SPC BENCHMARK 2™ (SPC-2™)

OFFICIAL Specification

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Document History

Effective Date	Version	Description
6 December 2005	0.1.0	Approved 12 October 2005 The first official release of the SPC Benchmark-2™ (SPC-2) specification. Approved unanimously by the SPC membership.
19 March 2006	1.1.0	Approved 18 January 2006 Revised Clause 9.1.6 to remove the requirement for pricing maintenance for HBAs included in the Priced Storage Configuration. Revised Clause 10.6.9 to allow the use of "Currently Available" for the SPC-2 Availability Date in the case where all components that comprise the Priced Storage Configuration are currently available for customer order and shipment. Revised 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-2 results and the source of labeling for each result. Added Clauses 4.6.1 and 4.6.2 to define two categories of SPC-2 results based on the absence or presence of all storage devices as a standard part of the Tested Storage Product. Revised Clause 4.5.1 to be consistent with the introduction of a Tested Storage Product as the focal point for each SPC-2 result. Revised Clause 8 to require statement of the appropriate TSP category when there is a public reference to a specific SPC-2 result. Revised Clause 10.6.1 to use the formal TSP name on the FDR title page rather than the TSC name. Revised Clause 10.6.5.3 and Table 108 to include an entry for the appropriate TSC category value.
25 September 2006	1.2.0	Approved 27 July 2006 Revised Clause 6.3.6 to address pre-fill/pre-allocation requirement. Revised Clause 6.4.1 and added Clause 6.4.2 to establish the approved Test Run sequence requirement. Revised Clauses 10.1.1-10.1.3 to only reference the data table and graph for LFP and LDQ, specifying a data table/graph pair for each Test. Revised Table 10-1 – Table 10-3 and Figure 10-1 – Figure 10-3

Effective Date	Version	Description
		(labeled bar charts). Revised Clauses 10.1.4-10.1.6 to move the reference to the VOD Test Run and renamed each clause for clarity. New Clauses 10.1.7-10.1.9 to define the required VOD FDR tables and graphs. New Table 10-6 - Table 10.7 to provide an example of the required VOD FDR tables. Added Figure 10-7 - Figure 10-10 in support of new Clauses 10.1.7-10.1.9. Revised Clauses 10.6.8.1 (LFP Test) and 10.6.8.2 (LDQ Test) to include the average Response Time table and graph FDR requirement. Revised Clauses 10.6.8.1 (LFP Test) and 10.6.8.2 (LDQ Test) for clarity and correct cross references. Revised Clauses 10.6.8.1-10.6.8.3 (LFP Test Phases) and Clauses 10.6.8.2.1-10.6.8.2.2 (LDQ Test Phases) for clarity and correct cross references. Revised Clause 10.6.8.3 (VOD Test) to support new Clauses 10.1.7-10.1.9. The new clauses define the required VOD FDR tables and graphs.
27 September 2006	1.2.1	Approved 27 September 2006 Revised Clauses 4.6.1 and 4.6.2 to clarify the SPC-2 Results categorization requirements. Deleted the requirement for a Data Rate per Stream graph in Clause 10.1.8. Added Clause 10.6.5.3 to require a brief description of the Tested Storage Product in the Executive Summary.
19 July 2009	1.3.0	Approved 20 May 2009
18 November 2012	1.4.0	Approved 19 September 2012 Clause 2.2: Revised to allow Physical Storage Capacity to be reported either as formatted capacity or capacity available for application use. Clause 2.7: Revised to define two levels of data protection: Protected

Effective Date	Version	Description
		1 and Protected 2. Clause 4.5.1: System software pricing exclusions to match SPC-2. Clause 6.3.3: New wording to require the SPC-2 ASU to be completely filled with specified content prior to audited Test Run execution (ASU pre-fill). Clause 6.3.13: New wording to allow Adaptive Data Migration. Clause 8.3: New wording to define SPC-2 Associated Data. Clauses 8.4.1 and 8.6.1: New wording listing the requirements for public reference when using a nonlocal currency. Clauses 8.4.2: Revised to clarify requirements when referencing a single SPC-2 Result. Clauses 8.4.2.1, 8.4.4, 8.6.2 and 8.6.3: Revised to require "current as of" date. Clause 8.3.4: Revised to address comparisons of SPC-2 Price-Performance and SPC-2 Total Price with regards to pricing currency and the "target country". Clause 8.4.4: Revised to clarify requirements when referencing a two or more SPC-2 Results. Clause 9.1.4.4: New wording to required appropriate racking/cabinetry and power distribution if the Priced Storage Configuration is greater than 20U. Clause 9.1.6: New wording to include the Host System(s) that are TSC components. Clause 9.1.6: Revised to require inclusion of applicable tariffs, duties, and import fees if not included listed product pricing and to exclude any shipping costs. Clause 9.1.6: Revised to exclude shipping cost. Clauses 9.2.1.4 and 9.2.1.5: Deleted requirement for local currency pricing. Clause 9.2.2.2: Revised to reference the specified "target country". Clause 9.2.2.5: Deleted because of redundancy. Clause 9.2.3: New wording to define the "target country" and requirements for pricing.

Effective Date	Version	Description
		Clause 9.2.4: New wording to define local and nonlocal currency pricing and requirements. Clause 9.3.1.4: Revised to require the total price to be stated in the minimum level of negotiable detail for the selected pricing currency. Clause 9.3.2: Deleted because of redundancy. Clause 10.6.5.1: Delete co-sponsor references. Clause 10.6.5.2: Revised to require FDR revision details to be highlighted when appropriate. Clause 10.6.5.4, Table 10-10: Revised to include the Currency Used and "Target Country". Clause 10.6.5.6: New wording requiring the Executive Summary to include the basis (type and justification) of discounts included in the pricing. Clause 10.6.6: Revised to delete the "UID" and "WG" annotations. Clause 10.6.8.1: Revised to require an annotation that addresses reserved system overhead storage capacity that might not be included in the reported Physical Storage Capacity. Clause 12: New wording for the SPC-2/E Energy Extension
12 May 2013	1.5.0	Approved 13 March 2013 **Clause 6.3.3.3:** New wording to explicitly require the ASU pre-fill to be executed as the first step in the uninterrupted benchmark execution sequence. **Clause 6.3.13:** Revised wording to expand the use of Adaptive Data Migration. **Clause 10.6.5.7:** Revised wording to clarify how differences between the Tested Storage Configuration and Priced Storage Configuration are documented. **Clause 10.6.8.1:** Revised wording to replace storage capacities illustration with four charts. **Clauses 10.6.9.1.1 – 10.6.9.1., 10.6.9.2.1 and 10.6.9.2.2:** Revised wording to allow hyperlinks to the required tables and graphs rather than embed the tables and graphs in the FDR.
15 January 2017	1.6.0	Approved 15 November 2016 **Clause: 9.3.1.7:** Include a required disclaimer on the Pricing

Effective Date	Version	Description
		Spreadsheet
18 September 2017	1.7.0	Approved 23 May 2017 **Clause: 4.3:** Remove references to System Software and replace with wording focused on Host Systems, to align with SPC-2 changes. **Clause 4.5:** Clarify Host System inclusion requirements
1 January 2021	1.8.0	Approved 17 November 2020 Align Storage Hierarchy with that used in SPC-1 Align FDR structure with SPC-1 Incorporate SPC Glossary Incorporate SPC Pricing Guide Revised Executive Summary Create stand-alone Energy Extension

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Clause 0 Introduction

0.1 Preamble

The SPC Benchmark-2™ (SPC-2) is a series of related benchmark performance tests that simulate the sequential component of demands placed upon on-line, non-volatile storage in server class computer systems. SPC-2 provides measurements in support of real-world environments characterized by:

- Large numbers of concurrent sequential transfers.
- Demanding data rate requirements, including requirements for real time processing.
- Diverse application techniques for sequential processing.
- Substantial storage capacity requirements.
- Data persistence requirements to ensure preservation of data without corruption or loss.

SPC-2 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-2 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) as well 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 (Data Repository), Clause 3 (Workload and I/O Operation Profile), and Clause 4 (Benchmark Configuration and Tested Storage Configuration).
- Readers who are examining or referring to test results obtained by running the SPC-2 benchmark should minimally examine Clause 8 (Reported Metrics), and Clause 6 (Test Measurement Requirements (Execution Rules)).
- Readers who wish to actually run an SPC-2 benchmark test should minimally examine Clause 2 (Data Repository), Clause 6 (Test Measurement Requirements (Execution Rules)), and Clause 8 (Reported Metrics).
- Finally, readers who wish to submit SPC-2 benchmark results for posting by the SPC must read the entire SPC-2 specification to ensure compliance with its provisions.

The SPC-2 specification is intended to be vendor and platform independent. Any vendor should be able to sponsor and publish an SPC-2 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-2 allows vendors to optimally demonstrate the performance features of their storage solutions. In addition, and regardless of implementation choices, SPC-2 will provide a means of robust and reliable performance verification.

Rather than requiring or favoring a particular implementation, it is the goal of the SPC-2 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:

- Are generally available to users.
- A significant percentage of the users in the target market segment (server class systems) would implement.
- Are relevant to the market segment that the SPC-2 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 A). 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, and 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 items necessary to reproduce the reported results even if the items are not explicitly required to be disclosed by the SPC-2 benchmark specification.

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

0.4 Related Documents

This benchmark specification relies on:

- Version 1 of the *SPC Pricing Guide*
- Version 1 of the SPC Glossary (included as Appendix B)

0.5 Document Conventions

This document follows the standard typographical conventions for SPC publications.

Generally, words and expressions will adhere to their common English usage. Where a particular term is being defined or assumed to have a benchmark-specific meaning, it appears in SMALLCAPS, and its formal definition can be found in the *SPC Glossary* (see Appendix B).

0.6 Disclaimer

While the SPC-2 benchmark 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-2 workload. The extrapolation of SPC-2 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-2 should not be used as a substitute for customer application benchmarking when critical performance requirements are called for.

SPC-2 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.

Clause 1 Workload Environment

1.1 Business and Application Environment

SPC-2 is comprised of a set of I/O operations designed to demonstrate the performance of a storage subsystem when running business critical applications that require the large-scale, sequential movement of data. SPC-2 represents a segment of applications characterized predominately by large I/O's, organized into one or more concurrent sequential patterns. Frequently encountered examples of such applications include:

- Large file processing: applications, in a wide range of fields, which require simple sequential processing of one or more large files. Specific examples include scientific computing and large-scale financial processing.
- Large database queries: scans or joins of large relational tables, such as those performed for data mining or business intelligence.
- Video on demand: individualized video entertainment provided to a community of subscribers, by drawing from a digital film library.

1.2 High-Level Workload Model

Each of the three categories of sequential workload just enumerated is considered to represent a widespread class of storage applications in itself, and also to be a useful indicator of sequential performance. Each of these three categories of sequential work also exhibits a distinctive set of sequential processing techniques being applied at the application level. SPC-2 therefore incorporates tests representative of all three of the identified categories of sequential work. Taking into account variations within the categories, SPC-2 incorporates a total of 19 individual tested workloads.

Tests of each workload are structured in a common way. Each workload defines a sequentially organized pattern of I/O requests, referred to as a Stream, which transfers a contiguous range of data (for example, a Stream might correspond to the reads or writes needed to transfer a specific file or to scan a specific table in a relational database). During SPC-2 test execution, the number of concurrent Streams of the defined type is varied, so as to observe the resulting range of data rates in megabytes per second. At least three different numbers of concurrent Streams are tested for each workload (a single stream, a maximum number of streams selected by the TEST SPONSOR, and an intermediate number of streams selected by the TEST SPONSOR). At the TEST SPONSOR's discretion, additional intermediate numbers of streams can be added to the test sequence.

The storage made available to the benchmark driver for use in running the SPC-2 benchmark is referred to as the APPLICATION STORAGE UNIT ("ASU"). The 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 2 (Data Repository). See Clause 4 (Benchmark Configuration and Tested Storage Configuration) for examples of supported configurations.

Clause 2 Data Repository

2.1 Storage Capacity Hierarchy

SPC-2 views storage capacity in terms of a three-level hierarchy, as follows:

- PHYSICAL STORAGE CAPACITY
- LOGICAL VOLUME ADDRESSABLE CAPACITY
- APPLICATION STORAGE UNIT CAPACITY.

2.2 Storage Devices & Physical Storage Capacity

2.2.1 The storage capacity of a STORAGE DEVICE is its formatted capacity, if that information is publicly available.

2.2.2 In cases where the formatted capacity of a STORAGE DEVICE is not publicly available, the storage capacity will be the maximum capacity that can be made available for application use from that STORAGE DEVICE .

2.2.3 In cases where both the formatted capacity and the capacity available for application use are publicly available information, the TEST SPONSOR shall report the formatted capacity.

The capacity of a STORAGE DEVICE, as used in computing the physical storage capacity , must be based on the maximum available storage capacity of the STORAGE DEVICE as configured by the manufacturer, regardless of whether it has subsequently been reconfigured to make a lesser storage capacity available for application use

2.3 Logical Volumes

Examples of an SPC-2 LOGICAL VOLUME include, but are not limited to:

- A single physical disk drive.
- A partition on a single physical disk drive.
- Multiple disk drives configured combined 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.

2.4 Application Storage Unit & ASU Capacity

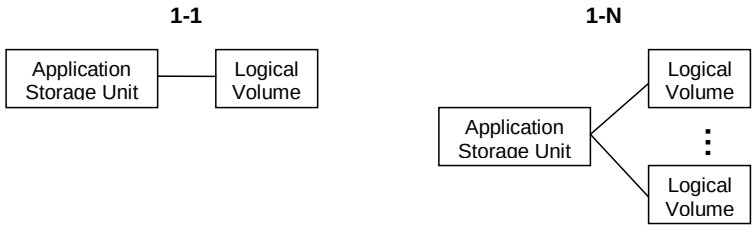


Figure 2-1: ASU-to-Logical Volume Address Mappings

2.4.1 An APPLICATION STORAGE UNIT ("ASU") represents is a logical interface between the SPC-2 benchmark's data set and the SPC WORKLOAD GENERATOR, and includes the persistent, non-volatile storage read and or written in the course of executing the benchmark.

2.4.2 All LOGICAL VOLUME to ASU mappings are permissible, provided they satisfy the requirements in Clauses 2.4.4 through 2.4.7.

2.4.3 The ASU must be contained in a unique address space that is addressable by the SPC WORKLOAD GENERATOR as a contiguous set of LOGICAL BLOCKS.

2.4.4 If the ASU is mapped to more than one LOGICAL VOLUME, each LOGICAL VOLUME shall have the same ADDRESSABLE CAPACITY.

2.4.5 If the ASU is mapped to multiple LOGICAL VOLUME and the storage capacity of the ASU is smaller than the total ADDRESSABLE CAPACITY of those LOGICAL VOLUMES, the storage capacity of the ASU shall be evenly distributed across those LOGICAL VOLUMES.

2.4.6 If the ASU is mapped to multiple LOGICAL VOLUMES, the address mapping shall be a simple concatenation of the storage capacity provide to the ASU by these LOGICAL VOLUMES.

2.4.7 Any portion of the ADDRESSABLE CAPACITY of a LOGICAL VOLUME to which no ASU is mapped is not included in the calculation of ASU CAPACITY.

2.4.8 The storage for the SPC-2 workload consists of a single APPLICATION STORAGE UNIT.

2.5 Data Protection

2.5.1 A compliant TSC shall protect against loss of data due to single component failure.

2.5.2 Data protection is required for the benchmark's data repository. Data protection is categorized as one of the following data protection levels:

- PROTECTED 1
- PROTECTED 2.

2.5.3 The TEST SPONSOR shall select one of the data protection levels defined in 2.5.2, and configure the TSC to provide the selected level of data protection.

2.6 Physical Capacity Utilization

PHYSICAL CAPACITY UTILIZATION shall not be less than 35%.

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-2 is to support multiple operating systems, hardware platforms and multiple workload instantiations. For this reason, some preliminary definitions are needed to minimize ambiguity and/or confusion. It should be noted that the scope of these definitions is limited to SPC-2.

3.1.1 Logical Block

3.1.1.1 For SPC-2, a logical block is assumed to be 512 bytes in size.

3.1.1.2 The i/o stream definitions are such that hardware that only supports a 4,096-byte logical block can execute the workload successfully.

3.1.1.3 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 (103) bytes.
- A megabyte (MB) is equal to 1,000,000 (106) bytes.
- A gigabyte (GB) is equal to 1,000,000,000 (109) bytes.
- A terabyte (TB) is equal to 1,000,000,000,000 (1012) bytes.
- A petabyte (PB) is equal to 1,000,000,000,000,000 (1015) bytes
- An exabyte (EB) is equal to 1,000,000,000,000,000,000 (1018) bytes

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

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

- A kibibyte (KiB) is equal to 1,024 (210) bytes.
- A mebibyte (MiB) is equal to 1,048,576 (220) bytes.
- A gigibyte (GiB) is equal to 1,073,741,824 (230) bytes.
- A tebibyte (TiB) is equal to 1,099,511,627,776 (240) bytes.

- A pebibyte (PiB) is equal to 1,125,899,906,842,624 (250) bytes.
- An exbibyte (EiB) is equal to 1,152,921,504,606,846,967 (260) bytes.

3.2 SPC-2 Workload Components

3.2.1 Overview

SPC-2 defines several distinct workload components, layered from highest to lowest level as follows:

- WORKLOAD: a collection of ASU STREAMS
- ASU STREAM: a collection of I/O STREAMS.
- I/O STREAM: a single, well-defined, sequence of I/O REQUESTS.
- I/O REQUEST or I/O COMMAND: a single atomic unit of work to an APPLICATION STORAGE UNIT.

3.2.2 SPC-2 Workload

The SPC-2 WORKLOAD consists of one or more ASU STREAMS that represent the entire measured I/O stimulus.

3.2.3 I/O Stream

3.2.3.1 The I/O STREAM is initiated at a specific point during the WORKLOAD execution, and has a specific lifespan.

3.2.3.2 The sequence of individual commands within the I/O STREAM is fully defined by the parameter settings defined for the WORKLOAD .

3.2.3.3 One definition is required for each I/O STREAM contained in the 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-2 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-2 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-2 Parameter 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

3.3.5.1 Definition

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.

3.3.5.2 Distribution type

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

- Constant – A single number. The value of this number is contained in the first element of the distribution parameter list.
- 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.
- Exponential – A number that is exponentially distributed with a mean value contained in the first element of the distribution parameter list.
- 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.

- Sparse Incremental: An ascending series of values. This distribution has two associated parameters, *sparse incremental (start, length)*.

The first parameter "start", defines the first value of a monotonically increasing sequence. "start" is an integer representing the block address location within the ASU address range that the sequence begins. The sequence will increase until "length" has been traversed, and then begin again at a new first value, repeating.

The second parameter, "length" which, is required, is used to define the range of addresses of the generated sequence. "Length" is an integer representing the number of blocks of the ASU address space over which the sequence is generated. "Length" is added to each new computed first value to determine the upper address of the series.

If "Sparse 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.

In the context of SPC-2, the aforementioned parameters are restricted in value in an attempt to minimize the performance benefits derived from cache as a result of reference locality. For the SPC-2 WORKLOADS consisting of multiple simultaneous IO streams, the ASU address range is sparsely traversed by each of the streams to limit temporal re-references.

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

3.3.5.3 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:

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

3.3.5.4 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.

3.3.5.5 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-2 Workload Parameters

3.4.1 Overview

A set of parameters is required for each io stream that is present in the SPC-2 WORKLOAD. These parameters are passed to the spc WORKLOAD GENERATOR. The set of parameters will enable the spc WORKLOAD GENERATOR to create and submit a stream of individual I/O REQUESTS to the APPLICATION STORAGE UNIT.

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

3.4.2 I/O Buffers

The I/O Buffers parameter specifies the number of buffers utilized for each Stream in the Video On Demand (VOD). Each buffer is the target of the I/O REQUESTS submitted by the SPC-2 Workload Generator.

3.4.2.1 Parameter Type

The I/O Buffers parameter is an integer variable.

3.4.2.2 Acceptable Values

The I/O Buffers parameter value must be greater than zero.

3.4.3 I/O Buffer Read Interval

The I/O Buffer Read Interval parameter specifies the required interval between I/O REQUESTS issued to the I/O Buffers for each VOD Stream. The interval represents the time to read ("consume") each I/O Buffer.

3.4.3.1 Parameter Type

The I/O Buffer Read Interval parameter is a real (floating point) variable.

3.4.3.2 Acceptable Values

The I/O Buffer Read Interval is a positive real (floating point) value greater than zero.

3.4.4 Model Type

3.4.4.1 Definition

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

(If the input is external to and independent of the model, it is an open model. In a closed model, there is no external input)

3.4.4.2 Parameter Type

The model type is an integer variable.

3.4.4.3 Acceptable Values

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

- Open
- Closed

3.4.5 Outstanding I/O Requests

3.4.5.1 Definition

The Outstanding I/O Requests parameter specifies the maximum number of concurrent I/O REQUESTS, associated with a given stream, which have been issued but not yet completed.

3.4.5.2 Parameter Type

The Outstanding I/O Requests parameter is an integer variable.

3.4.5.3 Acceptable Values

The Outstanding I/O Requests parameter is a positive integer constant.

3.4.6 Read Fraction

3.4.6.1 Definition

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

3.4.6.2 Parameter Type

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

3.4.6.3 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.

3.4.7 Transfer Address

3.4.7.1 Definition

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.

3.4.7.2 Parameter Type

The transfer address parameter is a distribution variable.

3.4.7.3 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.

3.4.8 **Transfer Size**

3.4.8.1 Definition

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

3.4.8.2 Parameter Type

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

3.4.8.3 Acceptable Values

In the SPC-2 benchmark, all streams use a transfer size specified as a positive integer constant.

3.4.9 **Workload Identifier**

3.4.9.1 Definition

The workload identifier, which is unique for all I/O STREAMS in the benchmark, is a 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 (i.e. an entire benchmark run).

3.4.9.2 Parameter Type

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

3.4.9.3 Acceptable Values

No restriction is placed on this parameter.

3.5 Technical Workload Description

3.5.1 SPC-2 defines three workloads:

- Workload 1 – Large File Processing (see 3.5.3)
- Workload 2 – Large Database Queries (see 3.5.4)
- Workload 3 – Video On Demand (see 3.5.5)

Each SPC-2 workload is defined as sequence of TESTS, which are to be executed in sequence.

3.5.2 Each TEST defines a specific set of workload parameters that are to be maintained throughout the test execution.

3.5.3 Workload 1 – Large File Processing

This workload represents large file read and write activity such as that encountered when processing large CAD files. For this workload, SPC-2 WORKLOAD GENERATOR will spawn a test sponsor selected number of workload streams. Each workload stream will:

- Select independent initial location for a read-only Sparse Incremental stream, and a statistically independent Sparse Incremental write-only stream.;
- Alternate between the two streams, issuing a sequential read from one, followed by a sequential write to the other;
- Assure that the two Sparse Incremental streams, taken together, preserve the parameter show in Table 3-1

Table 3-1: Large File Processing (LFP) Parameter Types and Values

Test	Transfer Size (KiB)	Read Fraction	Model Type	Transfer Address	Outstanding I/O Requests	ID
Large File Processing 1 (Write Only)	1024	0.0	Closed	Sparse Incremental (s,l)	1	SPC-2-FP
Large File Processing 2 (Write Only)	256	0.0	Closed	Sparse Incremental (s,l)	1	SPC-2-FP
Large File Processing 3 (Read-Write)	1024	0.5	Closed	Sparse Incremental (s,l)	1	SPC-2-FP
Large File Processing 4 (Read-Write)	256	0.5	Closed	Sparse Incremental (s,l)	1	SPC-2-FP
Large File Processing 5 (Read only)	1024	1.0	Closed	Sparse Incremental (s,l)	1	SPC-2-FP
Large File Processing 6 (Read Only)	256	1.0	Closed	Sparse Incremental (s,l)	1	SPC-2-FP

3.5.4 Workload 2 – Large Database Queries

This workload represents the IO activity encountered during queries of very large databases. For this workload, SPC-2 WORKLOAD GENERATOR will spawn a test sponsor selected number of workload streams. Each workload stream will:

- Select independent initial location for a read-only Sparse Incremental stream, and a statistically independent Sparse Incremental write-only stream.;
- Randomly select read and write operations which will be executed by the appropriate stream;
- Assure that the two Sparse Incremental streams, taken together, preserve the parameter show in Table 3-2.

Table 3-2: Large Database Query (LDQ) Parameter Types and Values

Test	Transfer Size (KiB)	Read Fraction	Model Type	Transfer Address	Outstanding I/O Requests	ID
Large Database Queries: 4 Outstanding I/Os	1024	0.99	Closed	Sparse Incremental (s,l)	4	SPC-2-DQ
Large Database Queries: 1 Outstanding I/O	1024	0.99	Closed	Sparse Incremental (s,l)	1	SPC-2- DQ
Large Database Queries: 4 Outstanding I/Os	64	0.99	Closed	Sparse Incremental (s,l)	4	SPC-2- DQ
Large Database Queries: 1 Outstanding I/O	64	0.99	Closed	Sparse Incremental (s,l)	1	SPC-2- DQ

3.5.5 Workload 3 – Video On Demand

This workload represents the IO activity encountered during the delivery of streaming video. This workload is distinctive, in START TIME and RESPONSE TIME of a given IO operation is managed so that the required bit rate is maintained, and that the modeled video stream could be delivered without any dropped frames or "jitter". For this workload, SPC-2 WORKLOAD GENERATOR will spawn a test sponsor selected number of workload streams. Each workload stream will:

- Select independent initial location for a read-only Sparse Incremental stream;
- Maintain a bitrate of 6 mbps;
- Preserve the parameter show in Table 3-3.

Table 3-3: Videos on Demand (VOD) Parameter Types and Values

Test	Transfer Size	Read Fraction	Model Type	Transfer Address	I/O Buffers	I/O Buffer Read Interval	ID
Video On Demand	256 KiB	1.0	Closed	Sparse Incremental (s,l)	8	23 IOPS	SPC-2-VOD

Clause 4 Benchmark Configuration and Tested Storage Configuration

4.1 Component Availability and Support

All hardware and software used in the BENCHMARK CONFIGURATION shall conform to the availability requirement in version 1 of the *SPC Pricing Guide*.

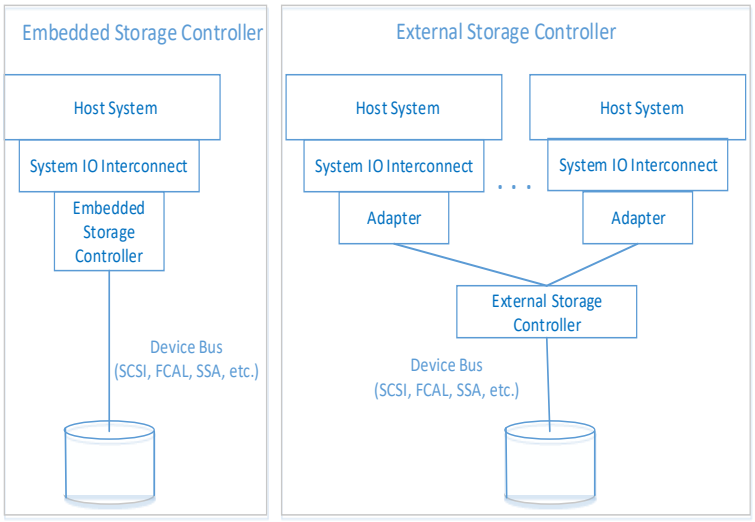
4.2 Benchmark Configuration Components

4.2.1 Host System

4.2.1.1 An SPC-2 HOST SYSTEM is responsible for organizing and managing the underlying LOGICAL VOLUMES used to implement the ASU.

4.2.1.2 The HOST SYSTEM(s), shall not cache or buffer any data associated with implementing the ASU on the BC nor be used to cache or buffer any ASU data.

Figure 4-1 Sample Benchmark Configurations: Direct Attach Storage

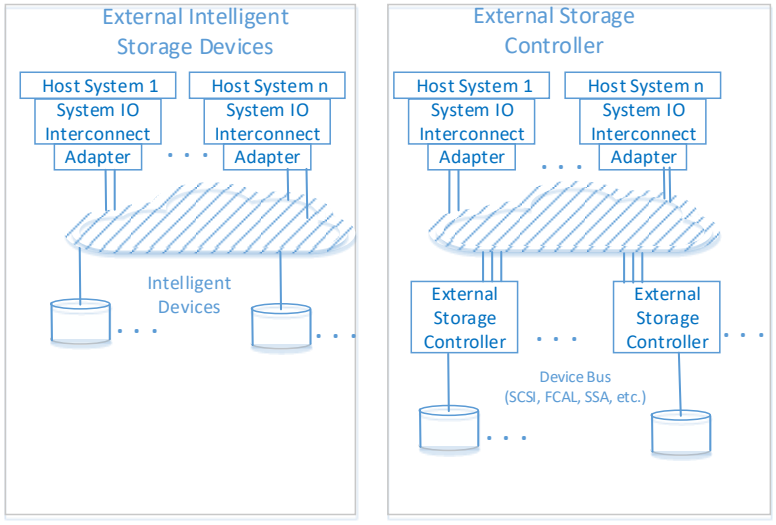


4.3 Benchmark Configuration Examples

TEST SPONSOR s 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 provided examples. In such a case, the TEST SPONSOR is encouraged to contact the SPC prior to

Figure 4-2 External Storage Configurations



engaging in an AUDIT to ensure the proposed configuration will meet the SPC benchmark requirements.

4.4 Tested Storage Configuration Components

4.4.1 Host System Inclusion

HOST SYSTEM inclusion in the PRICED STORAGE CONFIGURATION is defined in the *SPC Pricing Guide*.

4.4.2 Multiple Storage Subsystem Configurations

A TEST SPONSOR may choose to configure multiple, physically distinct storage subsystems in a BENCHMARK CONFIGURATION. In such a case, the TSC must provide a logically cohesive storage solution. In particular, its architecture must include a recognizable layer or component that unifies the response to I/O REQUESTS such that any portion of the storage can be accessed by any given request regardless of the physical origin of the request.

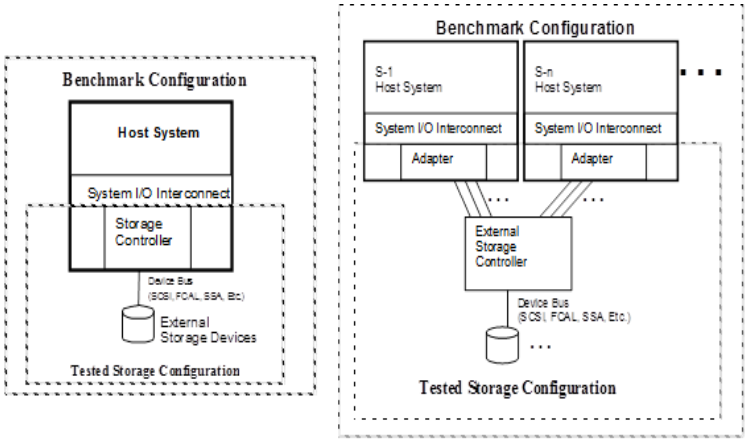
It is the intent of this clause to forbid the use of multiple functionally-independent storage products in the same TSC, if they are not tied together by an architectural layer as just described.

4.4.3 Tested Storage Configuration Examples

Clauses 4.4.4-4.4.6 describe and illustrate 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 provided. 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 benchmark requirements.

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



4.4.4 Embedded or External Storage Controller – External Storage Devices

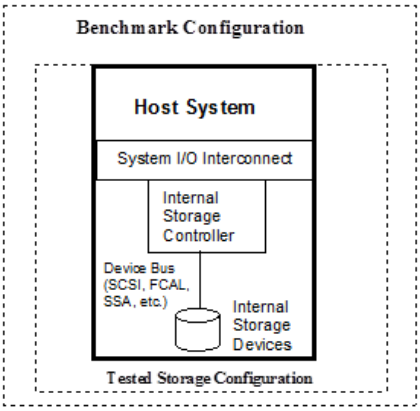
Figure 4-3 illustrates two BENCHMARK CONFIGURATIONS. The first BC includes a TESTED STORAGE CONFIGURATION comprised of an embedded storage controller and external STORAGE DEVICES. The second BC includes a TSC comprised of an external storage controller and external STORAGE DEVICES.

The components that comprise the TSC typically include:

- A storage controller that plugs into a system I/O interconnect on the HOST SYSTEM
- Batteries used to maintain power to cache/memory in the storage controller in the event of unexpected power failure.
- Cabling between the storage controller and the STORAGE DEVICES used to implement the ASUs.

- 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).
- Environmental monitoring systems and related cabling used to monitor the health of components of the TSC.
- Fans used to cool components of the TSC.
- Power supplies and related cabling used to power components of the TSC.
- Power distribution systems and related cabling in cabinetry used to route power to the individual component power supplies in the TSC.
- All management software necessary to present the ASUs to the spc WORKLOAD GENERATOR.
- STORAGE DEVICEs to provide the various levels of storage described in Clause 2.

Figure 4-4 Embedded Storage Controller – Embedded Storage Devices



4.4.5 Embedded Storage Controller – Embedded Storage Devices

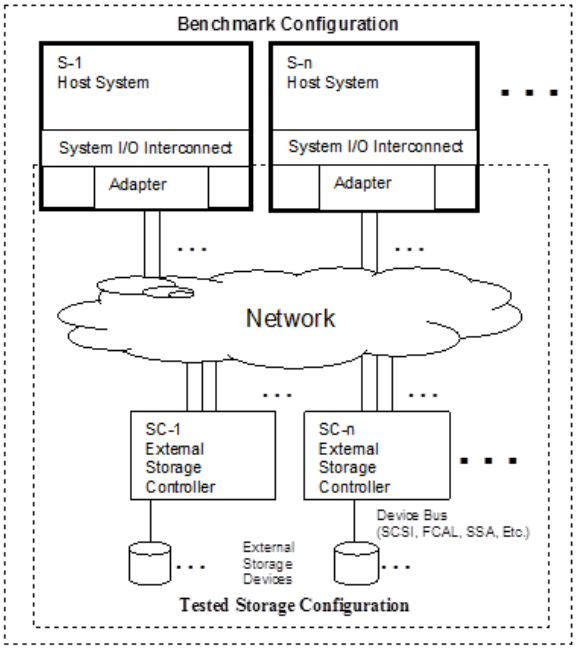
A TSC that utilizes HOST SYSTEM components is illustrated in Figure 4-4.

The components that comprise the TSC typically include:

- A storage controller that either plugs into a system I/O interconnect on the HOST SYSTEM or is an integral HOST SYSTEM component.
- Batteries used to maintain power to cache/memory in the storage controller in the event of unexpected power failure.
- STORAGE DEVICES to provide the various levels of storage described in Clause 2. The STORAGE DEVICES may either be connected externally to the HOST SYSTEM or connected internally as an integral HOST SYSTEM component.

- Cabling between the storage controller and the STORAGE DEVICES used to implement the ASUs.
- All cabinetry used to house components of the TSC.
- Environmental monitoring systems and related cabling used to monitor the health of components of the TSC.
- Fans used to cool components of the TSC.
- Power supplies and related cabling used to power components of the TSC.
- Power distribution systems and related cabling in cabinetry used to route power to the individual component power supplies in the TSC.
- All management software necessary to present the ASUs to the SPC WORKLOAD GENERATOR.

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



4.4.6 Network Storage – External Storage Controller and External Storage Devices

A network storage TSC utilizing external storage controllers and external STORAGE DEVICES as illustrated in Figure 4-5.

The TSC typically includes the following components:

- One or more host bus adapters that connect the storage network into system I/O interconnect(s) on HOST SYSTEM(s).
- 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 SYSTEM(s).
- All software used to manage and maintain the network infrastructure.
- External storage controllers or domain controllers including:
- Batteries used to maintain power to write cache in the storage controller in the event of unexpected power failure.
- Cabinetry used to house the storage controller.
- Monitoring systems and related cabling used to monitor the health of the storage controller.
- Equipment used to cool the storage controller.
- Power supplies and related cabling used to power the storage controller.
- Power distribution systems and related cabling used to route power to the storage controllers.
- All management software necessary to allow the storage controller(s) to present ASUs to the SPC WORKLOAD GENERATOR.
- STORAGE DEVICES to provide the various levels of storage described in 2.2.
- Cabling between the storage controller and the STORAGE DEVICES
- Cabinetry used to house the STORAGE DEVICES.
- Monitoring systems and related cabling used to monitor the health of the STORAGE DEVICES.
- Equipment used to cool STORAGE DEVICES.
- Power supplies and related cabling used to power the STORAGE DEVICES.
- Power distribution systems and related cabling in STORAGE DEVICE cabinetry used to route power to the individual STORAGE DEVICE power supplies.
- All management software necessary to present and manage the ASUs to the SPC WORKLOAD GENERATOR.

4.5 Tested Storage Product

The TESTED STORAGE PRODUCT (TSP) is a distinct, customer orderable product, which is the focal point of an SPC RESULT. Each SPC RESULT will be labeled with the formal name of the TSP.

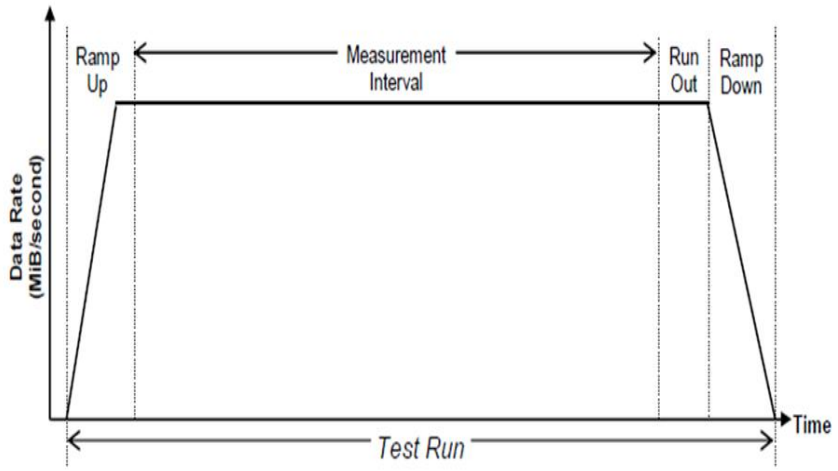
Clause 5 SPC-2 Test Methodology

5.1 Test Phase

5.1.1 Each TEST is comprised of one or more TEST PHASES. All TEST PHASES have a common structure comprised of three distinct sub-phases, which occur in the following sequence:

- TRANSITION, during which the IO load presented by the SPC WORKLOAD GENERATOR to the TSC is adjusted (the transition before a MEASUREMENT INTERVAL is also known as ramp up, the transition after a RUNOUT is also known as ramp down);
- MEASUREMENT INTERVAL, during which the TSC shall be in STEADY STATE;
- RUNOUT, during which the IO load presented by the SPC WORKLOAD GENERATOR to the TSC remains constant long enough for any IO issued during the MEASUREMENT INTERVAL to complete.

Figure 5-1 Sample Test Phase



The IO load presented to the TSC during a TEST PHASE may be zero and a TRANSITION may occur either from or to an I/O load of zero. The load levels shown during the transition portion of the figure are for illustration only and reflect a typical case.

5.1.2 Data about the TSC's response to the stimulus of the SPC WORKLOAD GENERATOR must be collected during all three sub-phases of each TEST PHASE.

5.2 Steady State

5.2.1 In SPC-2, STEADY STATE is based on throughput and response time. As a general guideline, STEADY STATE is achieved when throughput and response time are stable and

sustainable. Some behaviors, while not stable, still satisfy the STEADY STATE criteria, for example:

- Small and cyclical oscillation
- Brief excursion
- Significant but periodic events
- Other behaviors, while following a stable dynamic, do not satisfy the STEADY STATE criteria, for example:
- Gradual and constant increase or decrease, amounting to a significant delta over the duration of a MEASUREMENT INTERVAL
- Sudden and permanent change in behavior

5.3 Requirements and Constraints

5.3.1 SPC Approved Workload Generator

5.3.1.1 All SPC-2 measurements shall be produced using a current, supported version of the SPC-2 toolkit.

5.3.1.2 The documentation included with the SPC-2 toolkit shall be considered an extension of this benchmark specification. It will describe the appropriate use of the tools within the SPC-2 toolkit.

5.3.1.3 The procedures, requirements, and constraints described in the SPC-2 toolkit documentation shall be adhered to in order to produce a compliant SPC-2 measurement.

5.3.1.4 All TEST PHASE RESULTS or data used to compute RESULTS shall be obtained from the SPC WORKLOAD GENERATOR's RESULTS FILES.

5.3.2 SPC Toolkit Precedence

In cases where the SPC toolkit and this benchmark specification are in disagreement, the SPC toolkit prevails. Therefore, any such disagreement may not serve as the basis for a compliance challenge. All aspects of the current version of the SPC toolkit, as provided by the SPC, are deemed to be in compliance with this benchmark specification.

5.3.3 ASU Pre-Fill

5.3.3.1 The ASU defined for a WORKLOAD is required to be completely filled with specified content prior to execution of audited TESTS. The content shall consist of a random data pattern, and shall be produced by an SPC recommended tool.

5.3.3.2 The required ASU pre-fill must be executed as the first step in the uninterrupted benchmark execution sequence described in Clause **Error! Reference source not found.**.

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

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

5.3.4 **Steady State**

The TSC shall be in STEADY STATE for the duration of each MEASUREMENT INTERVAL.

5.3.5 **Benchmark Configuration Consistency**

5.3.5.1 The physical and logical configuration of the BC shall not be changed across TESTs or TEST PHASEs.

5.3.5.2 Configuration and tuning parameters of the BC shall not be changed across TESTs or TEST PHASEs .

5.3.6 **Failed I/O Requests**

All I/O REQUESTS initiated during any TEST PHASE in the SPC benchmark must complete during that TEST PHASE. A FAILED I/O REQUEST shall result in an invalid TEST PHASE.

This requirement applies to all sub-phases (i.e., TRANSITION, MEASUREMENT INTERVAL and RUNOUT) within each TEST PHASE.

5.3.7 **No Permitted Warm Up**

5.3.7.1 Other than booting/starting the HOST SYSTEMs, bringing ASUs on-line for use by the spc WORKLOAD GENERATOR, and starting the spc WORKLOAD GENERATOR, no substantive work shall be performed on the BC prior to or in between tests or TEST PHASEs.

It is the specific intent of this clause that the TEST SPONSOR s not be allowed to optimize configuration or tuning parameters between TESTS or TEST PHASEs.

5.3.8 **Adaptive Data Migration**

5.3.8.1 adaptive data migration causes ASU data to be migrated to alternate storage locations for subsequent access during TESTS .

5.3.8.2 Alternate storage locations, when used as destinations for migrated data, must use one or more type of supported STORAGE DEVICE.

5.3.8.3 Access to migrated data, during the TESTS , must be transparent to the spc WORKLOAD GENERATOR. When the spc WORKLOAD GENERATOR issues a reference to an ASU location, it is the responsibility of the TSC to transparently resolve the reference to the location of the migrated data.

5.3.8.4 If the ASUs exclude the storage which contains the alternate storage locations, that storage must provide data protection (see 2.5). The type of data protection provided by that storage need not be identical to the data protection specified provided by the storage that comprises the ASU

5.4 Multiple Host System Configurations

5.4.1 The TEST SPONSOR may choose to configure multiple HOST SYSTEMS in a BENCHMARK CONFIGURATION. In this case, the aggregate stimulus presented to each ASU from all HOST SYSTEMS shall preserve the workload parameters as defined in Clause 3.

5.4.2 Each instance of the WORKLOAD GENERATOR, regardless of the HOST SYSTEM on which it executes, must access all of the LOGICAL VOLUMES that comprise the ASUs, and must preserve the workload parameters as defined in Clause 3.

5.4.3 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.

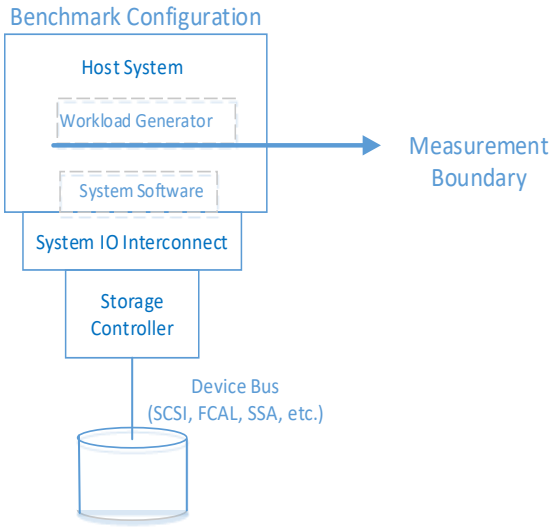
5.4.4 The mapping from an ASU's logical address to a STORAGE DEVICE's physical address shall be identical for all instances of the WORKLOAD GENERATOR, regardless of the HOST SYSTEM on which it executes.

5.4.5 The SPC-2 WORKLOAD GENERATOR will allocate I/O STREAMS in a "round-robin" fashion among the HOST SYSTEMS in a multiple HOST SYSTEM configuration.

5.4.6 The TEST SPONSOR is allowed to set a maximum I/O STREAMS count for each HOST SYSTEM in a multiple HOST SYSTEM configuration.

5.4.7 If the number of I/O STREAMS allocated to a HOST SYSTEM equals the maximum I/O STREAMS count set by the TEST SPONSOR for that HOST SYSTEM, no additional I/O STREAMS will be allocated to the HOST SYSTEM for the current TEST PHASE.

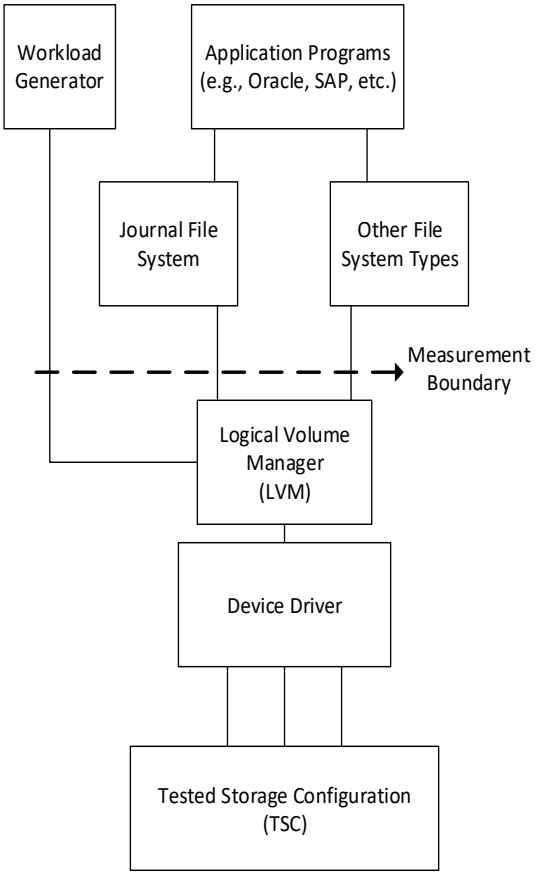
Figure 5-2 Measurement Boundary



5.4.8 **Measurement Boundary**

The MEASUREMENT BOUNDARY, (illustrated in Figure 5-3) occurs within the spc WORKLOAD GENERATOR where I/O REQUEST START TIMES and COMPLETION TIMES are recorded.

Figure 5-3 Measurement Boundary and ASU Access



5.4.9 **Un-Buffered ASU Access**

No file system functionality, such as caching or pre-fetching, provided by the HOST SYSTEM(s) may be used when accessing an ASU. As an example, the UNIX implementations of the SPC-2 WORKLOAD GENERATOR issues I/O REQUESTS via the raw, un-buffered I/O interface. Figure 5-4 illustrates that example.

All other operating system implementations of the SPC-2 WORKLOAD GENERATOR utilizes the operating system's mechanisms for performing I/O that is as close as possible to the raw, un-buffered I/O interface provided by UNIX.

5.4.10 No Operator Intervention

No user or operator intervention is allowed from the start of pre-fill to the completion of the persist_1 TEST PHASE.

5.4.11 Ramp-Up/Transition Period

The minimum Ramp-Up/Transition period for all SPC-2 Test Runs, unless otherwise specified, must be equal to or greater than three (3) minutes and ensure that the TSC has reached Steady State. The Start-Up periods, selected by the Test Sponsor, must be disclosed.

5.4.12 Measurement Resolution

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

5.4.13 I/O Request Completion

All I/O REQUESTS from one TEST PHASE must complete before the MEASUREMENT INTERVAL of the next TEST PHASE can begin

During the execution of each TEST PHASE, all I/O REQUESTS to read a block must be served by referencing the content of the block located on a configured STORAGE DEVICE, or by providing a cached copy of the block that was previously staged from a configured STORAGE DEVICE.

Specifically disallowed during the execution of each TEST PHASE is any technique that causes a read I/O REQUEST to respond as if the content of the referenced block is "initialized to zero" without actually obtaining the block image from a configured STORAGE DEVICE. That may require formatting, pre-allocating, or pre-filling the configured STORAGE DEVICE (s).

5.4.14 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.

5.4.15 Data Persistence

Data persistence properties and requirements as specified in Clause 7 will be maintained for all I/O REQUESTS.

5.4.16 Interpolation or Rounding

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

5.4.17 Uninterrupted Test Sequence

5.4.18 The required TESTs must be executed as part of an uninterrupted benchmark execution sequence. 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 required during the PERSISTENCE TEST, the measurement is invalid.

An exception may be made by the AUDITOR to the above requirement for an uninterrupted benchmark execution sequence. If such an exception is made, it must have no impact on the reported metrics, and be documented in the "Anomalies or Irregularities" section of the SPC-2 FULL DISCLOSURE REPORT as well as the "Audit Notes" portion of the Audit Certification Report.

Clause 6 Test Measurement Requirements (Execution Rules)

6.1 General Guidelines

6.1.1 This benchmark conforms to the general SPC test methodology defined in Clause 5 except where explicitly over-ridden by requirements in the detailed test descriptions in Clause 6.

6.1.2 The TEST SPONSOR may employ a reasonable number of attempts to complete the required, benchmark execution sequence.

6.2 Stream Counts

6.2.1 There are five TEST PHASES within each test of Large File Processing (LFP) or Large Database Query (LDQ) WORKLOAD. For each, the WORKLOAD GENERATOR shall vary the number of I/O STREAMS in five (5) discrete steps:

1. *Maximum number of I/O STREAMS, which is selected by the TEST SPONSOR*
2. *50% of the maximum number of I/O STREAMS used in step 1.*
3. *25% of the maximum number of I/O STREAMS used in step 1.*
4. *12.5% of the maximum number of I/O STREAMS used in step 1.*
5. *1 Stream.*

6.2.2 The value for maximum number of I/O STREAMS is selected by the TEST SPONSOR, and shall be greater than or equal to five (5).

6.2.3 The maximum number of I/O STREAMS may vary between TESTS.

6.2.4 If the maximum number of I/O STREAMS is greater than fifteen (15), the other stream counts are calculated using integer (truncation) arithmetic.

If maximum number of I/O STREAMS is less than or equal to fifteen (15), the other stream counts shall be taken from Table 6-1.

6.2.5 The duration of the Ramp-Up for each TEST PHASES is selected by the Test Sponsor subject to the following requirements:

The first test phase within each test shall use the same value for all tests in a given workload; the remaining test phases within each test shall use the same Ramp-Up value, but it may differ from that used in the first test phase

The selected value is required to be greater than or equal to three (3) minutes.

Table 6-1: Large File Processing (LFP) Required Stream Values

Maximum (Step 1)	Step 2	Step 3	Step 4	Step 5
15	7	3	2	1
14	7	3	2	1
13	6	3	2	1
12	6	3	2	1
11	5	3	2	1
10	5	3	2	1
9	4	3	2	1
8	4	3	2	1
7	4	3	2	1
6	4	3	2	1
5	4	3	2	1

6.3 SPC-2 Tests

6.3.1 Overview

A SPC-2 benchmark measurement includes the following components:

- ASU pre-fill (see 5.3.3)
- Three set of WORKLOAD TESTS, which may be executed in any sequence:
- The Large File Processing Workload Tests (Clause 6.3.2).
- The Large Database Query Workload Tests (Clause 6.3.3).
- The Video-On-Demand Delivery Workload Test (Clause 6.3.4).
- The Data Persistence Test (Clause 7).

Each TEST must be completed and reported for a SPC-2 benchmark RESULT.

6.3.2 Large File Processing Workload Tests

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

6.3.2.2 The TESTS defined for the Large File Processing WORKLOAD are defined in Table 3-1, and shall be executed in sequence (see 3.5).

Each test shall execute five (5) TEST PHASES to demonstrate performance with distinct numbers of I/O STREAMS (see 6.2).

6.3.2.3 The duration of the Measurement Interval shall be a minimum of (3) minutes.

6.3.2.4 The duration of the Run-Out period shall be forty-five (45) seconds.

6.3.2.5 The duration of the Ramp Down period shall be fifteen (15) seconds.

6.3.2.6 The SPC-2 WORKLOAD GENERATOR will set the Stream Segment size to 0.5 GiB for each TEST.

6.3.3 Large Database Query Test

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

6.3.3.2 The TESTS defined for the Large File Processing WORKLOAD are defined in Table 3-2, and shall be executed in sequence (see 3.5).

6.3.3.3 Each test shall execute five (5) TEST PHASES to demonstrate performance with distinct numbers of I/O STREAMS (see 6.2).

6.3.3.4 The duration of the Measurement Interval shall be a minimum of (3) minutes.

6.3.3.5 The duration of the Run-Out period shall be forty-five (45) seconds.

6.3.3.6 The duration of the Ramp Down period shall be fifteen (15) seconds.

6.3.3.7 The SPC WORKLOAD GENERATOR will set the Stream Segment size to 0.5 GiB for each TEST.

6.3.4 Video On Demand Delivery Test

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

6.3.4.2 The Video On Demand Delivery Test consists of one (1) Test. See Table 3-3.

6.3.4.3 The duration of the Ramp-Up period shall be a minimum of twenty (20) minutes.

6.3.4.4 The duration of the Measurement Interval shall be at least two hours (120 minutes).

6.3.4.5 The duration of the Run-Out period shall be forty-five (45) seconds.

6.3.4.6 The duration of the Ramp Down period shall be fifteen (15) seconds.

6.3.4.7 The SPC-2 WORKLOAD GENERATOR will set the Stream Segment size to 1GB, which is roughly equivalent to the content requested during a twenty (20) minute interval at the required bit rate of 6 Mb/s.

6.3.4.8 The value for "maximum number of Streams" is selected by the Test Sponsor.

Clause 7 Data Persistence Requirements and Test

7.1 Introduction

LOGICAL VOLUMES and related the APPLICATION STORAGE UNIT 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 must use LOGICAL VOLUMES and related ASU 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.

7.2 Persistence Test Validation

Validation that the SPC-2 Persistence Test completed successfully is provided by the Auditor, attesting to the fact that the test has been satisfactorily completed on the BC per the test requirements below.

7.3 SPC-2 Persistence Test Constraints

7.3.1 The SPC-2 Persistence Test consists of two Test Runs that are performed by the SPC WORKLOAD GENERATOR in isolation from other SPC-2 Tests.

7.3.2 The number of Streams specified for both Persistence Test Runs must be equal to the maximum number of Streams specified for the Large File Processing (LFP), Write Only Test Phase Test Runs (Test Runs 1-10).

7.3.3 The first Persistence Test Run will consist of a Ramp-Up period and Measurement Interval. The Ramp-Up period will be a minimum of three (3) minutes in duration, during which the specified number of Streams will be activated. The Measurement Interval will be five (5) minutes in duration, during which the specified number of Streams will be active concurrently. If the specified number of Streams are not active at the beginning of the Measurement Interval, the first Persistence Test will be considered invalid.

7.3.4 Any TSC that fails a Persistence Test can be rerun until it passes.

7.3.5 Success or failure of the Persistence Test shall be determined solely by information obtained from an SPC WORKLOAD GENERATOR Results File.

7.3.6 All I/O Requests initiated during any part of the Persistence Test in the SPC-2 benchmark must complete. A Failed I/O Request shall render a Persistence Test invalid.

7.3.7 No other work shall be performed on the BC during the execution of the Persistence

Test Procedure.

7.4 Data Persistence Test Procedure

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

- Execute Persistence Execute Persistence Test Run 1, which will consist of the SPC WORKLOAD GENERATOR writing a specific pattern at randomly selected locations throughout the Total ASU CAPACITY. The SPC WORKLOAD GENERATOR will retain the information necessary to later validate the pattern written at each location.
- Shutdown and power off the TESTED STORAGE CONFIGURATION (TSC). Any TSC caches employing battery backup must be flushed/emptied.
- 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.
- Restart the TSC, and if the HOST SYSTEM (s) were shutdown and powered off, restart the HOST SYSTEM (s).
- Execute Persistence Test Run 2, which will utilize the retained data from Persistence Test Run 1 to verify the bit patterns written in Persistence Test Run 1 and their corresponding location.
- If the results of Persistence Test Run 2 verifies the bit patterns are correct and at the proper location, the Persistence Test completes successfully. If Persistence Test Run 2 reports any verification error, the Persistence Test fails.

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 Auditor. A copy of the Persistence Test Results File will be produced in a human-readable format.

Clause 8 Reported Metrics

8.1 SPC-2 Reported Data

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

- SPC-2 Primary Metrics plus associated data, which characterizes the overall benchmark RESULT.
- Reported data for each SPC-2 WORKLOAD:
- Large File Processing (LFP),
- Large Database Query (LDQ), and
- Video On Demand (VOD).

8.2 SPC-2 Primary Metrics

8.2.1 The SPC-2 Primary Metrics consist of a data rate, price-performance, and storage capacity metric. The additional data associated with the SPC-2 Primary Metrics include the level of data protection used in the benchmark, total price of the storage configuration, formal name of the currency used in pricing, "target country" and SPC-2 Audit Identifier.

8.2.2 **SPC-2 MBPS™ *(Data Rate)***

8.2.2.1 The SPC-2 MBPS™ metric is defined as the arithmetic mean of the following data rate values:

- SPC-2 (LFP) Data Rate as defined in Clause 8.4.2.1.
- SPC-2 (LDQ) Data Rate as defined in Clause 8.4.5.
- SPC-2 (VOD) Data Rate as defined in Clause 8.4.7.2.

8.2.2.2 All public references to this data rate metric must be labeled as "SPC-2 MBPS™".

8.2.3 **SPC-2 Price-Performance™**

8.2.3.1 SPC-2 Price-Performance™ is the PRICE-PERFORMANCE metric for SPC-1.

8.2.3.2 SPC-2 Price-Performance™ and TOTAL SYSTEM PRICE are PRICED DISCLOSURE ITEMS for SPC-2. See SPC Pricing Guide for details on requirements for their presentation, resolution and reporting.

8.2.3.3 SPC-2 Price-Performance is defined as the ratio of the Total System Price, as defined in the SPC Pricing Guide version 1, to the SPC-2 MBPS™.

8.2.4 **SPC-2 ASU Capacity**

All public references to ASU CAPACITY must be labeled as "SPC-2 ASU Capacity" and expressed in GB, rounded down to the nearest integer.

8.2.5 **SPC-2 ASU Price**

8.2.5.1 SPC-2 ASU PRICE is a PRICED DISCLOSURE ITEM for SPC-2. See Clause 5 of the *SPC Pricing Guide* for details on its proper resolution and formatting.

8.2.5.2 All public references to this metric must be labeled as "SPC-2 ASU Price".

8.3 SPC-2 Associated Data

SPC-2 Associated Data consists of the following:

- Data Protection Level used in the benchmark measurement (see 2.5)
- Total price of the PRICED STORAGE CONFIGURATION (see *SPC Pricing Guide*)
- Formal name of the currency used in the PRICED STORAGE CONFIGURATION pricing.
- Target Country" if a non-local currency is used in the PRICED STORAGE CONFIGURATION pricing (see *SPC Pricing Guide*).
- SPC-2 Submission Identifier

8.4 SPC-2 Workload-Specific Reported Data

8.4.1 Large File Processing (LFP) Workload Data

8.4.1.1 The LFP WORKLOAD data consists of the data rate, the related stream value, and a calculated data rate per stream value for each TEST defined for the workload (see Table 3-1).

8.4.1.2 The data rate reported for each LFP TEST is selected by the TEST SPONSOR from the TEST PHASES that make up a given TEST.

8.4.1.3 The number of Streams reported for each LFP TEST is the number of Streams used to generate the reported LFP TEST data rate.

8.4.1.4 The data rate per Stream value reported for each LFP TEST is the ratio of data rate reported for that TEST to number of streams reported.

8.4.1.5 LFP Test Run Sequence Data Annotation

All LPF Test Run Sequence data must be labeled with the appropriate LFP TEST annotation, as taken from the following list:

- LFP, Write, 1024 KiB
- LFP, Write, 256 KiB
- LFP, Read-Write, 1024 KiB
- LFP, Read-Write, 256 KiB
- LFP, Read, 1024 KiB
- LFP, Read, 256 KiB

All public references to the data rate shall be labeled as SPC-2™ Data Rate, using the appropriate LFP annotation.

All public references to the number of Streams shall be labeled as SPC-2™ Number of Streams, using the appropriate LFP annotation.

All public references to the data rate per Stream shall be labeled as SPC-2™ Data Rate per Stream, using the appropriate LFP annotation.

8.4.2 **Large File Processing (LFP) Composite Data**

8.4.2.1 SPC-2 LFP Composite Data Rate is defined as the arithmetic mean of the data rate values reported six LFP TESTS. All public references to this composite data rate value shall be labeled as "SPC-2 LFP Composite".

Commented [JS1]: *Comment: Parallel in LDQ*

8.4.2.2 SPC-2 LFP Price-Performance is defined as the ratio of the Total System Price, as defined in version 1 of the *SPC-1 Pricing Guide*, to SPC-2 LFP Composite data rate, as defined in 50. All public references to this composite price-performance value must be labeled as "SPC-2 LFP Price-Performance".

8.4.3 **Large Database Query (LDQ) Test Run Sequence Data**

8.4.3.1 The LDQ workload data consists of the data rate, the related stream value, and a calculated data rate per stream value for each test defined for the workload (see Table 3-2).

8.4.3.2 The data rate reported for each LDQ TEST is selected by the TEST SPONSOR from the TEST PHASES that make up a given TEST.

8.4.3.3 The number of Streams reported for each LFP TEST is the number of Streams used to generate the reported LFP TEST data rate.

8.4.3.4 The data rate per Stream value reported for each LFP TEST is the ratio of data rate reported for that TEST to number of streams reported.

8.4.3.5 LDQ Test Run Sequence Data Annotation

All LDQ Test Run Sequence data must be labeled with the appropriate LDQ TEST annotation, as taken from the following list:

- LDQ, 1024 KiB, 4 I/Os
- LDQ, 1024 KiB, 1 I/O
- LDQ, 64 KiB, 4 I/Os
- LDQ, 64 KiB, 1 I/O

8.4.4 **Large Database Query (LDQ) Composite Data**

8.4.5 SPC-2 LDQ Composite Data Rate is defined as the arithmetic mean of the data rate values reported four LDQ TESTS. All public references to this composite data rate value shall be labeled as "SPC-2 LDQ Data Rate".

8.4.6 SPC-2 LDQ Price-Performance is defined as the ratio of the Total System Price, as defined in version 1 of the *SPC-1 Pricing Guide*, to SPC-2 LDQ Composite Data Rate. All public references to this composite price-performance value must be labeled as "SPC-2 LDQ Price-Performance".

8.4.7 **Video On Demand (VOD) Test Data**

8.4.7.1 The VOD test data consists of a data rate value reported by the single VOD Test Run, the number of Streams specified to obtain that data rate, the average data rate per stream, and a VOD-specific price-performance value.

8.4.7.2 SPC-2 VOD Data Rate is the average data rate obtained during the MEASUREMENT INTERVAL of the single VOD TEST. All public references to this reported data rate value shall be labeled as SPC-2 VOD MBPS™.".

8.4.7.3 SPC-2 VOD Number of Streams is number of Streams specified to generate the reported SPC-2 VOD Data Rate. All public references to this value must be labeled as "SPC-2 VOD Number of Streams".

8.4.7.4 SPC-2 VOD Data Rate per Stream is defined as the ratio of the SPC-2 VOD Data Rate to SPC-2 VOD Number of Streams. All public references to this value must be labeled as "SPC-2 VOD Data Rate per Stream".

8.4.7.5 SPC-2 VOD Price-Performance is defined as the ratio of the Total System Price, as defined in version 1 of the *SPC-1 Pricing Guide*, to SPC-2 VOD Data Rate. All public references to this price-performance value must be labeled as "SPC-2 VOD Price-Performance".

8.5 SPC-2 Results – Public Use Requirements

8.5.1 General Guidance

Section 11.2.1 of the *SPC Policies and Guidelines* defines the requirements for public use of RESULTS. The following clauses present public use requirements in the context of SPC-2. Section 11.2.1 of the *SPC Policies and Guidelines* should be reviewed in its entirety to ensure compliance with the complete set of requirements.

8.5.2 Referencing a Single SPC-2 Result

8.5.2.1 A public reference to an spc-2 result is required include one of the following:

- A complete URL (hyperlink) to the spc-2 result's entry on the "SPC-2 Results" page of the SPC website,
- The complete set of SPC-2 reported data as defined in Clause 8.1. This set of information shall use the same font style, font size, and text clarity for every item in the set. The set of information may appear as a text paragraph or table of information.

In either case, the public reference must include the "current as of" date.

8.5.2.2 Any of the SPC-2 reported data may be used in a public reference without stating the complete set of SPC-2 reported data as long as the following requirements are met:

The URL defined in Clause 8.5.2.1 is included in the public reference.

The public reference includes the "current as of" date.

8.5.3 Referencing Two or More SPC-2 Results

If a public reference of two or more SPC-2 RESULTS does not include any comparison of SPC-2 REPORTED DATA , the requirements in the *SPC Pricing Guide* and 8.5.2 are applicable.

8.5.4 Comparing Two or More SPC-2 Results

SPC-2 REPORTED DATA may be used in a public reference to compare two or more SPC-2 RESULTS under the following conditions:

In addition to the SPC-2 reported data used in the comparison, each referenced SPC-2 result must include either the complete set of SPC-2 reported data or the URL defined in Clause 8.5.2.1.

If the complete set of SPC-2 reported data is included for one of the referenced SPC-2 results, the complete set of SPC-2 reported data must be included for all of the referenced results.

The public reference must include the "current as of" date.

If the public reference consists of printed or displayed materials, the required items for each SPC-2 result must use the same font style, font size, and text clarity.

The pricing currency and target country must both be identical when a comparison includes SPC-2 price-performance and/or SPC-2 total system price.

Clause 9 Pricing

9.1 Overview

This benchmark conforms to version 1 of the *SPC Pricing Guide*.

9.2 Priced Components

The priced components for SPC-2 include:

- The hardware and software components present in the TSC.
- Any additional operational components required by the TSC.
- Maintenance on all of the above components, according to version 1 of the *SPC Pricing Guide*.

9.3 Maintenance Duration

The maintenance period for SPC-2 shall be three (3) years.

9.4 Pricing Related Data

The PRICED DISLOSURE ITEMS for SPC-2 include:

- ASU PRICE
- TOTAL SYSTEM PRICE

9.5 Pricing Disclosure

This benchmark requires all disclosures defined in version 1 of the *SPC Pricing Guide, with the following exceptions:*

None for this benchmark revision.

Clause 10 Full Disclosure Report (FDR)

10.1 Overview

The FULL DISCLOSURE REPORT (FDR) is a report detailing an SPC-2 benchmark RESULT, along with the procedures, configuration, and equipment used to produce the RESULT.

The FDR includes the following components:

- The FULL DISCLOSURE REPORT ("FDR") (see 10.3.1)
- The EXECUTIVE SUMMARY (see 10.3.2)
- The SUPPORTING FILES (see 10.3.3)

Additional items or modifications to the items listed above may be included and/or required at the discretion of the AUDITOR.

All components of the FDR must be electronically submitted by a TEST SPONSOR to the SPC Administrator after a successful completion of the required spc-2 AUDIT and prior to any public use of the benchmark RESULT.

An FDR is required for each spc-2 RESULT and is intended to allow the replication of the RESULT given access to appropriate documentation and products.

10.2 Result Documentation Requirements

10.2.1 Document Language

The FDR and the EXECUTIVE SUMMARY must be written in the English language.

10.2.2 Document Format

The FDR must be formatted as a stand-alone Adobe PDF document.

The EXECUTIVE SUMMARY must be formatted as a stand-alone Adobe PDF document, in addition to its inclusion in the FDR.

10.2.3 Full Disclosure Report Availability

The FDR must be readily available to the public at a reasonable charge, similar to charges for similar documents by that TEST SPONSOR.

10.3 Document Contents

10.3.1 Full Disclosure Report Document

The FDR must contain, in sequence:

- Front Matter, including in sequence:
  - Title Page (10.4.1)
  - Release and Trademarks Page (10.4.2)
  - Table of Contents (10.4.3)
  - Audit Certification(10.4.4)
  - Letter of Good Faith (**Error! Reference source not found.**)
- Executive Summary (10.5)

- Pricing Details (10.6)
- Publication Details, including in sequence:
  - Test Sponsor and Contact Information (10.7.1)
  - Revision Information and Key Dates (10.7.2)
  - Component Changes in Revised Full Disclosure Report (10.7.3)
  - Audit Notes (10.7.4)
  - Derivative Result Information (10.7.5)
- Configuration Information, including in sequence:
  - Tested Storage Product Description (10.8.1)
  - Host System and Tested Storage Configuration Components (10.8.2)
  - Configuration Diagrams (10.8.3)
  - Benchmark Configuration Creation Process (10.8.4)
- Benchmark Execution Results (10.9), including in sequence:
  - ASU Pre-Fill (10.9.2)
  - Large Database Query Test (10.9.4)
  - Video on Demand Delivery Test (10.9.5)
  - Data Persistence Test Results (10.9.6)
  - Benchmark Extension Results (10.9.7)
- Appendices
  - The list of SUPPORTING FILES
  - The third-party quotations, if any

10.3.2 Executive Summary

The EXECUTIVE SUMMARY must contain and be limited to the content defined in 10.5.

10.3.3 Supporting Files

For this benchmark, the supporting files submitted in conjunction with the FDR shall contain scripts, configuration files or other tools used in or produced during the measurement that was the basis of a given result. The precise contents of the SUPPORTING FILES will be determined by the AUDITOR for a given RESULT, but they will typically include:

- all configuration scripts and settings used to tune or adjust the HOST SYSTEM(S),
- all configuration scripts and settings used to tune or adjust the storage hierarchy,
- system output related to BC and TSC inventories,
- all configuration scripts and settings used to drive the WORKLOAD GENERATOR,
- all summaries, spreadsheets and graphs produced during the post-processing of a measurement to produce the RESULT.

10.4 Front Matter

10.4.1 Title Page

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

- Title: "SPC-2 Benchmark Full Disclosure Report"
- The applicable SPC-2 Benchmark Specification version

- The Test Sponsor's name, corporate website URL, and, optionally, a company logo
- The formal Tested Storage Product (TSP) name.
- The "Submitted for Review" notation and date, which designates the submission as a SPC-2 benchmark RESULT and the start of the 60-day Peer Review.
- The SPC-2 SUBMISSION IDENTIFIER assigned to the SPC-2 benchmark RESULT.

The "Submitted for Review" notation and date, which designates the submission as a new SPC-2 result and indicates the start of the 60-day Peer Review, as defined in the *SPC Policies and Guidelines*.

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10.4.2 Release and Trademarks Page

This page of the FDR shall contain:

- A release from the TEST SPONSOR allowing conditional public disclosure and reproduction of the FDR.
- A list of the trademarks claimed by the SPC and by the TEST SPONSOR.
- A reference to this Benchmark Specification document and to the glossary of terms used in the FDR.

10.4.3 Table of Contents

The Table of Contents shall identify the location of each 1st and 2nd level heading in the FDR.

10.4.4 Audit Certification

This section of the FDR must contain a copy of the certification letter issued by the AUDITOR 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 must contain an amended certification letter that includes the AUDITOR's review and approval of those changes.

10.4.5 Letter of Good Faith

This section of the FDR must contain a copy of the Letter of Good Faith issued by the TEST SPONSOR to the AUDITOR 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 A with the appropriate changes specific to the benchmark submission (e.g., TEST SPONSOR name, TSC name, date, etc.). Any other changes in content and format must be approved by the AUDITOR.

10.5 Executive Summary

10.5.1 Overview

This section of the FDR must faithfully mimic the format and content of the template EXECUTIVE SUMMARY included in **Error! Reference source not found.**, with the a ppropriate changes specific to the benchmark submission.

10.5.2 Detailed Content

All EXECUTIVE SUMMARY(s) shall contain:

A header section including:

- The SPC's logo
- Title: "SPC Benchmark 2™ Executive Summary"
- The test sponsor's logo or name
- The formal tested storage product name

An aggregate metrics section including:

- SPC-2 MBPS™
- SPC-2 Price-Performance

A workload metrics section including:

- SPC-2 LFP Composite metric
- SPC-2 LDQ Composite metric
- SPC-2 VOD Composite metric
- SPC-2 LFP Price-Performance metric
- SPC-2 LDQ Price-Performance metric
- SPC-2 VOD Price-Performance metric

A storage capacities section, including:

- SPC-2 data protection level (see 2.5),
- SPC-2 physical storage capacity (2.2)
- SPC-2 ASU capacity
- SPC-2 ASU price

A pricing summary section, including:

- SPC-2 total system price (as defined in the SPC Pricing Guide, version 1)
- SPC-2 overall discount (as defined in the SPC Pricing Guide, version 1)
- The currency used in the pricing and the target country
- The availability date

A price storage configuration section, including:

- A summary of the major components of the PSC
- The total RU consumed by the configuration

The data rate summary graph (see 10.5.3)

The test summary section, including the data rate, sponsor-selected stream count, and data rate per stream for each of the LFP, LDQ and VOD tests.

A revision section, including:

- The applicable SPC-2 Benchmark Specification version

- The SPC-2 SUBMISSION_IDENTIFIER assigned to the result.
- The applicable SPC-2 workload generator version
- The "Submitted for Review" date.
- The URL for the result on the SPC web site

10.5.3 Data Rate Summary Graph

The data rate summary graph provides a visual summary of the data rate information gathered during the measurement, including:

- SPC-2 MBPS™ aggregate data rate;
- The composite data rates calculated the from LFP, LDQ, and VOD tests;
- The data rates reported from the six TESTS comprising the LFP Composite metric, the four TESTS comprising the LDQ Composite metric, and the single VOD TEST.

10.6 Pricing Details

This section of the FDR must contain the following information, in sequence:

- The Pricing Spreadsheet (see *SPC Pricing Guide*, version 1)
- Discount and Warrantee Details (see *SPC Pricing Guide*, version 1)
- A description of any differences between the TSC and the PRICED STORAGE CONFIGURATION.

10.7 Publication Details

10.7.1 Test Sponsor and Contact Information

This section of the FDR must contain a table of contact information for the TEST SPONSOR and the AUDITOR. The appearance, content and format of the table containing this information are illustrated by example in Table 10-1.

Table 10-1 Contact Information

Role	Name	Details
Test Sponsor Primary Contact (1)	Company's Name Individual's Name	Company's Web Address, Individual's Email Address
SPC Auditor (2)	Company's Name Individual's Name	Company's Web Address, Individual's Email Address

Footnotes to Table 10-1:

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. *Contact information for the auditor who certified the new spc-2 result.*

10.7.2 Revision Information and Key Dates

This section of the FDR must contain a table of key dates and revision numbers associated with the published result. The content, appearance, and format of this table are illustrated in Table 10-2

.

Table 10-2 Revision Information and Key Dates

Date	FDR Revision	Details
{submission date}	{FDR Edition}	{brief description}

10.7.3 Component Changes in Revised Full Disclosure Report

In cases where the FULL DISCLOSURE REPORT is revised to change one or more components of the PRICED STORAGE CONFIGURATION, the revised FDR must contain a list of all PRICED STORAGE CONFIGURATION component changes that are included in this revision (see Clause 9.4). The list must contain the line item information of each original component, the line item information of the revised component, and a brief description of the change.

In the initial submission of the FDR the table may be omitted.

10.7.4 Audit Notes

This section of the FDR must contain a description of any anomalies, exceptions or waivers associated with the result.

10.7.5 Derivative Result Information

If the new spc-2 RESULT is based on an existing spc-2 RESULT (i.e., a SOURCE SPC-2 RESULT), the FDR must contain a table with the following information regarding the SOURCE SPC-2 RESULT:

- The SUBMISSION IDENTIFIER
- The submission date
- The TEST SPONSOR'S primary contact information
- The AUDITOR's contact information

The content and format of the table are illustrated by example in Table 10-3.

Table 10-3 Source SPC-2 Result Information

Source SPC-1 Result Information	
Source Test Sponsor Primary Contact (1)	Company, Company Web Address, Individual Name – Email Address Phone
Source SPC-1 Submission Identification Information (2)	Annnnn mmmm dd, yyyy {Submitted for Review/Accepted}
Auditor for The Source SPC-1 Result (3)	Company, Company Web Address, Individual Name – Email Address Phone

Footnotes to Table 10-3:

1. *The TEST SPONSOR contact responsible for the SOURCE spc-2 RESULT.*
2. *The SPC-2 SUBMISSION IDENTIFIER, publication information, and peer review status of the SOURCE spc-2 RESULT.*
3. *The AUDITOR for the SOURCE spc-2 RESULT.*

The FDR must contain the BC/TSC diagram (Clause 10.8.3.1), the storage network diagram (Clause 10.8.3.2), and the HOST SYSTEM/TSC component table (Clause 10.8.2), from the SOURCE spc-2 RESULT. This information must appear in an appendix.

10.8 Configuration Information

10.8.1 Tested Storage Product Description

10.8.1.1 This section of the FDR must 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 4.5.

10.8.1.2 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.

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

10.8.1.4 The description may include a website link to official product information available from the test sponsor.

10.8.1.5 Features of the TSC and its architecture that ensure that it can survive the instantaneous loss of power to the entire TSC at any time without the loss of any committed data must be described (see Clause 7).

10.8.2 Host System and Tested Storage Configuration Components

Table 10-4 Host System

Host System
Host System name/model *(1)*
CPU information *(2)*
Main Memory configuration *(3)*
Operating system name and version *(4)*
TSC Software *(5)*

Footnotes to **Error! Reference source not found.**:

1. *The product name and model of each HOST SYSTEM used in the benchmark.*
2. *The number, product/model name, and description of the CPUs in each HOST SYSTEM. The description will include clock speed.*

The FDR must contain a table that lists the major components of each HOST SYSTEM and of the TESTED STORAGE CONFIGURATION. The content, appearance, and format of this table are illustrated by example in Table 10-4**Error! Reference source not found.**.

10.8.3 Configuration Diagrams

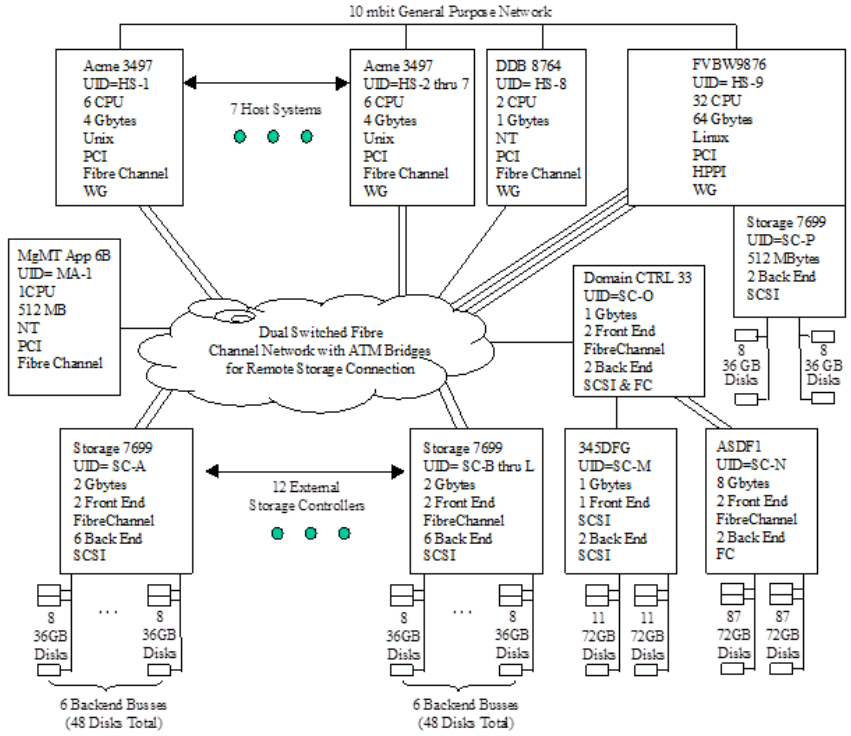
10.8.3.1 BC and TSC Diagrams

The FDR must contain a one page diagram of the BC and TSC illustrating the following information:

- All HOST SYSTEMs and Management Appliances in the BC. Each HOST SYSTEM shall designate (in sequence):
  - The model or name of the product.
  - The number of CPUs or processors.
  - The amount of main memory in the system.
  - The name and revision(s) of the operating system.
  - 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.
- All Storage Controllers or Domain Controllers in the TSC. Each Controller shall designate (in sequence):
  - The model or name.
  - 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.
- The number of STORAGE DEVICE as well as their capacities.
- An illustration and description of the networks used to implement the BC. 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 10-2 Storage Network Configuration Diagram

The content, appearance, and format of this diagram are illustrated by example in Figure 10-1 BC/TSC Configuration Diagram.

Figure 10-1 BC/TSC Configuration Diagram



Detailed diagrams for system configurations and architectures can widely vary, and general guidelines may not be suitable for all implementations. The intent is to describe the system components and connections in sufficient detail to allow independent reconstruction of the BC environment.

10.8.3.2 Storage Network Configuration

If a storage network was included as a part of the TESTED STORAGE CONFIGURATION and the BENCHMARK CONFIGURATION diagram described in BC and TSC Diagrams sufficiently illustrates the network configuration, the FDR must contain a brief description of the illustrated network.

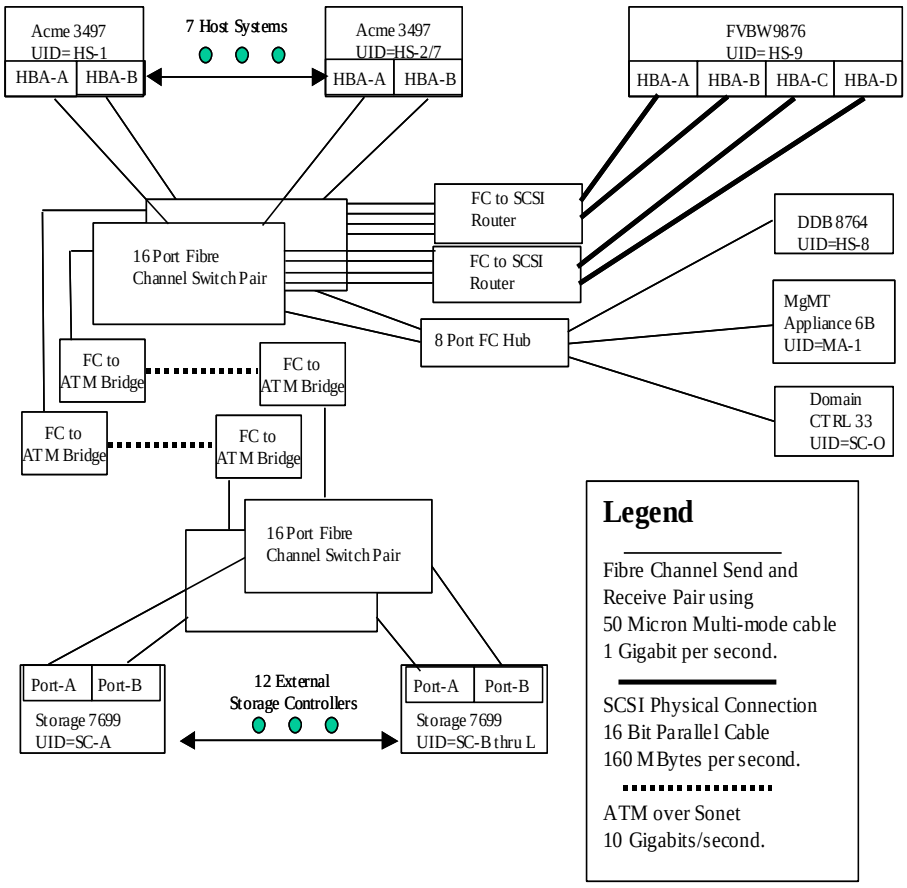
If the network configuration cannot be adequately represented in the diagram described in BC and TSC Diagrams10.8.3.1, the FDR must contain a one-page topology diagram, illustrating the following information:

- Storage Controllers and Domain Controllers

- HOST SYSTEM(s)
- Routers and Bridges
- Hubs and Switches
- HBAs to HOST SYSTEMs and Front End Port to Storage Controllers.
- Additionally, the diagram must:
    - Illustrate the physical connection between components.
    - Describe the type of each physical connection.
    - Describe the network protocol used over each physical connection.
    - List the maximum theoretical transfer rate of each class of interconnect used in the configuration.
    - Correlate with the BC Configuration Diagram.

The content, appearance, and format of this diagram are illustrated by example in Figure 10-2.

Figure 10-2 Storage Network Configuration Diagram



10.8.4 Benchmark Configuration Creation Process

10.8.4.1 Overview

The FDR must contain all the information necessary to recreate the complete BENCHMARK CONFIGURATION.

10.8.4.2 Customer Tuning Parameters and Options

All BENCHMARK CONFIGURATION components with customer tunable parameters and options that have been altered from their default values must be listed in the FDR. This

information must also be included in the SUPPORTING FILES. The 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.

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.

10.8.4.3 Tested Storage Configuration Creation

The FDR must contain sufficient information to recreate the logical representation of the TSC. This information must also be included in the SUPPORTING FILES. In addition to customer tunable parameters and options, that information must include at a minimum, the following:

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 10.8.3.1 and/or the storage network configuration diagram in 10.8.3.2.
- The logical representation of the TSC presented to the spc-2 WORKLOAD GENERATOR.
- Listings of scripts used to create the logical representation of the TSC.
- If scripts were not used, a description of the process used with sufficient detail to recreate the logical representation of the TSC.

10.8.4.4 Test Storage Configuration Inventory

An inventory of the components in the TSC as seen by the BENCHMARK CONFIGURATION must be included in the FDR or the SUPPORTING FILES.

10.8.4.5 Workload Generator Storage Configuration

The FDR must contain all spc-2 WORKLOAD GENERATOR storage configuration commands and parameters. (See *SPC Workload Generator Users' Guide* for details). This information must also be included in the SUPPORTING FILES.

10.8.4.6 Logical Volume and ASU Capacity

The FDR must contain a table illustrating the capacity of the ASU and the mapping of ASU to LOGICAL VOLUMES presented as follows:

- 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.

- LOGICAL VOLUMEs must be sequenced in the table from top to bottom per their position in the contiguous address space of the ASU.
- The addressable capacity of each LOGICAL VOLUME must be stated.

The content, appearance, and format of this table are illustrated by example in Table 10-6Table 10-6 Logical Volume Addressable Capacity and ASU Mapping**Error!**

Table 10-5 Logical Volume Addressable Capacity and ASU Mapping

Logical Volumes	Capacity (GB)	Used (GB)	Unused (GB)
N	N,NNN.N	N,NNN.N	N,NNN.N
SPC-2 ASU Capacity		N,NNN.N	

Reference source not found..

10.8.4.7 Physical Storage Capacity and Utilization

The FDR must contain a table providing a list of the STORAGE DEVICEs and their physical capacity, the PHYSICAL STORAGE CAPACITY of the TESTED STORAGE CONFIGURATION and the PHYSICAL CAPACITY UTILIZATION.

The content, appearance, and format of this table are illustrated by example in Table 10-7

Table 10-6 Physical Capacity and Storage Device Summary

Devices	Count	Physical Capacity	Total Capacity
Storage device description	NN	NNN.N	NN.NNN.N
Storage device description	NN	NNN.N	NN.NNN.N
Storage device description	NN	NNN.N	NN.NNN.N
Total Physical Capacity			NNN.NNN.N
Physical Capacity Utilization			NN.NN%

10.8.4.8 Data Protection

The FDR must contain a description of the type of data protection (see 2.5) used on each LOGICAL VOLUME.

10.9 Benchmark Execution Results

10.9.1 Benchmark Execution Overview

10.9.1.1 The FDR must contain the following general information about the execution of the benchmark:

- The name of the file included in the SUPPORTING FILES and that contains the SPC-2 WORKLOAD GENERATOR input parameters for the PRIMARY METRICS TEST PHASEs, as produced by a supported version of the SPC-2 data reduction tool.
- The Data Rate Summary Graph (see 10.5.3)

Commented [JS3]: ***Comment:*** *Reverse reference to make FDR section paramount*

10.9.1.2 The data rate summary graph provides a visual summary of the data rate information gathered during the measurement, including:

- SPC-2 MBPS™ aggregate data rate;

- The composite data rates calculated the from LFP, LDQ, and VOD tests;
- The data rates reported from the six tests comprising the LFP Composite metric, the four tests comprising the LDQ Composite metric, and the single VOD test.

10.9.2 ASU Pre-Fill

For the ASU pre-fill (see 5.3.3) the FDR must contain:

- The name of the file included in the SUPPORTING FILES and that contains the data resulting from the execution of the ASU pre-fill as produced by a supported version of the SPC-1 data reduction tool.
- The timing of the execution of the ASU pre-fill, including the start time, the end time, and the duration.
- The requested IOP level.
- The observed IOP level, calculated as the ASU CAPACITY divided by the duration of the ASU pre-fill, and reported as MB/second.

10.9.3 Large File Processing Test

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

1. A listing of the SPC-2 Workload Generator commands and parameters used to execute each of the Test Runs in the Large File Processing Test.

The human readable SPC-2 Test Results File for each of the Test Runs in the Large File Processing Test.

A table containing the average Data Rate, in MB per second, for the Measurement Interval of each Test Run in the Large File Processing Test, and an accompanying graph of that information.

A table containing the average Data Rate per Stream, in MB per second, for the Measurement Interval of each Test Run in the Large File Processing Test, and an accompanying graph of that information.

A table containing the average Response Time, in milliseconds (ms), for the Measurement Interval of each Test Run in the Large File Processing Test, and an accompanying graph of that information.

Links to the output data produced by the SPC workload generator for each test run within the test phases defined for the Large File Processing Test.

10.9.4 Large Database Query Test

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

1. A listing of the SPC-2 Workload Generator commands and parameters used to execute each of the Test Runs in the Large Database Query Test.

The human readable SPC-2 Test Results File for each of the Test Runs in the Large Database Query Test.

A table containing the average Data Rate, in MB per second, for the Measurement Interval of each Test Run in the Large Database Query Test, and an accompanying graph of that information.
A table containing the average Data Rate per Stream, in MB per second, for the Measurement Interval of each Test Run in the Large Database Query Test, and an accompanying graph of that information.
A table containing the average Response Time, in milliseconds (ms), for the Measurement Interval of each Test Run in the Large Database Query Test, and an accompanying graph of that information.
Links to the output date produced by the SPC workload generator for each test run within the test phases defined for the Large File Processing Test.

10.9.5 Video on Demand Delivery Test

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

A listing of the SPC-2 Workload Generator commands and parameters used to execute the Test Run in the Video on Demand Delivery Test.

The human readable SPC-2 Test Results File for the Test Run in the Video on Demand Delivery Test.

A table that contains the following information for the Test Run in the Video on Demand Delivery Test:

- The number Streams specified.
- The Ramp-Up duration in seconds.
- The Measurement Interval duration in seconds.
- The average data rate, in MB per second, for the Measurement Interval.
- The average data rate, in MB per second, per Stream for the Measurement Interval.
- The average response time from the VOD test run, expressed in mSec.
- The average of the maximum response times reported for each interval in the VOD test run, expressed in mSec.

Graphs representing:

- Average Data Rate by Interval;
- Average Data Rate per Stream by Interval;
- Average Response Time by Interval graph for the single Video on Demand Delivery Test Run.
- A Maximum Response Time by Interval graph for the single Video on Demand Delivery Test Run.

Commented [JS4]: ***Comment:*** *Drop this graph*

Links to the output date produced by the SPC workload generator for each test run within the test phases defined for the Large File Processing Test.

10.9.6 Data Persistence Test Results

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

- A listing of the SPC-2 Workload Generator commands and parameters used to execute each of the Test Runs in the Persistence Test.
- The human readable SPC-2 Test Results File for each of the Test Runs in the Data Persistence Test.
- A table from the successful Persistence Test, which contains the results from the test. The content, format, and appearance of the table are specified in Table 10-8.

Table 10-7: Data Persistence Test Results

Data Persistence Test Results Data Persistence Test Number: N (1)	
Total Number of Logical Blocks Written (2)	nn,nnn,nnn
Total Number of Logical Blocks Re-referenced (3)	nn,nnn,nnn
Total Number of Logical Blocks Verified (4)	nn,nnn,nnn
Total Number of Logical Blocks that Failed Verification (5)	nn
Number of Failed I/O Requests in the process of the Test (6)	n

Footnotes to Table 10-7:

1. *Within the set of Data Persistence Tests executed to pass the Data Persistence Requirement, the Persistence Test Number. Persistence Test Run Number shall be an integer value beginning with the number one (1).*
2. *The total number of Logical Blocks written in Persistence Test Run 1.*
3. *The total number of Logical Blocks re-reference in Persistence Test Run 1*
4. *The total number of Logical Blocks that passed verification in Test Run 2.*
5. *The total number of Logical Blocks that failed verification in Test Run 2.*
6. *For all I/O Requests issued during the course of the Persistence Test the number of Failed I/O Requests per the definition in* ***Error! Reference source not found.***.

10.9.7 Benchmark Extension Results

For each benchmark extension executed as part of the MEASUREMENT, the FDR shall contain:

- The name of the extension;
- The revision of the extension;
- All disclosures required by the benchmark extension.

Clause 11 Audit and Results Submission

11.1.1 **Overview**

The purpose of the SPC-2 AUDIT is to verify a benchmark RESULT is eligible for submission.

There are two types of SPC-2 AUDIT , onsite (Clause 11.4.1) and remote (11.4.2). Both require:

- Execution of the SPC-2 AUDIT procedures (11.4.3).
- Submission of a complete set of SPC-2 results files resulting from the execution of the complete set of SPC-2 tests,
- Submission of an fdr, and other required AUDIT materials.

An SPC-2 AUDIT does not provide final certification that an SPC-2 RESULT is compliant with the specification. Certification that an SPC-2 RESULT is compliant with the specification is a function of the SPC Peer Review *(Clause **Error! Reference source not found.**)*.

11.2 SPC-2 Audited Measurements

The execution of the complete set of SPC-2 Tests to create a complete set of SPC-2 RESULTS FILES , which will form the basis of an SPC-2 RESULT, is performed by the TEST SPONSOR in the course of either an Onsite or Remote SPC-2 AUDIT .

11.3 Auditor

An SPC-2 auditor is an individual who has been certified by the SPC to perform an SPC-2 AUDIT .

The auditor will, in the course of the SPC-2 AUDIT, determine if the benchmark RESULT is eligible for submission to the SPC.

The SPC will provide a list of auditors to the test sponsor. The test sponsor is free to choose any auditor from that list.

11.4 General Audit Procedures

11.4.1 **SPC-2 On-Site Audit**

11.4.1.1 To satisfy the SPC-2 AUDIT requirements an SPC-2 benchmark execution may require the on-site presence of an auditor. This is referred to as a SPC-2 on-site AUDIT . The auditor will determine when a SPC-2 on-site AUDIT is required.

11.4.1.2 During an on-site AUDIT , the auditor is physically present at the site where the test sponsor has assembled the BENCHMARK CONFIGURATION.

11.4.1.3 The test sponsor is responsible for the costs of an SPC-2 on-site AUDIT .

11.4.2 **SPC-2 Remote Audit**

11.4.2.1 An SPC-2 benchmark execution may satisfy SPC-2 AUDIT requirements, without the on-site presence of an auditor, subject to the approval of an auditor. This is referred to as a SPC-2 remote AUDIT .

11.4.2.2 Remote access to the BC can be optionally supplied by the test sponsor to facilitate the SPC-2 remote AUDIT process.

11.4.3 **General Rules**

11.4.3.1 An independent AUDIT of the benchmark RESULT by an auditor is required.

11.4.3.2 The auditor's attestation letter is to be made readily available to the public as part of the FULL DISCLOSURE REPORT. A detailed report from the auditor is not required.

11.4.4 **New SPC-2 Result based on an Existing SPC-2 Result**

11.4.4.1 If the new SPC-2 RESULT is based on an existing SPC-2 RESULT(i.e., a source SPC-2 RESULT), the following audit requirements apply to the new SPC-2 RESULT:

- The auditor must verify that the hardware and software components used in the PRICED STORAGE CONFIGURATION of the new SPC-2 RESULT are the same as those used in the source SPC-2 RESULT, except for differences related to branding or packaging;
- The auditor must compare the fdr of the new SPC-2 RESULT with the FDR of the SOURCE SPC-2 RESULT and ensures that differences are related to test sponsor identification, submission date, branding or packaging;
- The auditor must review the validity of the pricing used for the new SPC-2 RESULT.

11.4.4.2 In the event that all conditions listed in Clause 11.6.4.1 are met, the auditor is not required to follow the clause specific AUDIT procedures from Clause 11.7.

11.5 Clause Specific Audit Procedures

11.5.1 *Error! Reference source not found.* **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 **Error! Reference s ource not found.** 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.

11.6 Audit Procedures

11.6.1 **Clause 0: Introduction Audit 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 A 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.

11.6.2 Clause 1: Workload Environment Audit Items

None

11.6.3 Clause 2: Data Repository Audit Items

1. Verify the PHYSICAL STORAGE CAPACITY and requirements stated in Clause 2.2.

Verify LOGICAL VOLUME ADDRESSABLE CAPACITY and requirements stated in 2.3.

Verify the ASU CAPACITY of each APPLICATION STORAGE UNIT and requirements stated in Clause 2.3.

11.6.4 Clause 3: Workload and I/O Operation Profile Audit Items

None

11.6.5 Clause 4: Benchmark Configuration and Tested Storage Configuration Audit Items

1. Obtain a copy of BENCHMARK CONFIGURATION diagram (BC/TSC Configuration Diagram). If a storage network is employed in the BC/TSC, obtain a copy of **Error! Reference source not found.** (Storage Network Configuration Diagram). Confirm the components illustrated in the two figures.

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.

Obtain information that is sufficient to recreate the logical representation of the TSC (Clause 10.8.4.3). 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 presented to the SPC-2 WORKLOAD GENERATOR.

Verify the required configuration information for each HOST SYSTEM (Clause **Error! Reference source not found.**).

Verify the presence and version number of each SPC-2 WORKLOAD GENERATOR on each HOST SYSTEM in the BC.

Verify the TESTED STORAGE CONFIGURATION boundary within each HOST SYSTEM of the BC as documented in Clause 4.4 and as illustrated in Figure 4-1 through Figure 4-5.

In a multi-host configuration, verify compliance with Clause **Error! Reference s ource not found.**.

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 **Error! Reference source not found.**.

Verification of items #6, #7 and #8 may be done using the appropriate spc-1 results files.

11.6.6 **Clause 5: SPC-2 Test Methodology Audit Items**

1. Verify the presence and version number of the SPC-2 WORKLOAD GENERATOR on each HOST SYSTEM in the BC.

Verify the presence of a valid, appropriate SPC-2 Site/Corporate License.
In a multi-host configuration, verify that the execution of multiple WORKLOAD GENERATORs on the multiple HOST SYSTEMS was synchronized in time (Clause 5.3).

Verification of items #1, #2, and #3 is done using the appropriate Test Results files.

11.6.7 **Clause 6: Test Measurement Requirements (Execution Rules) Audit Items**

11.6.7.1 Remote Audit Items

1. Obtain the SPC-2 Results Files for each Test Run

Authenticate the Results Files obtained in #1.
Inspect each authenticated Results File to determine compliance with all the constraints and requirements of Clause 4, 4.2.1.2, and Clause 6.

11.6.7.2 Onsite Audit Items

1. Observe the execution of each Test, Test Phase, and Test Run and determine compliance with the requirements and constraints of Clause 6.

Obtain the SPC-2 Results Files for each Test Run.
Authenticate the Results Files obtained in #2.
Inspect each authenticated Results File to determine compliance with all the constraints and requirements of Clause 4, 4.2.1.2, and Clause 6.

11.6.8 **Clause 7: Data Persistence Requirements and Test Audit Items**

11.6.8.1 Remote Audit Items

1. Obtain the successful Persistence Test Results file.

Authenticate the Persistence Test Results file obtained in #1.
Inspect each authenticated Results File to determine compliance with all the constraints and requirements of Clause 7.

11.6.8.2 Onsite Audit Items

1. Observe the successful Persistence Test and determine its compliance with the requirements and constraints of Clause 7.

Obtain the Persistence Test Results file from each Test Run.
Authenticate the successful Persistence Test Results file obtained in #1.
Inspect each authenticated Persistence Test Results file to determine compliance with all the constraints and requirements of Clause 7.

11.6.9 **Clause 8 Reported Metrics Audit Items**

None

11.6.10 **Clause 9 Audit 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.

Review a preliminary copy of the pricing spreadsheet, described in Clause **Error! Reference source not found.**, and verify that it meets all the requirements and constraints of □. It is not required to review the final pricing prior to issuing the AUDIT certification letter.

11.6.11 **Clause 10 Audit Items**

For both Onsite and Remote AUDITS, verify the Full Disclosure Report (FDR) is complete and accurate based on the requirements in 9.4.

Appendix A Letter of Good Faith

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 Auditor prior to the benchmark submission.

Date: Date the benchmark result is submitted to the Auditor

From: Test Sponsor Name and Contact Information

To: SPC Auditor Name and Contact Information

Subject: SPC-2 Letter of Good Faith for the ***Tested Storage Configuration name***

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

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

Signed: Date:

_____ _____

Name and title of an appropriate Test Sponsor senior executive

Date of Signature

Appendix B Sample Executive Summary

Storage Performance Council

SPC Benchmark 2™

Executive Summary

Sponsor Logo

{TSP Name}

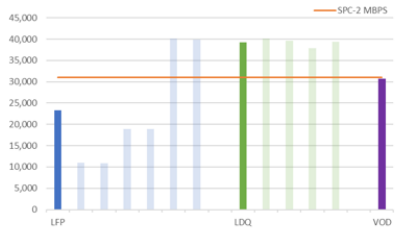
SPC-2 MBPS™	**0.00**	**SPC-2 Price Performance**	**$0.00/SPC-2 MBPS™**
SPC-2 LFP Composite	0.00 MB/s	SPC-2 LFP Price-Performance	$0.00/MBPS
SPC-2 LDQ Composite	0.00 MB/s	SPC-2 LDQ Price-Performance	$0.00/MBPS
SPC-2 VOD Data Rate	0.00 MB/s	SPC-2 VOD Price-Performance	$0.00/MBPS

Storage Metrics		*Pricing Summary*	
SPC-2 Data Protection Level	Protected #	SPC-2 Total System Price	$0.00
SPC-2 Physical Storage Capacity	0.000 GB	SPC-2 Overall Discount	0.00
SPC-2 ASU Capacity	0.000 GB	Currency / Target Country	??? / ???
SPC-2 ASU Price	$0.00/GB	Availability Date	January 1, 2020

Priced Storage Configuration Summary

##	{HBA Controller Model}
#	{TSP Name}
##	{Controllers / Nodes}
#,###	GB Total Cache
##	Total Front-End Ports
##	Total Storage Devices ({Type})
#	{Switches, etc}
#	Total RUs

Data Rate Summary (MB/s)



Large File Processing (LFP) Summary

	MB/s	Streams	Per Stream
Write Only			
1,024 KiB Xfer	0.00	0	0.00
256 KiB Xfer	0.00	0	0.00
Read / Write			
1,024 KiB Xfer	0.00	0	0.00
256 KiB Xfer	0.00	0	0.00
Read Only			
1,024 KiB Xfer	0.00	0	0.00
256 KiB Xfer	0.00	0	0.00

Large Database Query (LDQ) Summary

	MB/s	Streams	Per Stream
1,024 KiB Xfer			
4 I/Os Outstanding	0.00	0	0.00
1 I/O Outstanding	0.00	0	0.00
64 KiB Xfer			
4 I/Os Outstanding	0.00	0	0.00
1 I/O Outstanding	0.00	0	0.00

Video on Demand (VOD) Summary

Streams	0	Per Stream	0.00 MB/s

SPC Benchmark 2™ Specification Revision	v#.#.#	Submitted for Review	January 1, 2020
SPC Benchmark 2™ Workload Generator Revision	v#.#.#	Submission Details	www.storageperformance.org/r/#######

Appendix C Glossary

The SPC Glossary is used in all SPC specifications, and is available as a stand-alone document. It is included here in its entirety for ease of reference.

The following content is from *SPC Glossary, version* ***Error! Unknown document property name.****, which* was current as of **Error! Unknown document property name.**

C.1 A

addressable capacity
the portion of the storage capacity of a LOGICAL VOLUME that is accessible to the WORKLOAD GENERATOR.

application storage unit (asu)
the logical representation of the persistent, non-volatile storage read and or written in the course of executing a BENCHMARK.

An asu represents is a logical interface between a BENCHMARK CONFIGURATION's data and a workload generator.

application storage unit capacity
the total ADDRESSABLE CAPACITY of all the portions of LOGICAL VOLUMES to which an ASU is mapped.

application storage unit stream
a collection of one or more I/O STREAMs, that completely defines the I/O sent to a given ASU.

associated data
data and measurements defined by a given BENCHMARK that are used to calculate, clarify or reinforce the metrics reported as part of a RESULT.

asu *see APPLICATION STORAGE UNIT.*

asu capacity *see APPLICATION STORAGE UNIT CAPACITY.*

asu price *the ratio of TOTAL SYSTEM PRICE to ASU CAPACITY.*

asu stream *see APPLICATION STORAGE UNIT STREAM.*

audit *the process that verifies that a MEASUREMENT is eligible for submission as a RESULT.*

auditor *An individual who has been certified by the SPC to perform an AUDIT.*

availability date
a date by which a given product, component or configuration is released for general availability.

average response time
the sum of the RESPONSE TIMES for all MEASURED I/O REQUESTS within a given interval, divided by the total number of MEASURED I/O REQUESTS.

C.2 B

bc *see BENCHMARK CONFIGURATION.*

benchmark *a collection of TESTS, TEST PHASES, documentation requirements, and comparability constraints that fully define the process for taking a MEASUREMENT and creating a RESULT.*

benchmark configuration
all hardware and software components used in the creation of a MEASUREMENT.

C.3 C

completed i/o request *an I/O REQUEST with a START TIME and a COMPLETION TIME.*

completion time
the time recorded by the WORKLOAD GENERATOR when an I/O REQUEST is satisfied by the TSC.

committed *Of an IO operation, written to persistent, non-volatile storage, in such a manner that the data can be retrieved after recovery from a TSC failure.*

concurrent io requests
the maximum number of independent, concurrent IO REQUESTS that may be initiated by an IO STREAM.

crash-consistent
A data image (logical or physical) is considered crash consistent if there exists a point in time such that all write operations completed prior to that time are included in the image, and no write operation initiated after that time is included.

C.4 D

data rate *the data volume transferred in a given interval divided by the duration of the interval, in seconds.*

C.5 E

extension *optional addition(s) to an existing BENCHMARK that showcase a feature or set of features not captured by the BENCHMARK'S existing metrics.*

extension configuration
all hardware and software components used in the execution of an EXTENSION.

expected i/o count
for any given I/O STREAM and TEST PHASE, the product of requested IO load in IOs per second, the duration of the TEST PHASE in seconds, and the INTENSITY MULTIPLIER parameter for that I/O STREAM.

executive summary
a high-level report summarizing a RESULT, and the configuration used to produce it.

C.6 F

failed i/o request
any I/O REQUEST issued by the WORKLOAD GENERATOR that could not be completed or was signaled as failed by the OS running on the HOST SYSTEM .

A failed i/o request has no COMPLETION TIME.

fdr*see FULL DISCLOSURE REPORT.*

full disclosure report
a report detailing a RESULT, along with the procedures, configuration, and equipment used to produce it.

C.7 G

No terms defined.

C.8 H

host system *a computer system where the WORKLOAD GENERATOR executes.*

C.9 I

in-flight i/o request
an I/O REQUEST issued by the WORKLOAD GENERATOR that does not complete within a given MEASUREMENT INTERVAL.

integrated execution
of a benchmark extension: completed during one of the test phases of a benchmark execution.

intensity multiplier
the ratio of the IO load produced by a given I/O STREAM to the total IO load produced by all active I/O STREAMS.

i/o command *see I/O REQUEST.*

i/o stream *a single, well-defined, sequence of I/O REQUESTS.*

i/o request *a single, atomic I/O operation.*

i/o request throughput
the total number of MEASURED I/O REQUESTS in a TEST PHASE, divided by the duration of that TEST PHASE's MEASUREMENT INTERVAL, expressed in seconds.

C.10 J

No terms defined.

C.11 K

No terms defined.

C.12 L

logical block *the smallest directly addressable unit of storage on the ASU.*

logical volume *an individually addressable logical unit of storage presented to the WORKLOAD GENERATOR.*

C.13 M

measured i/o request
an I/O REQUEST with a COMPLETION TIME occurring within the MEASUREMENT INTERVAL.

measured intensity multiplier
the percentage of all MEASURED I/O REQUESTS that were issued by a given I/O STREAM.

measurement *the data gathered during the execution of a BENCHMARK.*

measurement boundary
of the point within a BENCHMARK CONFIGURATION at which measurements are taken.

measurement interval
of a TEST PHASE, the time from the end of the TRANSITION to the start of the RUNOUT.

C.14 N

No terms defined.

C.15 O

on-site audit *an AUDIT for which the AUDITOR is physically present.*

C.16 P

physical capacity utilization
ASU CAPACITY divided by the PHYSICAL STORAGE CAPACITY.

physical free space
the persistent storage capacity that could be used to hold application data and the metadata required to access, maintain and protect that data, but is not in use at the time of the measurement.

physical storage capacity
the total storage capacity of all of the STORAGE DEVICES in the TESTED STORAGE CONFIGURATION.

priced disclosure item
a pricing-related data item that is included in the FDR, and is subject to requirements defined in the SPC Pricing Guide.

priced storage configuration ("psc")
the customer-orderable version of the TSC.

price-performance
the ratio of the TOTAL SYSTEM PRICE to the primary performance metric for a BENCHMARK").

pricing spreadsheet
a detailed computation of the total cost of ownership for a PRICED STORAGE CONFIGURATION.

primary metric *a metric that provides a primary basis for comparison of RESULTS.*

protected 1 *a data protection level in which the failure of any single STORAGE DEVICE in the TSC will not require user intervention to restore access to the BENCHMARK'S") data repository.*

protected 2 *a data protection level in which the failure of any single component in the TSC will not require user intervention to restore access to the BENCHMARK'S data repository.*

psc *see PRICED STORAGE CONFIGURATION.*

C.17 Q

No terms defined

C.18 R

ramp-down *A specified, contiguous period of time in which the TSC is required to complete I/O REQUESTS started but not completed during the preceding RUNOUT period.*

ramp-up *A specified, contiguous period of time required for the BC to produce STEADY STATE throughput after the WORKLOAD GENERATOR begins submitting I/O REQUESTS to the TSC for execution.*

reference price
the price at which component or subsystem could be ordered individually from the TEST SPONSOR or designated third-party suppler.

remote audit *an AUDIT for which the AUDITOR is not physically present. See ON-SITE AUDIT.*

replication *the automatic execution of all I/O operations executed against a primary storage system on a one or more, independent storage systems.*

reported data *the set of data, as defined by a given BENCHMARK, which fully characterizes a MEASUREMENT.*

response time *for an I/O REQUEST, COMPLETION TIME minus START TIME.*

result *an audited MEASUREMENT which has been submitted to the SPC for publication*

results files *the output of the WORKLOAD GENERATOR, created during a MEASUREMENT.*

runout *of a TEST PHASE, the time period immediately following the MEASUREMENT INTERVAL during which the IO load presented by the WORKLOAD GENERATOR to the TSC remains constant long enough for any IO issued during the MEASUREMENT INTERVAL to complete.*

C.19 S

secondary metric
a metric that is not a primary basis for comparison of RESULTS, but still provides important information.

ser *see SPACE EFFECTIVENESS RATIO.*

sor *see SPACE OPTIMIZATION RATIO.*

snapshot *a logical, point-in-time, CRASH-CONSISTENT image of one or more LOGICAL VOLUMES.*

snapshot set *a crash-consistent collection of SNAPSHOTS, taken and managed as a unit.*

space effectiveness ratio ("ser")
the ratio of the total amount of data that the TSC can hold to its PHYSICAL CAPACITY.

space optimization ratio ("sor")
the size of a data set as generated by the WORKLOAD GENERATOR divided by the amount of incremental space consumed by that data set.

spc result *see RESULT.*

ssu *see STIMULUS SCALING UNIT.*

start time *for an I/O REQUEST, the time recorded by the WORKLOAD GENERATOR when the request is submitted for execution on the TSC.*

steady state *a state in which the behavior of the TSC is stable and sustainable while the load presented to the TSC by the WORKLOAD GENERATOR is constant.*

stimulus scaling unit
a logical abstraction that captures the key elements in the IO demands of an application's user population.

storage device
a discrete, physical hardware component, such as an HDD or an SSD, that provides permanent data storage.

> *A STORAGE DEVICE must be capable of storing data indefinitely without external power. The requirement excludes components that provide volatile data storage, such as a read and/or write cache.*

stream *A collection of STREAM SEGMENTS.*

stream segment
A sequentially organized pattern of I/O requests, which transfers a contiguous range of data.

synchronous replication
replication in which the initial I/O operation is not marked as complete until the related operation has completed on the other, independent storage system(s).

submission identifier
a unique identifier, assigned by the SPC, for each new RESULT.

supporting files
a collection of data, documentation, and illustrations used to demonstrate the validity of a RESULT.

C.20 T

target country
the country in which the PRICED STORAGE CONFIGURATION is available for sale no later than the AVAILABILITY DATE, and in which the required hardware maintenance and software support is provided either directly from the TEST SPONSOR or indirectly via a third-party supplier

test *a collection of one or more TEST PHASES sharing a common objective.*

test phase *the smallest logical component of a TEST, during which a data is collected to satisfy the requirements of a BENCHMARK.*

test sponsor *a distinctly identifiable entity that acts as the sponsor of an RESULT.*

tested storage configuration
all software and hardware necessary to implement and support the storage configuration defined for a MEASUREMENT.

tested storage product
a distinct, customer orderable product, which is the focal point of a RESULT.

total system price
the total cost of ownership for the PRICED STORAGE CONFIGURATION.

transition *of a TEST PHASE, a time period during which the IO load presented by the WORKLOAD GENERATOR to the TSC is changing, either increasing or decreasing.*

tsc *see TESTED STORAGE CONFIGURATION.*

tsc boundary *the boundary between the HOST SYSTEM and TSC.*

tsc executive *the software component of the TSC.*

tsp *see TESTED STORAGE PRODUCT.*

C.21 U

No terms defined.

C.22 V

No terms defined.

C.23 W

workload *a collection of ASU STREAMS.*

workload generator
a user-space application, provided by the SPC, that produces benchmark-specific IO STREAMS.

C.24 X

No terms defined.

C.25 Y

No terms defined.

C.26 Z

No terms defined