 Total	346000	ASU-1 Total	13.20
ASU-2, Stream-1 Reads	47699	ASU-2, Stream-1 Reads	15.18
ASU-2, Stream-1 Writes	49573	ASU-2, Stream-1 Writes	15.25
ASU-2, Stream-1 Total	97273	ASU-2, Stream-1	15.21
ASU-2, Stream-2 Reads	49851	ASU-2, Stream-2 Reads	15.32
ASU-2, Stream-2 Writes	52269	ASU-2, Stream-2 Writes	15.75
ASU-2, Stream-2 Total	102121	ASU-2, Stream-2	15.53
ASU-2, Stream-3 Reads	52556	ASU-2, Stream-3 Reads	16.37
ASU-2, Stream-3 Writes	54823	ASU-2, Stream-3 Writes	16.89
ASU-2, Stream-3 Total	107379	ASU-2, Stream-3	16.63
ASU-2 Total	306772	ASU-2	15.79
ASU-3, Stream-1 Reads	55790	ASU-3, Stream-1 Reads	17.47
ASU-3, Stream-1 Writes	57310	ASU-3, Stream-1 Writes	17.94
ASU-3, Stream-1 Total	469941	ASU-3, Stream-1	17.71
ASU-3 Total	469941	ASU-3	17.71
GRAND TOTAL	1122713	ALL ASUs	15.56

Failed I/O Requests	Result		
ASU-1, Stream-1 Total	0		
ASU-1, Stream-2 Total	0		
ASU-1, Stream-3 Total	0		
ASU-1, Stream-4 Total	0		
ASU-2, Stream-1 Total	1		
ASU-2, Stream-2 Total	0		
ASU-2, Stream-3 Total	0		
ASU-3, Stream-1 Total	0		
GRAND TOTAL	1		
Transfer Size (KBytes)	Min	Max	Avg.
ASU-1, Stream-1	4,096	6,028	5467
ASU-1, Stream-2	4,096	6,028	5467
ASU-1, Stream-3	4,096	6,028	5467
ASU-1, Stream-4	4,096	6,028	5467
ASU-2, Stream-1	4,096	6,028	5467
ASU-2, Stream-2	4,096	6,028	5467
ASU-2, Stream-3	4,096	6,028	5467
ASU-3, Stream-1	4,096	6,028	5467

Response Time Frequency (ms)	0-.25	>.25-.5	>.5-.75	>.75-1	>1-1.25	>1.25-1.5	>1.5-1.75	>1.75-2	>2-2.5	>2.5-3	>3-3.5	>3.5-4
ASU-1, Stream-1 Reads	5	8	20	35	67	134	267	456	789	1567	3678	4356
ASU-1, Stream-1 Writes	2	4	6	13	20	46	89	201	303	567	1678	1823
ASU-1, Stream-1 Total	7	12	26	48	87	180	356	657	1092	2134	5356	6179
ASU-1, Stream-2 Reads	4	10	13	24	44	90	178	329	546	1067	2678	3090
ASU-1, Stream-2 Writes	2	6	8	14	26	54	107	197	328	640	1607	1854
ASU-1, Stream-2 Total	6	16	21	38	70	144	285	526	874	1707	4285	4943
ASU-1, Stream-3 Reads	1	4	5	10	17	36	71	131	218	427	1071	1236
ASU-1, Stream-3 Writes	5	8	20	35	67	134	267	456	789	1567	3678	4356
ASU-1, Stream-3 Total	6	12	25	45	84	170	338	587	1007	1994	4749	5592
ASU-1, Stream-4 Reads	2	4	6	13	20	46	89	201	303	567	1678	1823
ASU-1, Stream-4 Writes	5	8	20	35	67	134	267	456	789	1567	3678	4356
ASU-1, Stream-4 Total	7	12	26	48	87	180	356	657	1092	2134	5356	6179
ASU-1 Total	26	52	98	179	328	674	1335	2427	4065	7969	19746	22893
ASU-2, Stream-1 Reads	2	4	6	13	20	46	89	201	303	567	1678	1823
ASU-2, Stream-1 Writes	5	8	20	35	67	134	267	456	789	1567	3678	4356
ASU-2, Stream-1 Total	7	12	26	48	87	180	356	657	1092	2134	5356	6179
ASU-2, Stream-2 Reads	2	4	6	13	20	46	89	201	303	567	1678	1823
ASU-2, Stream-2 Writes	5	8	20	35	67	134	267	456	789	1567	3678	4356
ASU-2, Stream-2 Total	7	12	26	48	87	180	356	657	1092	2134	5356	6179
ASU-2, Stream-3 Reads	2	4	6	13	20	46	89	201	303	567	1678	1823
ASU-2, Stream-3 Writes	5	8	20	35	67	134	267	456	789	1567	3678	4356
ASU-2, Stream-3 Total	7	12	26	48	87	180	356	657	1092	2134	5356	6179
ASU-2 Total	21	36	78	144	261	540	1068	1971	3276	6402	16068	18537
ASU-3, Stream-1 Reads	2	4	6	13	20	46	89	201	303	567	1678	1823
ASU-3, Stream-1 Writes	2	4	6	13	20	46	89	201	303	567	1678	1823
ASU-3, Stream-1 Total	4	8	12	26	40	92	178	402	606	1134	3356	3646
ASU-3 Total	4	8	12	26	40	92	178	402	606	1134	3356	3646
GRAND TOTAL	51	96	188	349	629	1306	2581	4800	7947	15505	39170	45076

Response Time Frequency (ms)	>4-4.5	>4.5-5	>5-6	>6-7	>7-8	>8-9	>9-10	>10-15	>15-20	>20-25	>25-30	>30
ASU-1, Stream-1 Reads	3678	4356	1567	789	456	267	134	67	35	20	8	5
ASU-1, Stream-1 Writes	1678	1823	567	303	201	89	46	20	13	6	4	2
ASU-1, Stream-1 Total	5356	6179	2134	1092	657	356	180	87	48	26	12	7
ASU-1, Stream-2 Reads	1678	1823	567	303	201	89	46	20	13	6	4	2
ASU-1, Stream-2 Writes	3678	4356	1567	789	456	267	134	67	35	20	8	5
ASU-1, Stream-2 Total	5356	6179	2134	1092	657	356	180	87	48	26	12	7
ASU-1, Stream-3 Reads	1678	1823	567	303	201	89	46	20	13	6	4	2
ASU-1, Stream-3 Writes	3678	4356	1567	789	456	267	134	67	35	20	8	5
ASU-1, Stream-3 Total	5356	6179	2134	1092	657	356	180	87	48	26	12	7
ASU-1, Stream-4 Reads	1678	1823	567	303	201	89	46	20	13	6	4	2
ASU-1, Stream-4 Writes	3678	4356	1567	789	456	267	134	67	35	20	8	5
ASU-1, Stream-4 Total	5356	6179	2134	1092	657	356	180	87	48	26	12	7
ASU-1 Total	21424	24716	8536	4368	2628	1424	720	348	192	104	48	28
ASU-2, Stream-1 Reads	1678	1823	567	303	201	89	46	20	13	6	4	2
ASU-2, Stream-1 Writes	3678	4356	1567	789	456	267	134	67	35	20	8	5
ASU-2, Stream-1 Total	5356	6179	2134	1092	657	356	180	87	48	26	12	7
ASU-2, Stream-2 Reads	1678	1823	567	303	201	89	46	20	13	6	4	2
ASU-2, Stream-2 Writes	3678	4356	1567	789	456	267	134	67	35	20	8	5
ASU-2, Stream-2 Total	5356	6179	2134	1092	657	356	180	87	48	26	12	7
ASU-2, Stream-3 Reads	1678	1823	567	303	201	89	46	20	13	6	4	2
ASU-2, Stream-3 Writes	3678	4356	1567	789	456	267	134	67	35	20	8	5
ASU-2, Stream-3 Total	5356	6179	2134	1092	657	356	180	87	48	26	12	7
ASU-2 Total	16068	18537	6402	3276	1971	1068	540	261	144	78	36	21
ASU-3, Stream-1 Reads	1678	1823	567	303	201	89	46	20	13	6	4	2
ASU-3, Stream-1 Writes	1678	1823	567	303	201	89	46	20	13	6	4	2
ASU-3, Stream-1 Total	3356	3646	1134	606	402	178	92	40	26	12	8	4
ASU-3 Total	3356	3646	1134	606	402	178	92	40	26	12	8	4
GRAND TOTAL	40848	46899	16072	8250	5001	2670	1352	649	362	194	92	53

Test Run Interval Statistics										
Minutes of Test Run	1	2	3	4	5	6	7	8	9	► All Test Run Minutes
BSU Load Level	434	434	434	434	434	434	434	434	434	434
Minutes of Test Run	1	2	3	4	5	6	7	8	9	► All Test Run Minutes
I/O Requests Completed										
ASU-1, Stream-1 Reads	2345	3456	5454	9789	12456	15367	14367	14789	14665	
ASU-1, Stream-1 Writes	2701	3745	6042	12002	13295	18317	14402	16400	17825	
ASU-1, Stream-1 Total	5046	7201	11496	21791	25751	33684	28769	31189	32490	
ASU-1, Stream-2 Reads	2366	4169	5791	11734	14874	17193	16911	16347	15677	
ASU-1, Stream-2 Writes	2709	3812	5671	11531	14643	18563	17016	18442	17311	
ASU-1, Stream-2 Total	5076	7980	11462	23265	29517	35757	33927	34789	32988	
ASU-1, Stream-3 Reads	2867	3930	5829	10552	14457	17942	14488	16239	17111	
ASU-1, Stream-3 Writes	2511	4262	6004	11737	14485	16813	17232	16841	14692	
ASU-1, Stream-3 Total	5378	8192	11834	22290	28942	34755	31720	33079	31803	
ASU-1, Stream-4 Reads	2913	4104	6077	10265	12986	16633	16481	15178	17127	
ASU-1, Stream-4 Writes	2599	3496	6297	10511	12922	15641	17389	15539	16972	
ASU-1, Stream-4 Total	5512	7600	12374	20775	25907	32274	33870	30717	34099	
ASU-1 Total	21011	30973	47166	88121	110117	136470	128286	129774	131379	
ASU-2, Stream-1 Reads	2456	3791	6461	9854	14448	15624	16399	15376	16386	
ASU-2, Stream-1 Writes	2516	3602	5792	11419	14545	18302	15260	17272	17746	
ASU-2, Stream-1 Total	4973	7393	12253	21272	28994	33926	31659	32648	34132	
ASU-2, Stream-2 Reads	2693	3553	5458	11549	14271	16415	17423	16918	15259	
ASU-2, Stream-2 Writes	2528	4242	6331	9968	15490	19028	15771	16226	15447	
ASU-2, Stream-2 Total	5221	7795	11789	21517	29761	35443	33195	33144	30706	
ASU-2, Stream-3 Reads	2863	3935	6228	11479	14962	18998	16561	18085	15837	
ASU-2, Stream-3 Writes	2586	4152	6766	12174	14447	18230	17523	18334	17982	
ASU-2, Stream-3 Total	5449	8086	12994	23653	29409	37228	34085	36419	33819	
ASU-2 Total	15642	23274	37036	66443	88163	106598	98938	102211	98657	
ASU-3, Stream-1 Reads	2496	3713	5650	11108	14462	16434	16852	16031	16444	
ASU-3, Stream-1 Writes	2745	4072	6293	10433	13414	16205	16368	17034	15676	
ASU-3, Stream-1 Total	5242	7784	11942	21541	27875	32639	33220	33066	32120	
ASU-3 Total	5242	7784	11942	21541	27875	32639	33220	33066	32120	
GRAND TOTAL	41895	62031	96144	176105	226156	275706	260444	265050	262157	
Minutes of Test Run	1	2	3	4	5	6	7	8	9	► All Test Run Minutes
Total Response Time (ms)										
ASU-1, Stream-1 Reads	1287.37	1594.34	1934.43	2374.32	2383.75	2467.52	2471.60	2490.02	2468.30	
ASU-1, Stream-1 Writes	1310.39	1644.66	1947.66	2474.85	2413.01	2587.62	2489.17	2493.81	2574.22	
ASU-1, Stream-1 Total	2597.76	3239.00	3882.09	4849.17	4796.76	5055.14	4960.77	4983.83	5042.52	
ASU-1, Stream-2 Reads	1328.86	1639.06	2028.08	2486.45	2455.47	2585.26	2505.42	2524.65	2547.77	
ASU-1, Stream-2 Writes	1351.01	1662.20	2007.76	2455.15	2472.17	2474.12	2509.09	2535.97	2509.80	
ASU-1, Stream-2 Total	2679.88	3301.26	4035.83	4941.60	4927.63	5059.38	5014.51	5060.62	5057.58	
ASU-1, Stream-3 Reads	1331.51	1657.23	1981.84	2467.56	2428.38	2589.09	2551.23	2541.73	2482.75	
ASU-1, Stream-3 Writes	1318.06	1629.63	1950.18	2408.82	2468.63	2586.74	2522.97	2572.69	2473.65	
ASU-1, Stream-3 Total	2649.57	3286.85	3932.02	4876.37	4897.01	5175.83	5074.20	5114.42	4956.40	
ASU-1, Stream-4 Reads	1303.03	1634.38	1997.50	2427.64	2432.78	2544.80	2516.72	2563.09	2567.31	
ASU-1, Stream-4 Writes	1333.52	1656.59	1975.70	2394.64	2468.50	2483.35	2559.66	2614.43	2514.35	
ASU-1, Stream-4 Total	2636.55	3290.98	3973.20	4822.28	4901.28	5028.15	5076.38	5177.51	5081.65	
ASU-1 Total	10563.76	13118.09	15823.15	19489.43	19522.69	20318.50	20125.87	20336.39	20138.15	
ASU-2, Stream-1 Reads	1291.04	1631.01	1957.62	2470.74	2492.68	2589.46	2572.69	2580.03	2519.98	
ASU-2, Stream-1 Writes	1327.36	1671.08	1958.78	2396.49	2449.82	2587.69	2544.33	2607.33	2523.95	
ASU-2, Stream-1 Total	2618.40	3302.09	3916.40	4867.23	4942.50	5177.15	5117.02	5187.37	5043.93	
ASU-2, Stream-2 Reads	1324.10	1605.93	2006.98	2437.47	2498.21	2475.39	2545.40	2546.98	2575.81	
ASU-2, Stream-2 Writes	1324.44	1672.30	1987.74	2417.22	2432.01	2497.56	2587.10	2579.32	2494.06	
ASU-2, Stream-2 Total	2648.54	3278.23	3994.72	4854.68	4930.22	4972.95	5132.49	5126.30	5069.87	
ASU-2, Stream-3 Reads	1339.84	1617.99	2014.15	2427.37	2416.35	2583.94	2556.50	2512.04	2566.45	
ASU-2, Stream-3 Writes	1311.98	1602.82	1963.10	2381.52	2475.62	2495.23	2515.29	2510.49	2488.00	
ASU-2, Stream-3 Total	2651.83	3220.81	3977.25	4808.89	4891.96	5079.17	5071.79	5022.53	5054.46	
ASU-2 Total	7918.76	9801.14	11888.36	14530.81	14764.68	15229.27	15321.30	15336.21	15168.26	
ASU-3, Stream-1 Reads	1335.68	1611.36	2021.59	2461.87	2400.96	2488.61	2494.54	2547.43	2519.65	
ASU-3, Stream-1 Writes	1329.15	1604.87	1991.65	2436.82	2449.88	2562.64	2567.08	2552.59	2515.10	
ASU-3, Stream-1 Total	2664.82	3216.23	4013.24	4898.69	4850.84	5051.24	5061.62	5100.02	5034.74	
ASU-3 Total	2664.82	3216.23	4013.24	4898.69	4850.84	5051.24	5061.62	5100.02	5034.74	
GRAND TOTAL	21147.35	26135.45	31724.75	38918.92	39138.21	40599.01	40508.79	40772.61	40341.15	

Minutes of Test Run	1	2	3	4	5	6	7	8	9 → All Test Run Minutes
Data Transferred (MBytes)									
ASU-1, Stream-1 Reads	2398.00	3498.00	4587.00	5478.00	5389.00	5392.00	5463.00	5435.00	5476.00
ASU-1, Stream-1 Writes	3435.03	4362.65	6532.16	8552.10	6750.03	6199.52	5755.29	8091.91	6489.38
ASU-1, Stream-1 Total	5833.03	7860.65	11119.16	14030.10	12139.03	11591.52	11218.29	13526.91	11965.38
ASU-1, Stream-2 Reads	2962.40	4734.03	4726.47	6046.08	8096.54	6180.57	7776.71	5641.68	8831.42
ASU-1, Stream-2 Writes	3489.29	3934.96	5128.85	6703.66	8714.92	6005.28	5712.82	7327.66	7346.94
ASU-1, Stream-2 Total	6451.69	8668.99	9855.32	12749.74	16811.46	12185.85	13489.53	12969.34	16178.36
ASU-1, Stream-3 Reads	3276.43	3585.24	6861.69	8151.14	7586.98	5864.01	7582.87	6238.32	6317.64
ASU-1, Stream-3 Writes	3016.38	4576.69	5378.44	6882.23	5724.00	8092.95	5919.52	7999.04	8637.61
ASU-1, Stream-3 Total	6292.81	8161.93	12240.13	15033.37	13310.98	13956.96	13502.40	14237.35	14955.25
ASU-1, Stream-4 Reads	3712.50	4646.28	5494.71	8521.45	7934.30	7920.93	8236.84	7564.99	7359.27
ASU-1, Stream-4 Writes	2714.06	4886.09	6422.31	6754.30	6700.79	7002.58	7666.07	7383.86	6758.52
ASU-1, Stream-4 Total	6426.56	9532.38	11917.02	15275.75	14635.09	14923.51	15902.92	14948.85	14117.80
ASU-1 Total	25004.09	34223.94	45131.62	57088.96	56896.56	52657.84	54113.13	55682.45	57216.79
ASU-2, Stream-1 Reads	3817.14	5554.84	6358.65	8700.20	5468.23	7540.30	7602.25	8070.94	8708.23
ASU-2, Stream-1 Writes	3166.53	3692.04	6830.17	5920.29	7335.79	6228.15	8276.25	6305.43	5859.74
ASU-2, Stream-1 Total	6983.66	9246.88	13188.82	14620.48	12804.01	13768.46	15878.50	14376.37	14567.98
ASU-2, Stream-2 Reads	3428.12	4043.60	7418.40	5723.89	5681.87	8272.01	6300.42	6944.10	7050.66
ASU-2, Stream-2 Writes	3381.58	4360.87	7185.52	6647.57	7010.75	7993.67	8022.39	8373.17	7335.95
ASU-2, Stream-2 Total	6809.70	8404.47	14603.92	12371.45	12692.62	16265.68	14322.81	15317.28	14386.61
ASU-2, Stream-3 Reads	3099.91	3743.72	6529.16	6517.38	5683.86	5803.89	7071.39	6781.38	8123.83
ASU-2, Stream-3 Writes	3136.55	3705.62	5329.91	6521.29	5612.29	5541.56	6634.90	8132.42	6004.46
ASU-2, Stream-3 Total	6236.46	7449.34	11859.07	13038.67	11296.15	11345.45	13706.29	14913.80	14128.29
ASU-2 Total	20029.82	25100.70	39651.81	40030.61	36792.79	41379.59	43907.60	44607.45	43082.87
ASU-3, Stream-1 Reads	3149.24	5514.53	6319.83	5997.59	5459.48	8571.08	6797.05	7942.68	7736.23
ASU-3, Stream-1 Writes	3598.60	5022.96	6593.24	6936.58	8857.62	5724.10	6832.45	5959.48	5663.33
ASU-3, Stream-1 Total	6747.84	10537.48	12913.06	12934.18	14317.10	14295.19	13629.49	13902.17	13399.56
ASU-3 Total	6747.84	10537.48	12913.06	12934.18	14317.10	14295.19	13629.49	13902.17	13399.56
GRAND TOTAL	51781.76	69862.12	97696.50	110053.74	108006.44	108332.62	111650.22	114192.06	113699.21

Minutes of Test Run	1	2	3	4	5	6	7	8	9 → All Test Run Minutes
I/O Request Throughput									
ASU-1, Stream-1 Reads	234	367	567	956	1234	1567	1456	1498	1478
ASU-1, Stream-1 Writes	248	381	651	1011	1460	1848	1723	1617	1602
ASU-1, Stream-1 Total	241	374	609	983	1347	1708	1590	1557	1540
ASU-1, Stream-2 Reads	244	384	650	1152	1311	1707	1678	1683	1795
ASU-1, Stream-2 Writes	279	423	577	1001	1376	1785	1814	1622	1790
ASU-1, Stream-2 Total	261	403	613	1077	1343	1746	1746	1652	1793
ASU-1, Stream-3 Reads	278	376	601	1140	1439	1624	1633	1518	1544
ASU-1, Stream-3 Writes	248	432	615	1082	1298	1872	1523	1616	1677
ASU-1, Stream-3 Total	263	404	608	1111	1368	1748	1578	1567	1610
ASU-1, Stream-4 Reads	257	429	707	1188	1537	1765	1473	1654	1498
ASU-1, Stream-4 Writes	285	456	660	1032	1274	1580	1620	1792	1626
ASU-1, Stream-4 Total	271	443	684	1110	1405	1672	1546	1723	1562
ASU-1	259	406	629	1070	1366	1719	1615	1625	1626
ASU-2, Stream-1 Reads	285	416	696	963	1415	1896	1707	1823	1506
ASU-2, Stream-1 Writes	249	371	682	1152	1510	1738	1565	1715	1514
ASU-2, Stream-1 Total	267	394	689	1058	1462	1817	1636	1769	1510
ASU-2, Stream-2 Reads	285	447	697	1181	1511	1681	1714	1664	1832
ASU-2, Stream-2 Writes	264	453	689	1104	1238	1913	1565	1739	1565
ASU-2, Stream-2 Total	274	450	693	1143	1374	1797	1639	1702	1699
ASU-2, Stream-3 Reads	254	371	574	969	1338	1863	1605	1560	1542
ASU-2, Stream-3 Writes	289	414	648	1093	1338	1602	1466	1662	1732
ASU-2, Stream-3 Total	272	393	611	1031	1338	1732	1535	1611	1637
ASU-2	271	412	664	1077	1392	1782	1604	1694	1615
ASU-3, Stream-1 Reads	270	439	634	1183	1327	1756	1551	1842	1761
ASU-3, Stream-1 Writes	236	400	611	1000	1371	1673	1801	1589	1563
ASU-3, Stream-1 Total	253	419	622	1092	1349	1715	1676	1715	1662
ASU-3	253	419	622	1092	1349	1715	1676	1715	1662
All ASUs	261	412	638	1080	1369	1738	1632	1678	1635

Minutes of Test Run	1	2	3	4	5	6	7	8	9 → All Test Run Minutes
Average Response Time (ms)									
ASU-1, Stream-1 Reads	6.44	7.97	9.67	11.87	12.09	12.32	12.20	12.14	12.16
ASU-1, Stream-1 Writes	6.47	8.08	9.68	11.95	12.56	12.69	12.77	12.20	12.41
ASU-1, Stream-1	6.45	8.02	9.68	11.91	12.33	12.50	12.48	12.17	12.29
ASU-1, Stream-2 Reads	6.56	8.12	9.69	11.93	12.38	12.93	12.32	12.57	12.71
ASU-1, Stream-2 Writes	6.54	8.22	10.03	12.38	12.40	12.64	12.74	12.16	12.22
ASU-1, Stream-2	6.55	8.17	9.86	12.16	12.39	12.78	12.53	12.36	12.46
ASU-1, Stream-3 Reads	6.55	7.98	10.00	12.41	12.55	12.93	12.24	12.51	12.69
ASU-1, Stream-3 Writes	6.75	8.07	9.70	12.30	12.21	12.42	12.27	12.22	12.20
ASU-1, Stream-3	6.65	8.03	9.85	12.36	12.38	12.67	12.25	12.37	12.45
ASU-1, Stream-4 Reads	6.56	8.25	9.88	11.95	12.48	12.51	12.32	12.41	12.44
ASU-1, Stream-4 Writes	6.68	8.05	9.75	12.21	12.19	12.78	12.76	12.39	12.59
ASU-1, Stream-4	6.62	8.15	9.82	12.08	12.34	12.64	12.54	12.40	12.52
ASU-1	6.57	8.09	9.80	12.13	12.36	12.65	12.45	12.33	12.43
ASU-2, Stream-1 Reads	6.70	8.14	10.06	11.93	12.59	12.87	12.32	12.25	12.27
ASU-2, Stream-1 Writes	6.58	8.26	10.01	11.92	12.24	12.85	12.68	12.25	12.48
ASU-2, Stream-1	6.64	8.20	10.04	11.92	12.41	12.86	12.50	12.25	12.37
ASU-2, Stream-2 Reads	6.50	8.35	9.80	11.88	12.47	12.89	12.66	12.51	12.37
ASU-2, Stream-2 Writes	6.61	8.00	10.14	12.16	12.32	12.92	12.25	12.31	12.67
ASU-2, Stream-2	6.55	8.17	9.97	12.02	12.40	12.91	12.46	12.41	12.52
ASU-2, Stream-3 Reads	6.56	8.12	9.88	12.13	12.11	12.53	12.58	12.68	12.32
ASU-2, Stream-3 Writes	6.65	7.98	9.98	12.29	12.44	12.65	12.60	12.59	12.36
ASU-2, Stream-3	6.61	8.05	9.93	12.21	12.28	12.59	12.59	12.63	12.34
ASU-2	6.60	8.14	9.98	12.05	12.36	12.79	12.51	12.43	12.41
ASU-3, Stream-1 Reads	6.55	8.33	9.96	12.22	12.63	12.92	12.29	12.52	12.20
ASU-3, Stream-1 Writes	6.52	8.03	10.14	12.28	12.38	12.33	12.43	12.63	12.40
ASU-3, Stream-1	6.53	8.18	10.05	12.25	12.50	12.62	12.36	12.58	12.30
ASU-3	6.53	8.18	10.05	12.25	12.50	12.62	12.36	12.58	12.30
All ASUs	6.57	8.14	9.94	12.14	12.41	12.69	12.44	12.44	12.38

Minutes of Test Run	1	2	3	4	5	6	7	8	9 → All Test Run Minutes
Data Rate (MBytes/sec)									
ASU-1, Stream-1 Reads	8.56	9.56	10.46	12.34	13.45	14.56	14.45	14.34	14.23
ASU-1, Stream-1 Writes	9.75	9.81	11.87	13.94	14.58	16.03	16.31	14.62	15.70
ASU-1, Stream-1	9.15	9.68	11.16	13.14	14.01	15.30	15.38	14.48	14.96
ASU-1, Stream-2 Reads	9.09	9.78	11.64	13.44	14.36	15.23	16.14	16.03	16.31
ASU-1, Stream-2 Writes	8.76	10.49	10.87	12.69	14.11	16.28	15.13	16.05	14.66
ASU-1, Stream-2	8.92	10.13	11.25	13.07	14.24	15.76	15.64	16.04	15.49
ASU-1, Stream-3 Reads	8.75	9.86	11.01	13.87	15.27	16.29	15.86	15.62	15.46
ASU-1, Stream-3 Writes	8.86	10.52	11.67	12.99	15.09	16.21	15.17	14.99	15.42
ASU-1, Stream-3	8.80	10.19	11.34	13.43	15.18	16.25	15.52	15.30	15.44
ASU-1, Stream-4 Reads	8.65	9.64	11.58	13.98	13.85	14.87	14.97	15.40	16.36
ASU-1, Stream-4 Writes	9.03	10.46	11.60	13.15	15.09	14.83	15.61	16.18	15.26
ASU-1, Stream-4	8.84	10.05	11.59	13.57	14.47	14.85	15.29	15.79	15.81
ASU-1	8.93	10.01	11.34	13.30	14.48	15.54	15.45	15.40	15.42
ASU-2, Stream-1 Reads	9.16	10.30	10.62	13.34	15.18	15.09	16.31	14.83	15.87
ASU-2, Stream-1 Writes	8.72	10.16	10.61	12.54	14.72	15.77	15.34	15.78	16.20
ASU-2, Stream-1	8.94	10.23	10.62	12.94	14.95	15.43	15.82	15.30	16.04
ASU-2, Stream-2 Reads	8.85	10.97	10.64	13.75	15.42	15.93	14.50	15.65	14.46
ASU-2, Stream-2 Writes	9.10	10.60	10.76	13.65	13.83	14.85	15.85	15.40	15.11
ASU-2, Stream-2	8.97	10.79	10.70	13.70	14.62	15.39	15.18	15.52	14.78
ASU-2, Stream-3 Reads	9.36	9.62	11.13	12.74	13.53	16.33	15.86	15.12	15.78
ASU-2, Stream-3 Writes	8.99	10.86	11.70	13.60	14.88	16.72	15.79	15.15	15.97
ASU-2, Stream-3	9.18	10.24	11.41	13.17	14.21	16.52	15.83	15.14	15.88
ASU-2	9.03	10.42	10.91	13.27	14.59	15.78	15.61	15.32	15.57
ASU-3, Stream-1 Reads	8.75	10.66	11.54	12.88	14.74	16.24	16.36	15.65	15.85
ASU-3, Stream-1 Writes	9.70	9.85	11.58	13.02	14.04	14.72	16.15	15.20	14.65
ASU-3, Stream-1 Total	9.23	10.26	11.56	12.95	14.39	15.48	16.25	15.42	15.25
ASU-3	9.23	10.26	11.56	12.95	14.39	15.48	16.25	15.42	15.25
ALL ASU	9.06	10.23	11.27	13.17	14.49	15.60	15.77	15.38	15.41

Appendix D: Letter of Good Faith Template

The required Letter of Good Faith submitted by a Test Sponsor must be identical in format and content to the template listed below with the appropriate changes specific to the benchmark submission (Test Sponsor name, TSC name, date, etc.). Any other changes in content or format must be approved by the SPC Compliance Review Committee (CRC) prior to the benchmark submission.

Date: *Date the benchmark result is submitted to the SPC Audit Service*

From: *Test Sponsor Name and Contact Information*

To: *SPC Auditor Name and Contact Information*

Subject: SPC-1 Letter of Good Faith for the *Tested Storage Configuration name*

Test Sponsor Name is the SPC-1 Test Sponsor for the above listed product. To the best of our knowledge and belief, the required SPC-1 benchmark results and materials we have submitted for that product are complete, accurate, and in full compliance with *Vn.n* of the SPC-1 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-1 benchmark specification.

Signed:

Date:

Name and title of an appropriate
Test Sponsor senior executive

Date of Signature

Appendix E: The Hierarchical Reuse Random Walk

This appendix describes the “hierarchical reuse” random walk, which is employed in the specifications of the two random access patterns R1 and W1. Readers desiring a more in-depth treatment of this subject are also referred to Chapter 2 of *The Fractal Structure of Data Reference: Applications to the Memory Hierarchy*, by Bruce McNutt (ISBN 0-7923-7945-4, available from Kluwer Academic Publishers).

The objective of the hierarchical reuse random walk is to produce a pattern of requests in which the probability of data reuse is inversely proportional to the time since the first use. This characteristic, which matches well with real-world data reference behavior, reflects a specific form of self-similarity in the distribution of re-use events.

The hierarchical reuse random walk is performed within the leaves of a symmetric binary tree. Each leaf (each storage location) is assigned a leaf number $0 \leq l \leq 2^{Hmax}$. The tree structure makes it possible to emulate the desired self-similar distribution of re-use events.

Starting from a given leaf l_i of the tree, the next leaf l_{i+1} is determined as follows. First, climb a number of nodes $0 \leq k \ll Hmax$ above leaf l_i . Then, with probability v climb one node higher; with another probability of v , climb an additional node higher; and so on (but stop at the top of the tree). Finally, select a leaf at random from all of those belonging to the sub-tree under the current node.

No special data structure is needed to implement the random tree-climbing operation just described. Instead, it is only necessary to calculate the random height $0 \leq H \leq Hmax$ at which climbing terminates. The next leaf is then given by the formula:

$$l_{i+1} = 2^H [l_i / 2^H] + [2^H R]$$

where R is a uniformly distributed random number in the range $0 \leq R < 1$, and where the brackets ($[]$) indicate truncation to an integer.

Appendix F: References

[Massiglia97] Paul Massiglia: “The RAID book A Storage System Technology Handbook, 6th Edition”, RAID Advisory Board 1997, p.14, p. 16, p.261