SPC BENCHMARK 1C™ (SPC-1C™)

SPC BENCHMARK 1C/ENERGY™ EXTENSION (SPC-1C/E™)

OFFICIAL SPECIFICATION

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DOCUMENT HISTORY

Effective Date	Version	Description
2 April 2008	1.0.0	The first official release of the SPC Benchmark 1C™ (SPC-1C).
17 September 2008	1.1.0	Revised Clause 6.3.13.3 to change the COV requirement from 0.2 to 0.5
		Revised Clause 2.6.8.2 to include data protection capacity in the 50% utilization calculation.
	1.2.0	Revised Clause 8.4 to align public use requirements with SPC-2C.
20 May 2009	1.3.0	Revised Clause11.3 to include an on-site audit
		Added the SPC-1C/E extension (Clause 12)
18 November 2012	1.4.0	**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 create two levels of "protected" data protection: Protected 1 and Protected 2.
		Clause 4.4.1.2: Revised the Small Storage Subsystem configuration constraint to be a single enclosure with a maximum size of 4U.
		Clause 6.3.3: New wording to require all three ASUs to be completely filled with specified content prior to audited Test Run execution (ASU pre-fill).

Clause 6.4.3.2.1: Revised to require Measurement Interval duration for the Sustainability Test Run to be a minimum of 8 hours.

Clause 7.5: New wording to allow use of the SPC-2 Persistence Test with auditor approval.

Clause 8.4.1: New wording listing the requirements for public reference when using a non-local currency.

Clause 8.4.2.1: Revised to clarify references to a single SPC-1C Result.

Clause 8.4.2.1: Revised to require "current as of" date.

Clause 8.4.4: Revised to address comparisons of SPC-1C Total Price with regards to pricing currency and the "target country".

Clause 8.4.4: Revised to require "current as of" date.

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.

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.

Clause 9.2.4: New wording to define local and non-local 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 10.4.5.1: Delete co-sponsor references.

Clause 10.4.5.2: Revised to require FDR revision details to be highlighted when appropriate.

Clause 10.4.5.4, Table 10-9: Revised to include the SPC-1C Submission Identifier, Currency Used, and "Target Country".

Clause 10.4.5.7: New wording requiring the Executive Summary to include the basis (type and justification) of discounts included in the pricing.

Clause 10.4.5.11: Revised to delete the "UID" and "WG" annotations.

Clause 10.4.7.1: Revised to require an annotation that addresses reserved system overhead storage capacity that might not be included in the reported Physical Storage Capacity.

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Clause 0: Introduction

0.1 Preamble

SPC Benchmark 1C™ (SPC-1C™) is the first industry-standard storage performance benchmark for storage components such as:

- Storage Devices (disks, solid devices, etc.)
- Storage Adapters/Controllers (HBAs, RAID controllers, etc.)
- Enclosures
- Storage Software (volume managers, data protection, etc.)

SPC-1C consists of a benchmark workload that is representative of end user applications characterized by:

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

SPC-1C Results are a reliable, accurate source of storage performance characterization information for individual storage components, as well as providing the basis for performance comparison between storage components offered by multiple vendors.

The information provided by SPC-1C Results is intended to provide value throughout a storage component's lifecycle (e.g. development of product requirements; product implementation; performance tuning; capacity planning, market positioning; and purchase evaluations). In addition, the information can provide valuable insight into the expected performance of the larger storage configurations, of which each component is a part.

SPC-1C is intended to be vendor and platform independent. Any vendor should be able to sponsor and publish an SPC-1C Result, provided their benchmark configuration satisfies the performance, integrity, and availability requirements of this specification. Rather than requiring or favoring a particular implementation, it is the goal of SPC-1C to provide a robust, verifiable, reproducible environment within which the relative strengths of differing design and configuration approaches can be evaluated.

0.2 General Guidelines

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

1. Are generally available to users.
2. A significant percentage of the users in the target market segment would implement.
3. Are relevant to the market segment that the SPC-1C 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 *(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-1C benchmark specification.

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

0.4 Disclaimer

While the SPC-1C 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-1C workload. The extrapolation of SPC-1C 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-1C should not be used as a substitute for customer application benchmarking when critical performance requirements are called for.

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

0.5 SPC Benchmark Series

SPC-1C is the first of a series of storage oriented system benchmarks focused on storage components and small storage subsystems. It utilizes a common SPC benchmark framework, which was also previously used by SPC-1.

Clause 1: Workload Environment

1.1 Business and Application Environment

SPC-1C is comprised of a set of I/O operations designed to demonstrate the performance of a storage component while performing the typical functions of a business critical application. SPC-1C represents a segment of applications characterized by predominately random I/O operations and requiring both queries as well as update operations. (Examples of those types of applications include OLTP systems, database systems, and mail server applications.

1.2 High-Level Workload Model

The segment of applications represented by SPC-1C covers a broad range of user profiles and business functions. Since the focus of SPC-1 is on the commonalties of those applications, it was necessary to develop a model that would simplify the workload to the point that highlighted the similarities of its business segment while removing any conflicts and details that weren't central to performance evaluation. The model used in SPC-1C has two major components:

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

1.2.1 Business Scaling Units (BSUs)

Each Business Scaling Unit (BSU) represents the aggregate I/O load created by a specified number of users. By focusing on this aggregated I/O load, SPC-1C is able to provide a scalable stimulus that will provide a broad test of the storage component without getting lost in the detail that would be necessary for the accurate modeling of any one application. The result is a benchmark workload that retains its relevance across many generations of a particular application and through a broad spectrum of possible applications.

SPC-1C performance throughput is be scaled by increasing or decreasing the number of BSUs specified to the SPC-1C Workload Generator *(Clause 5)*. Each BSU represents a community of users who collectively generate five (5) I/Os per second. Throughput of five (5) I/Os per second for each BSU specified, represents a best case in which no significant contention occurs for configuration resources. The actual throughput measured will depend upon each individual storage configuration measured.

1.2.2 Application Storage Units (ASUs)

The storage accessed by the SPC-1C Workload Generator is referred to as Application Storage Units (ASUs). Each 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 SPC-1C Storage Hierarchy

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

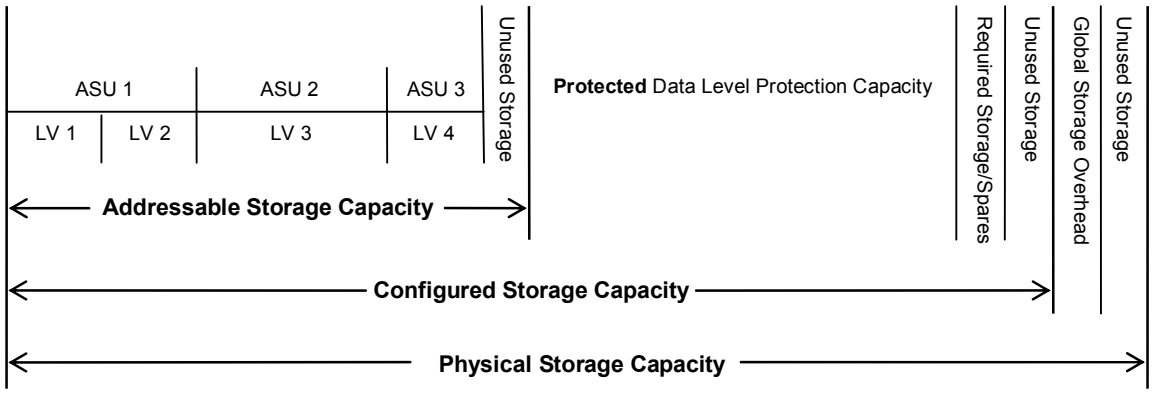
- Physical Storage Capacity defined in Clause 2.2.
- Configured Storage Capacity defined in Clause 2.3.
- Addressable Storage Capacity defined in Clause 2.4.
- Logical Volumes (LV) defined in Clause 2.5.
- Application Storage Unit (ASU) Capacity defined in Clause 2.6.

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

Included in the above storage capacities are:

- Storage capacity used for Data Protection as defined in Clause 2.7.
- Required Storage defined in Clause 2.3.2.
- Global Storage Overhead defined in Clause 2.2.3.
- Unused Storage defined in Clause 2.2.4.

Figure 2-1: SPC-1C Storage Hierarchy



2.2 Physical Storage Capacity

2.2.1 Physical Storage Capacity is typically the formatted capacity of all Storage Devices that are physically present in the Tested Storage Configuration.

2.2.1.1 In cases where the formatted capacity of a configured Storage Device is not publicly available information, the reported value will be the capacity reported as available for application use.

2.2.1.2 In cases where both the formatted capacity and the capacity available for application use are publicly available information, the Test Sponsor will report either value. In such cases, the choice made by the Test Sponsor must be applied to all configured Storage Devices of the same model.

2.2.1.3 If the Test Sponsor reconfigures the capacity of a Storage Device as documented in Clauses 2.2.1.1 or 2.2.1.2 so that the resultant capacity is less than the original value, the difference is reported as Global Storage Overhead, as described in 2.2.3, and included in the reported Physical Storage Capacity.

2.2.2 All Storage Devices present in the TSC must be included in Physical Storage Capacity, whether or not it is cabled in or powered up.

2.2.3 Global Storage Overhead consists of the Physical Storage Capacity that is required for storage subsystem use, such as metadata, and unavailable for use by application programs such as the SPC-1C Workload Generator.

2.2.4 Unused Storage within the Physical Storage Capacity consists of Physical Storage Capacity available for use but not included in Required Storage/Spares, Addressable Storage Capacity, and Unused Storage described in Clauses 2.3.2 and 2.4.3.

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

> ***Comment:*** *The intent of this clause is to accurately disclose the physical storage that could be configured application use, plus the storage reserved for system use and unavailable for application use. For example, this would exclude the difference between unformatted and formatted storage or storage devices that have failed.*

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

2.3 Configured Storage Capacity

2.3.1 Configured Storage includes the Addressable Storage Capacity and any other storage capacity necessary to implement the Addressable Storage Capacity described in Clause 2.4 such as hot spares, parity disks, journal disks, log disks, etc.

2.3.2 Unused Storage within Configured Storage Capacity consists of Configured Storage Capacity available for use but not included in Required Storage/Spares, Addressable Storage Capacity, and the Unused Storage described in Clause 2.4.3.

2.3.3 Required Storage/Spares typically consists of:

- Storage capacity used for data protection (parity, mirroring, etc.)
- Required or optionally configured spares.
- Metadata used by a controller of volume manager.

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

2.4 Addressable Storage Capacity (ASC)

2.4.1 Addressable Storage Capacity represents the total storage that can be read and written by application programs on Host Systems such as the SPC-1C Workload Generator.

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

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

2.4.3 Unused Storage is the difference between Addressable Storage Capacity and ASU Storage Capacity if they are not equal. This difference is counted twice if the Addressable Storage Capacity is mirrored

2.4.4 Addressable Storage Capacity must be less than or equal to the Configured Storage Capacity.

2.5 Logical Volumes (LV)

2.5.1 Logical Volumes (LV) represent the division of Addressable Storage Capacity into individually addressable logical units of storage used in the SPC-1C benchmark. Each Logical Volume must be implemented as a single contiguous address space.

2.5.2 Addressable Storage Capacity may contain one or more Logical Volumes.

2.5.3 The total capacity of all Logical volumes is equal to the Addressable Storage Capacity.

2.5.4 Examples of Logical Volumes include:

A single physical disk drive.

A partition on a single physical disk drive.

Multiple disk drives configured in an array.

A single logical partition on a multi-drive array.

Multiple, non-contiguous segments of one or more physical disk drives.

A RAM disk.

A hierarchy of any of the above.

2.6 Application Storage Units (ASUs)

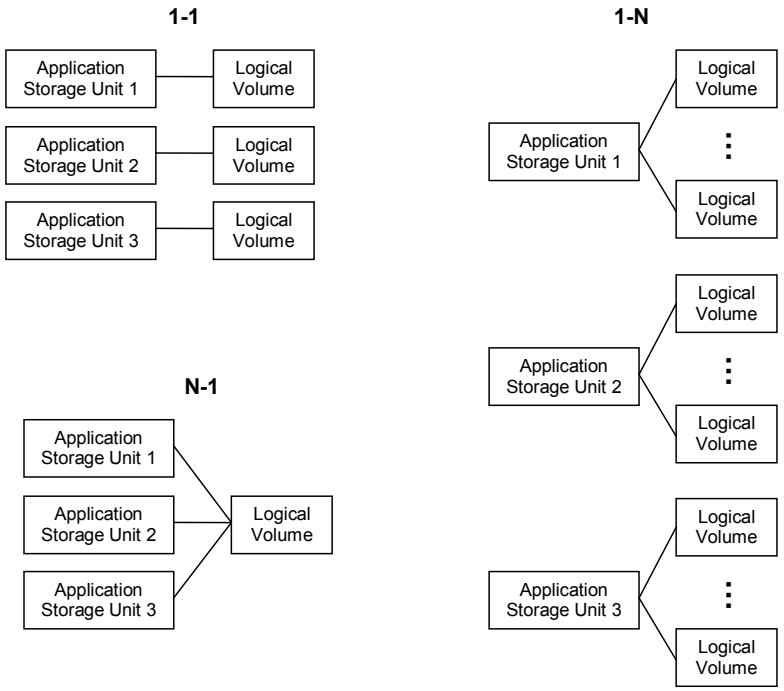
2.6.1 Each Application Storage Unit (ASU) represents a logical interface between the Logical Volumes and the SPC-1C Workload Generator, providing the persistent non-volatile storage (see Clause 7: Data Persistence Requirements and Test) read and written in the course of executing the benchmark.

2.6.2 SPC-1C defines three ASUs:

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

2.6.3 The Logical Volume to ASU mappings that are permissible are illustrated in Figure 2-2 and must satisfy the requirements in Clauses 2.6.4 through 2.6.8.

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



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

2.6.5 If the ASU is implemented on multiple Logical Volumes and the size of the ASU is smaller than the combined Logical Volumes, the ASU is not required to be evenly distributed across the Logical Volumes.

2.6.6 In the case of an ASU that is mapped to multiple Logical Volumes, the address mapping is a simple concatenation of volumes.

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

2.6.8 Total ASU Capacity must be configured in one of the following two relationships to Physical Storage Capacity.

2.6.8.1 **100%:** The Tested Storage Configuration must be configured so that there is 1 GiB or less of total Unused Storage.

2.6.8.2 **50%:** Total ASU Capacity must be configured so that the sum of Total ASU Capacity and capacity required for data protection is 50% of the Physical Storage Capacity within a tolerance of ±1 GiB or 0.5% of the Physical Storage Capacity, whichever is greater.

2.7 Data Protection

2.7.1 Data protection may be configured at any level of the SPC-1C Storage Hierarchy.

2.7.2 Data protection will be categorized in one of the following Data Protection Levels:

- **Protected 1:** The single point of failure of any storage device in the configuration will not result in permanent loss of access to or integrity of the SPC-1C Data Repository.
- **Protected 2**: The single point of failure of any component in the configuration will not result in permanent loss of access to or integrity of the SPC-1C Data Repository.
- **Unprotected:** Test Sponsor asserts no claim of data protection in the event of a single point of failure.

2.7.3 Selection of a data protected level other than **Unprotected** will require data protection for all three ASUs. The data protection method utilized is not required to be identical for each ASU.

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-1C 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-1C.

3.1.1 Logical Block

A logical block is the smallest directly addressable unit of storage on the ASU. It is a fixed quantity of 512 bytes.

3.1.2 Logical Block Address (LBA)

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

3.1.3 Measurement Units

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

In the storage industry, the terms "kilo", "mega", "giga", "tera", "peta", and "exa" are commonly used prefixes for computing performance and capacity. For the purposes of the SPC workload definitions, all of these terms are defined in powers of 10. Specifically:

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

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

The sizes reported by many operating system components use "power of two" 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 (2^{10}) bytes.
- A mebibyte (MiB) is equal to 1,048,576 (2^{20}) bytes.
- A gigibyte (GiB) is equal to 1,073,741,824 (2^{30}) bytes.
- A tebibyte (TiB) is equal to 1,099,511,627,776 (2^{40}) bytes.
- A pebibyte (PiB) is equal to 1,125,899,906,842,624 (2^{50}) bytes.
- An exbibyte (EiB) is equal to 1,152,921,504,606,846,967 (2^{60}) bytes.

3.2 SPC-1C Workload Components

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

- **SPC-1C Working Set**: Three *Application Storage Units (ASUs) Streams*.
- **Application Storage Unit Stream:** One or more *I/O Streams*.
- **I/O Stream**: A single, well-defined, sequence of *I/O Commands*.
- **I/O Command or I/O Request**: A single atomic unit of work to the Application Storage Unit.

3.2.1 SPC-1C Working Set

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

3.2.2 Application Storage Unit (ASU) Stream

An Application Storage Unit stream consists of one or more I/O streams, and completely defines the I/O sent each SPC-1C ASU.

3.2.3 I/O Stream

An I/O Stream consists of a sequence of one or more I/O commands. An I/O Stream is initiated at a specific point during the I/O workload, and has a specific life. The sequence of individual commands within the I/O Stream is fully defined by the workload parameters associated with the SPC-1C workload. One definition is required for each I/O Stream contained in the SPC-1C 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-1C 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-1C Workload Generator to issue an I/O operation to the Application Storage Unit in conformance with the SPC-1C 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-1C Parameter Types

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

3.3.1 Integer

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

3.3.2 Long Integer

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

3.3.3 Real

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

3.3.4 ASCII string

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

3.3.5 Distribution

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

3.3.5.1 Distribution type

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

0: Constant – A single number. The value of this number is contained in the first element of the distribution parameter list.

1: Uniform – A number that is uniformly distributed between (and including) two values. The lower of these values is contained in the first element of the distribution parameter list, and the upper value is contained in the second element.

2: Exponential – A number that is exponentially distributed with a mean value contained in the first element of the distribution parameter list.

3: Table – A table distribution is an n-dimensional array containing the discrete table values. There is no limit on the number of dimensions or entries in the array. The pointer component (section) of the distribution data type points to the start of the array. The contents of the array are undefined, and must be specified for each case.

4. Incremental: An ascending series of values. This distribution has four associated parameters, *incremental (start, startvar, stride, length).*

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

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

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

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

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

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

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

6. Random access pattern W1 – Also a random walk with "hierarchical reuse" behavior, using a leaf size of 32768 bytes and parameters k=6, ν=.44. The leaf L0 initially selected in this manner, however, is then used to obtain the final leaf selection L = 8*Floor(L0/8). Within the selected leaf, the 4096-byte block to be written is determined as follows. With 50 percent probability, the 4096-byte block is chosen using a random uniform distribution across all blocks of this size contained in the leaf. With the remaining 50 percent probability, the most recently read block is chosen. Once the full address of the write operation is obtained, as just described, then with an 85 percent probability, a single write is performed to the selected address. With the remaining 15 percent probability, *two* writes are performed to this address (that is, an exception occurs to the random walk scheme, in that no step is taken prior to the second write of the pair).

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

3.3.5.2 Result type

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

0: Integer – The output of the distribution is an integer.

1: Long - The output of the distribution is a long integer.

2: Real – The output of the distribution is a real number.

3.3.5.3 Distribution parameter list

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

3.3.5.4 Extended pointer

The extended pointer is used when it is necessary to include more that 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-1C Workload Parameters

A set of parameters is required for each I/O Stream that is present in the SPC-1C workload. These parameters are passed to the SPC-1C Workload Generator. The set of parameters will enable the SPC-1C Workload Generator to create and submit a stream of I/O requests to the SPC-1C Application Storage Unit.

Conceptually, the SPC-1C Workload Generator will examine the parameters, and by using the values contained in these parameters, generate a sequence of I/O commands, with each individual command being issued at the appropriate time.

3.4.1 ASU Transfer Alignment

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

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

3.4.1.1 Parameter Type

The ASU transfer alignment parameter is an integer variable.

3.4.1.2 Acceptable Values

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

3.4.2 Data Re-reference

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

In the SPC-1C benchmark, data re-reference is specified by applying an appropriate distribution to the selection of reference addresses. More specifically, certain streams of the SPC-1C benchmark, as specified in Clause 3.4.9, select the next reference address by performing a random walk. The sequence of addresses visited in the random walk includes both those where reads are performed, and those where writes are performed. The next step of the random walk is computed, based upon the most recent visit location, by applying distribution R1 when it is intended to perform a read, and distribution W1 when it is intended to perform a write.

3.4.3 Intensity Multiplier

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

3.4.3.1 Parameter type

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

3.4.3.2 Acceptable values

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

3.4.4 Memory Alignment

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

3.4.4.1 Parameter type

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

3.4.4.2 Acceptable values

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

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

3.4.5 Model Type

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

3.4.5.1 Parameter type

The model type is an integer variable.

3.4.5.2 Acceptable values

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

Open

Closed

3.4.6 Population

The population parameter specifies the number of execution instances associated with this stream *(Clause 5.1.1)*.

3.4.6.1 Parameter type

The population parameter is an integer variable.

3.4.6.2 Acceptable values

Each I/O Stream of the SPC-1C benchmark has a population equal to the integer number of BSUs currently being run on the Host System(s).

3.4.7 Read Fraction

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

3.4.7.1 Parameter type

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

3.4.7.2 Acceptable values

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

3.4.8 Stream Identifier

The stream identifier, which is assigned by the SPC-1C specification, is a value that uniquely identifies an I/O Stream within a specific workload. The purpose of this parameter is to allow analysis programs to extract performance data for a specific I/O Stream from a workload. Note that this value needs only to be unique within a workload; it is not required to be unique across all workloads.

3.4.8.1 Parameter type

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

3.4.8.2 Acceptable values

No restriction is placed on this parameter.

3.4.9 Transfer Address

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

3.4.9.1 Parameter type

The transfer address parameter is a distribution variable.

3.4.9.2 Acceptable values

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

3.4.10 Transfer Size

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

3.4.10.1 Parameter type

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

3.4.10.2 Acceptable values

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

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

3.4.11 Workload Identifier

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

3.4.11.1 Parameter type

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

3.4.11.2 Acceptable values

No restriction is placed on this parameter.

3.5 Technical Workload Description

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

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

ASU 1 - Data Store

ASU 2 - User Store

ASU 3 – Log/Sequential Write

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

Definitions and descriptions of each parameter type used to define the SPC-1C parameters may be found in Clause 3.3. Each SPC-1C parameter is defined and described in Clause 3.4.

3.5.1 ASU 1 – Data Store

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

Table 3-1: ASU 1 Parameter Types and Values

Parameter Type	I/O Stream 1	I/O Stream 2	I/O Stream 3	I/O Stream 4
ASU	1	1	1	1
Transfer alignment *(512 byte blocks)*	8	8	8	8
Data re-reference	N/A	See Clause 3.4.2	N/A	See Clause 3.4.2
Intensity multiplier	0.035	0.281	0.070	0.210
Memory alignment	8	8	8	8
Model type	Open	Open	Open	Open
Population	=BSU	=BSU	=BSU	=BSU
Read fraction	0.5	0.5	1.0	0.5
Stream identifier	“ASU 1-1”	ASU 1-2”	“ASU 1-3”	“ASU 1-4”
Transfer address	Uniform: 0.0 – 1.0	R1/W1: 0.15 – 0.2	Incremental (0.4, 0.4, 0, 0.1)	R1/W1: 0.7 – 0.75
Transfer size *(512 byte blocks)*	8	8	SMIX	8
Workload identifier	“SPC-1.00”	“SPC-1.00”	“SPC-1.00”	“SPC-1.00”

3.5.2 ASU 2 – User Store

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

Table 3-2: ASU 2 Parameter Types and Values

Parameter Type	I/O Stream 1	I/O Stream 2	I/O Stream 3
ASU	2	2	2
Transfer alignment *(512 byte blocks)*	8	8	8
Data re-reference	N/A	See Clause 3.4.2	N/A
Intensity multiplier	0.018	0.070	0.035
Memory alignment	8	8	8
Model type	Open	Open	Open
Population	=BSU	=BSU	=BSU
Read fraction	0.3	0.3	1.0
Stream identifier	"ASU 2-1"	"ASU 2-2"	"ASU 2-3"
Transfer address	Uniform: 0.0 – 1.0	R1/W1: 0.47 – 0.52	Incremental (0.4, 0.4, 0, 0.1)
Transfer size *(512 byte blocks)*	8	8	SMIX
Workload identifier	"SPC-1.00"	"SPC-1.00"	"SPC1.00"

3.5.3 ASU 3 – Log/Sequential Write

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

Table 3-3: ASU 3 Parameter Types and Values

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

Clause 4: Benchmark Configuration and Tested Storage Configuration

4.1 Overview

The Benchmark Configuration (BC) consists of all hardware and software components used in the execution of the SPC-1C benchmark. The Tested Storage Configuration (TSC) consists of all software and hardware necessary to implement and support the three configured Application Storage Units (ASUs) as defined in Clause 2.6.

4.2 Benchmark Configuration Component Availability and Support

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

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

4.3 Benchmark Configuration Components

The Benchmark Configuration consists of the following components:

1. One or more Host Systems as defined in Clause 4.3.1.
2. All hardware and software needed to communicate between the Host System(s) and Tested Storage Configuration.
3. System Software, as defined in Clause 4.3.2.
4. The Tested Storage Configuration (TSC), defined in Clause 4.4.
5. The Tested Storage Product (TSP) defined in Clause 4.5.

4.3.1 Host System(s)

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

4.3.2 System Software

4.3.2.1 System Software, which may include the Host System's operating system, is responsible for presenting and managing unique names that instantiate the three Application Storage Units (ASUs) to the SPC-1C Workload Generator, as well as organizing and managing the underlying Logical Volumes used to implement the ASUs.

4.3.2.2 System Software shall provide for error recovery, as well as all services needed to execute the SPC-1C Workload Generator on the Benchmark Configuration.

4.3.2.3 System Software may be used to implement RAID 0 (striping) and/or data protection functionality as defined in Clause 2.7.

4.3.2.4 System Software, executing on 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.

4.4 Tested Storage Configuration (TSC)

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

4.4.1 Tested Storage Configuration (TSC) Components

The TSC will consist of one or more Host Bus Adapters (HBAs)/controllers (external or embedded) and one of the following storage device configurations.

4.4.1.1 One, Two, or Four Physical Storage Devices

One (1), two (2), or four (4) physical storage devices are directly connected to one or more HBAs/controllers. The storage devices may be located in an enclosure, but the enclosure may only provide power and/or direct connectivity. If the enclosure includes the HBA/controller or provides any functionality other than power and direct connectivity, the TSC will be considered a Small Storage Subsystem as described below.

4.4.1.2 Small Storage Subsystem

A Small Storage Subsystem consists of a single enclosure with a maximum size of 4U, which may contain any number of physical storage devices. The enclosure may optionally include one or more controllers. An enclosure may include System Software, which provide functionality such as data protection as defined in Clause 2.7

4.4.2 Host System as a TSC Component

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

1. The Host System contains an integral component that is a TSC hardware component, which cannot be unplugged and moved to a different Host System such as an embedded Host Bus Adapter.
2. The Host System includes physical storage devices that contain the SPC-1C Data Repository *(Clause 2)* and are connected internally as integral Host System components.
3. System Software that provides data protection functionality *(Clause 2.7)*.

System Software, as defined in Clause 4.3.2, which provides the following functionality for the TSC will not require the Host System to be included as a priced TSC component:

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

An example of a TSC that includes the Host System as a TSC component is described in Clause 4.4.3.1 and illustrated in Figure 4-1.

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

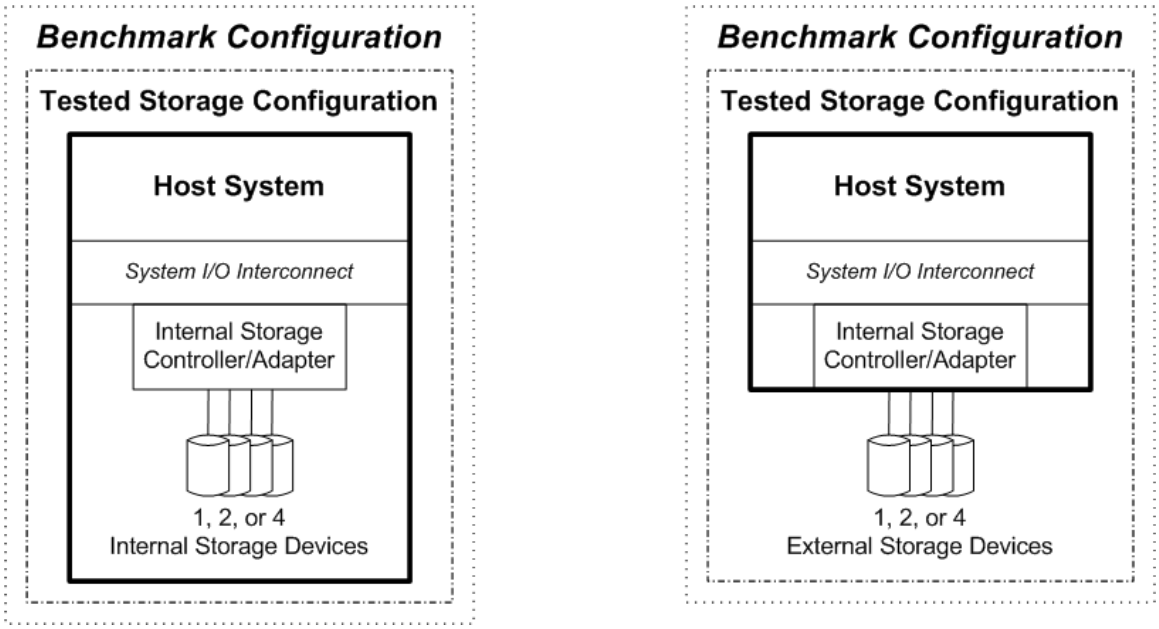
4.4.3 Tested Storage Configuration (TSC) Examples

Clauses 4.4.3.1 – 4.4.3.3 describe and illustrate, in detail, the allowed Tested Storage Configurations, including the boundary between the Host System and TSC (TSC Boundary).

4.4.3.1 Embedded Storage Adapter/Controller – Internal/External Physical Storage Devices

A TSC that utilizes an embedded storage adapter/controller and internal or external Storage Devices is illustrated in Figure 4-1.

Figure 4-1: Embedded Storage Adapter/Controller – Internal/External Physical Storage Devices



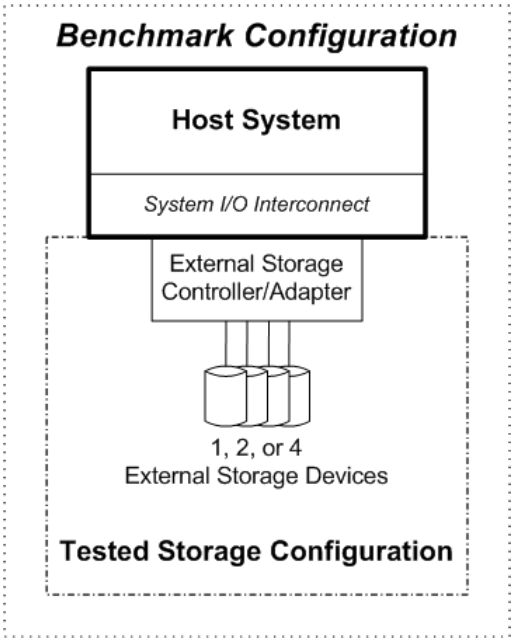
The components that comprise the TSC include:

1. A Host System with one or more storage adapters/controllers embedded on the motherboard or a daughter card attached to the motherboard.
2. One (1), two (2), or four (4) directly attached physical storage devices.
3. Cabling between the embedded storage adapters/controllers and the physical storage devices.
4. Optionally, an enclosure to hold the storage devices. The enclosure may only provide power and/or direct connectivity. If the enclosure includes the HBA/controller or provides any functionality other than power and direct connectivity, the TSC will be considered a Small Storage Subsystem. *(Clauses 4.4.1.1 and 4.4.1.2).*

4.4.3.2 External Storage Adapter/Controller – External Storage Devices

A TSC that utilizes an external adapter/controller and external Storage Devices is illustrated in Figure 4-2.

Figure 4-2: External Storage Adapter/Controller – External Storage Devices



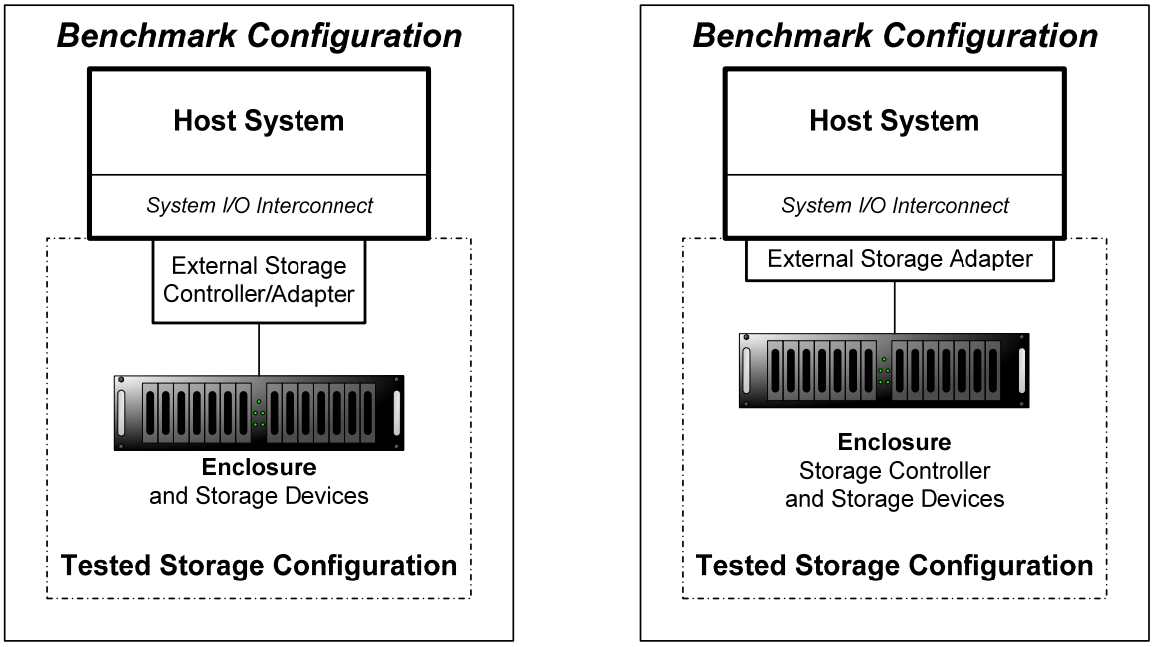
The components that comprise the TSC typically include:

1. One or more external storage adapters/controllers that plug into a system I/O interconnect on the Host System.
2. One (1), two (2), or four (4) directly attached physical storage devices.
3. Cabling between the embedded storage adapters/controllers and the physical storage devices.
4. Optionally, an enclosure to hold the physical storage devices. The enclosure may only provide power and/or direct connectivity. If the enclosure includes the HBA/controller or provides any functionality other than power and direct connectivity, the TSC will be considered a Small Storage Subsystem. *(Clauses 4.4.1.1 and 4.4.1.2).*

4.4.3.3 Small Storage Subsystem

A TSC utilizing a small storage subsystem is illustrated in Figure 4-3.

Figure 4-3: Small Storage Subsystem



The TSC typically includes the following components:

1. One or more enclosures.
2. One or more storage adapters/controllers, which may be internal to the enclosure or external that plug into a system I/O interconnect on the Host System.
3. An aggregate maximum of twenty-four (24) physical storage devices.
4. All cabling required for connections within the enclosure, as well as between the enclosure and the Host System.

4.5 Tested Storage Product (TSP)

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

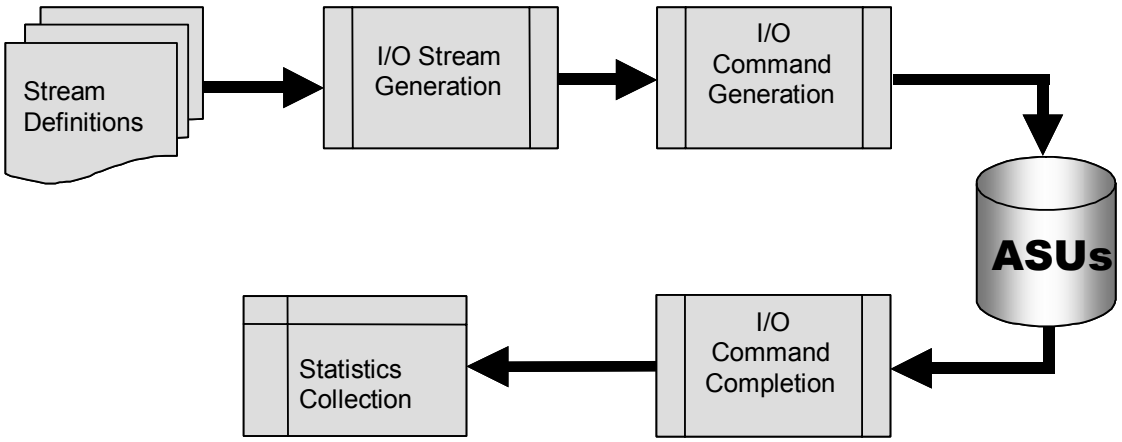
Clause 5: SPC-1C Workload Generator

5.1 Overview

An SPC-1C Result is produced using the current SPC-1C-Workload Generator, which is a user-space application, instantiated by one or more processes running on one or more Host Systems. The SPC-1C Workload Generator is capable of randomly referencing any block within the configured capacity of the three Application Storage Units (ASUs).

The functional components of the SPC-1C Workload Generator are illustrated below in Figure 5-3.

Figure 5-1: Workload Generator Functional Components



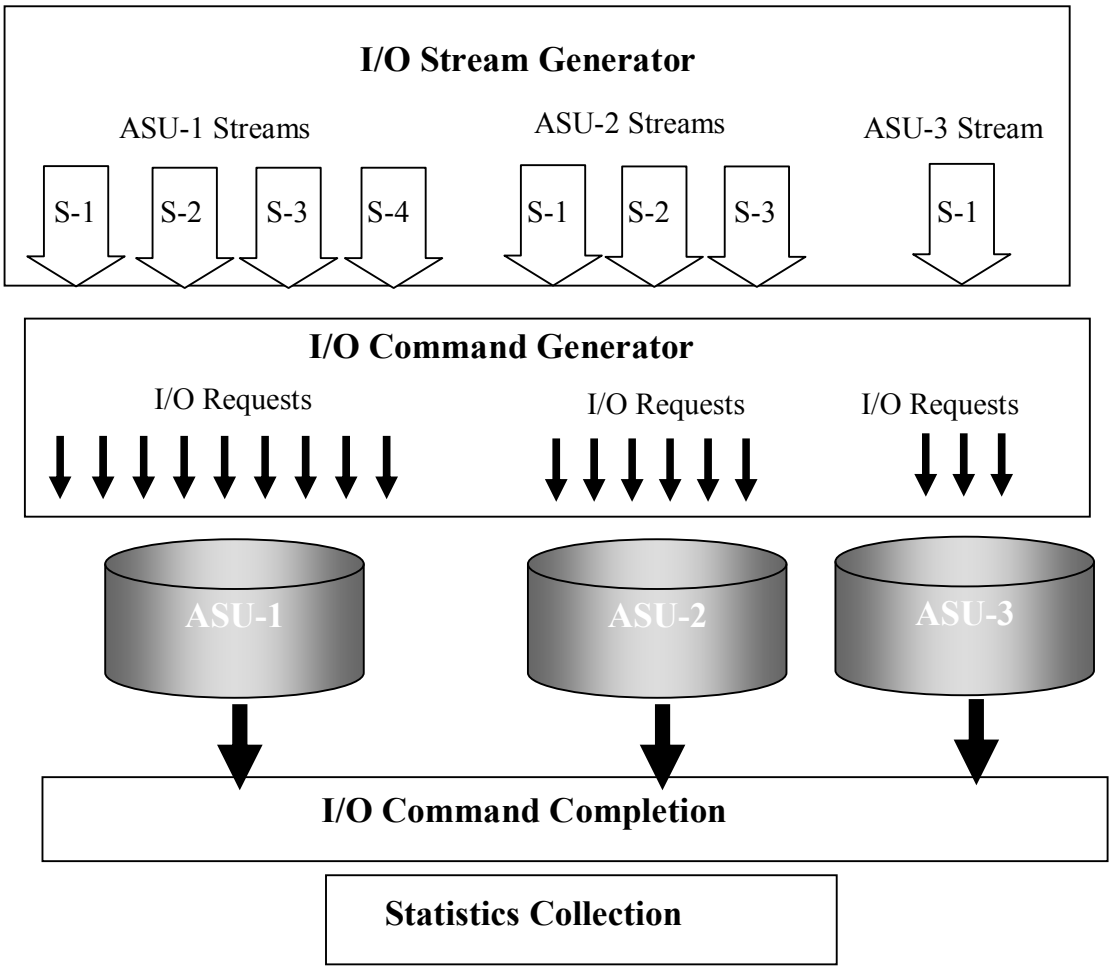
Each I/O request of the SPC-1C workload is associated with a specific I/O Stream. The workload incorporates a number of distinct types of I/O Streams. The definitions of each stream type are presented in Clause 3.4.9.

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

The relationships between the Workload Generator components, I/O streams and ASUs are illustrated in Figure 5.2.

The specific functions of the SPC-1C Workload Generator are described in 5.1.1–5.1.4.

Figure 5-2: Workload Generator Components, I/O Streams, and ASUs



5.1.1 I/O Stream Generator

The I/O Stream Generator is responsible for generating a sequence of I/O requests for each instance of each ASU Stream as defined and described in Clauses 3.5.1, 3.5.2, and 3.5.3. As such, the I/O Stream Generator will compute the Transfer size, Transfer Address, type of I/O operation (Read or Write), and Transfer Alignment for each I/O request in each instance of each ASU I/O Stream.

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

5.1.2 I/O Command Generator

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

5.1.3 I/O Command Completion

The I/O Command completion module is responsible for:

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

5.1.4 Statistics Collection and Data Reduction

The Statistics Collection Module exists to reduce CPU overhead and storage requirements by computing key "on-the-fly" statistics for an SPC-1C Test Run. This functional module is also responsible for writing an SPC-1C Results File for each Test Run executed in the course of the benchmark.

5.2 Multiple Host System Configuration Requirements

If a Test Sponsor chooses to configure multiple Host Systems in a Benchmark Configuration the following requirements must be met:

- Each Host System must have access to and utilize the entire ASU.
- Each Host System must maintain the workload parameter requirements defined in Clause 3.4.9.
- The aggregate workload presented by the multiple Host System configuration must maintain the workload parameter requirements defined in Clause 3.4.9.
- The workload presented from the Host Systems must be synchronized in time.
- The measurement results from a multiple Host System configuration must be equivalent to the results generated by a comparable single Host System configuration when using the same TSC.

Comment: *It is the intent of this clause that a multiple Host System Configuration and comparable single Host System Configuration produce equivalent workloads and measurement results when using the same Tested Storage Configuration..*

5.3 Application Storage Unit (ASU) Access

The SPC-1C Workload Generator is not allowed to utilize any file system functionality, such as caching or pre-fetching, provided by the Host System(s) when accessing an ASU. As an example, the UNIX implementations of the SPC-1C Workload Generator will issue I/O Requests via the raw, unblocked I/O interface. Figure 5-4 illustrates that example

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

5.4 Measurement Boundary

The Measurement Boundary for computing SPC-1C results is primarily defined by the implementation of the SPC-1C Workload Generator as illustrated in Figure 5-3 and Figure 5-4.

The Measurement Boundary occurs within the SPC-1C Workload Generator where start and completion times of I/O Requests are recorded.

Figure 5-3: Measurement Boundary

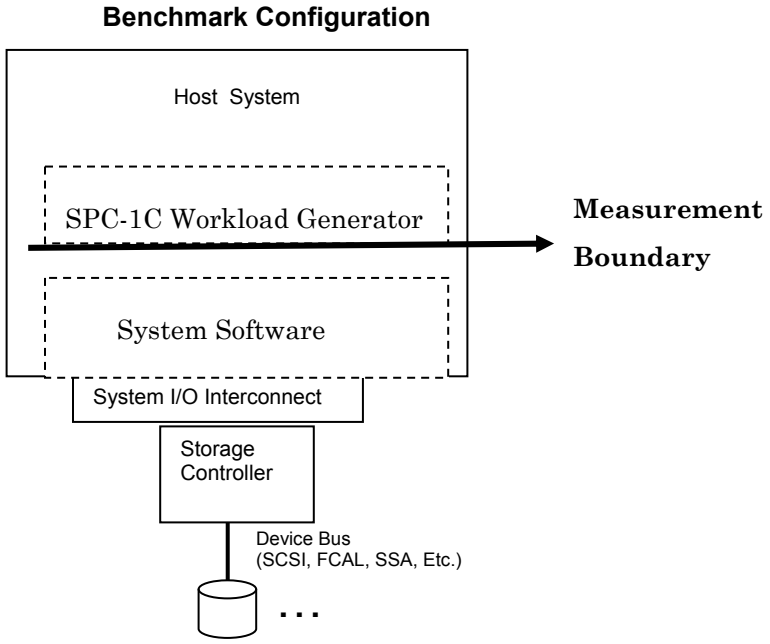
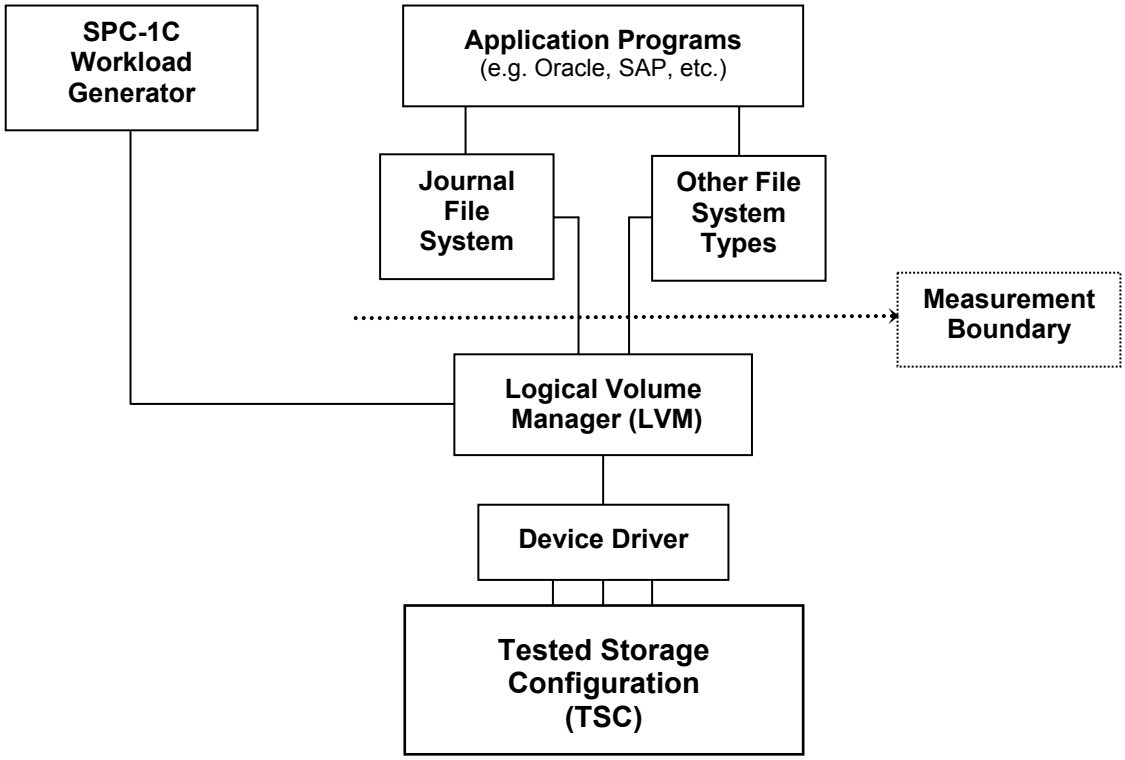


Figure 5-4: Measurement Boundary in an UNIX System Implementation



Clause 6: Test Measurement Requirements (Execution Rules)

6.1 Supporting Definitions

6.1.1 **Average Response Time:** The sum of the Response Times for all Measured I/O Requests divided by the total number of Measured I/O Requests.

6.1.2 **Completed I/O Request:** An I/O Request with a Start Time and a Completion Time (see Figure 6-2)

6.1.3 **Completion Time:** The time recorded by the Workload Generator when an I/O Request is satisfied by the TSC as signaled by System Software.

6.1.4 **Data Rate:** The data transferred in all Measured I/O Requests in an SPC-1C Test Run divided by the length of the Test Run in seconds.

6.1.5 **Expected I/O Count:** For any given I/O Stream and Test Phase, the product of 5 times the BSU level, the duration of the test phase in seconds, and the Intensity Multiplier for that I/O stream as defined in either Table 3-1, Table 3-2, or Table 3-3.

6.1.6 **Failed I/O Request:** Any I/O Request issued by the Workload Generator that could not be completed or was signaled as failed by System Software. A Failed I/O Request has no Completion Time *(Figure 6-2)*.

6.1.7 **I/O Request Throughput:** The total number of Measured I/O requests in an SPC-1C Test Run divided by the duration of the Measurement Interval in seconds.

6.1.8 **In-Flight I/O Request:** An I/O Request issued by the I/O Command Generator to the TSC that has a recorded Start Time, but does not complete within the Measurement Interval (see Figure 6-2).

6.1.9 **Measured I/O Request:** A Completed I/O Request with a Completion Time occurring within the Measurement Interval *(Figure 6-2)*.

6.1.10 **Measured Intensity Multiplier:** The percentage of all Measured I/O Requests that were issued by a given I/O stream.

6.1.11 **Measurement Interval:** The finite and contiguous time period, after the TSC has reached Steady State, when data is collected by a Test Sponsor to generate an SPC-1C test result or support an SPC-1C test result.

6.1.12 **Ramp-Up:** The time required for the Benchmark Configuration (BC) to produce Steady State throughput after the Workload Generator begins submitting I/O Requests to the TSC for execution.

6.1.13 **Ramp-Down:** The time required for the BC to complete all I/O Requests issued by the Workload Generator. The Ramp-Down period begins when the Workload Generator ceases to issue new I/O Requests to the TSC.

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

6.1.15 **Start Time:** The time recorded by the Workload Generator when an I/O Request is submitted, by the Workload Generator, to the System Software for execution on the Tested Storage Configuration (TSC).

6.1.16 **Start-Up:** The period that begins after the Workload Generator starts to submit I/O requests to the TSC and ends at the beginning of the Measurement Interval.

6.1.17 **Shut-Down:** The period between the end of the Measurement Interval and the time when all I/O Requests issued by the Workload Generator have completed or failed.

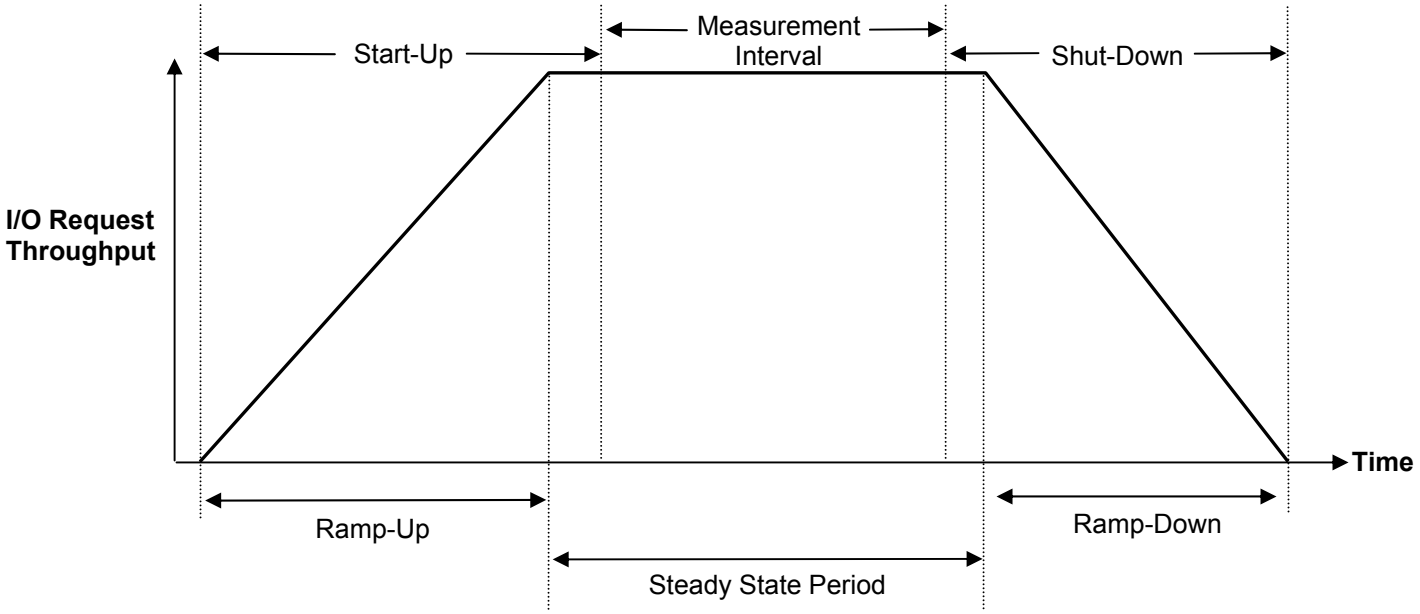
6.1.18 **Steady State:** The consistent and sustainable throughput of the TSC. During this period the load presented to the TSC by the Workload Generator is constant.

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

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

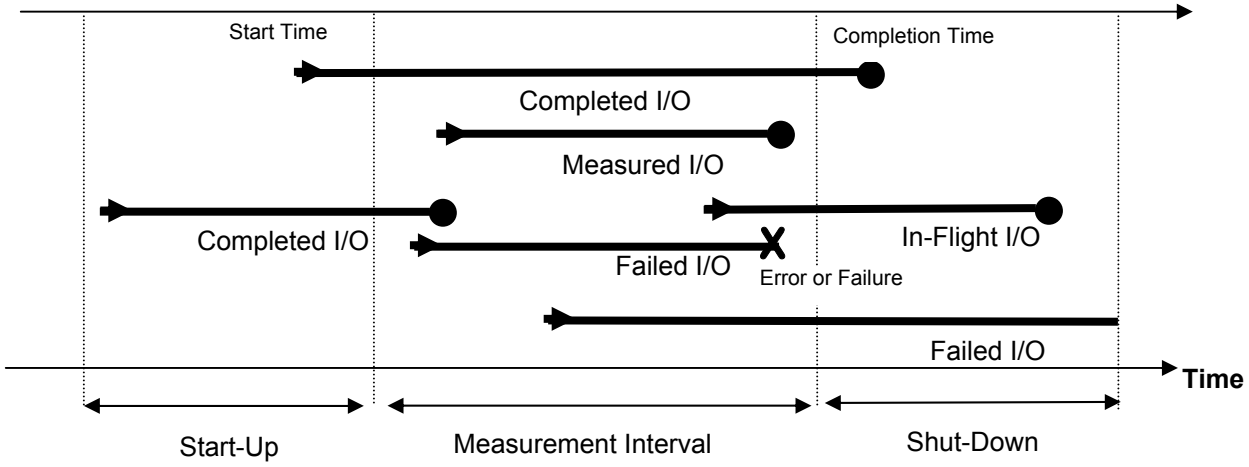
6.1.20 **Test Run:** The execution of SPC-1C for the purpose of producing or supporting an SPC-1C test result. SPC-1C Test Runs may have a finite and measured Ramp-Up period, Start-Up period, Shut-Down period, and Ramp-Down period as illustrated in Figure 6-1 below. All SPC-1C Test Runs shall have a Steady State period and a Measurement Interval.

Figure 6-1: Sample Test Run



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

Figure 6-2: I/O Completion Types



6.2 Storage Capacities

The storage capacities, defined in Clause 2: Data Repository, are configured at the discretion of the Test Sponsor subject to the requirements of that clause.

6.3 Requirements and Constraints

6.3.1 SPC Approved Workload Generator

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

6.3.2 Audit

A SPC-1C benchmark measurement must successfully complete an Audit as defined in Clause 11 before it can be submitted to the SPC and become a SPC-1C Result.

6.3.3 ASU Pre-Fill

6.3.3.1 Each of the three SPC-1C ASUs *(ASU-1, ASU-2 and ASU-3)* is required to be completely filled with specified content prior to execution of audited SPC-1C Tests. The content is required to consist of a random data pattern such as that produced by an SPC recommended tool.

6.3.3.2 If the Test Sponsor chooses to use a tool other than a SPC recommended tool, the Test Sponsor is required to provide adequate proof, to the Auditor satisfaction, that the resultant ASU content is equivalent to that produced by a SPC recommended tool as described above.

6.3.3.3 If approved by the Auditor, the Test Sponsor may complete the required ASU pre-fill prior to the execution of the audited SPC-1C Tests and not as part of the SPC-1C Tests execution sequence. In that case, the pre-filled ASUs may then be used for SPC-1C benchmark execution prior to that of the audited SPC-1C Tests and the Auditor will verify the required random data pattern content in each ASU prior to the execution of the audited SPC-1C Tests. If that verification fails, the Test Sponsor is required to reload the specified content to each ASU that failed the verification.

6.3.4 Benchmark Configuration (BC) Consistency

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

6.3.5 Start-Up Period

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

6.3.6 Shut-Down Period

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

6.3.7 Measurement Resolution

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

6.3.8 I/O Request Completion

All I/O Requests from one Test Run must complete before the Measurement Interval of the next Test Run can begin.

During the execution of each Test Run, 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.

> ***Comment:*** *Specifically disallowed during the execution of each Test Run 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).*

6.3.9 Failed I/O Requests

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

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

6.3.10 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.

6.3.11 Data Persistence

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

6.3.12 No Warm-up

Other than booting/starting the Host System(s), bringing ASUs on-line for use by the SPC-1C Workload Generator, and starting the SPC-1C Workload Generator, no substantive work shall be performed on the BC prior to or in between SPC-1C Tests, Test Phases, or Test Runs.

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

6.3.13 Interpolation or Rounding

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

6.3.14 I/O Profile Preservation

6.3.14.1 Each execution of a measurement interval during a test phase must produce Measured I/O Requests that reflect the workload profiles that are defined in Clause 3.4.9.

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

a. The stream's Measured Intensity Multiplier may differ from the Intensity Multiplier defined for that stream by no more than 5% of the value provided in Table 3-1, Table 3-2, or Table 3-3.

b. The number of Measured I/O Requests for that stream shall differ from the product of Intensity Multiplier (defined in Clause 6.1.10) and Measured I/O Requests (defined in Clause 6.1.9) by no more than 5 I/Os.

6.3.14.3 For each I/O stream executed during a test phase, the coefficient of variation for the Measured Intensity Multiplier may be no more than 0.5, when calculated from the Measured Intensity Multiplier reported at one minute intervals throughout the measurement interval of the test phase.

Coefficient of variation is defined to be:

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

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

6.3.14.4 A benchmark execution that produces a Measured Intensity Multiplier that does not satisfy the requirements defined in Clauses 6.3.14.2 and 6.3.14.3 is not compliant with this specification.

6.4 SPC-1C Tests

6.4.1 An Overview of the SPC-1C Benchmark Tests

A SPC-1C benchmark measurement includes the following three (3) Tests:

- The Primary Metrics Test *(Clause 6.4.3)*.
- The Repeatability Test *(Clause 6.4.4)*.
- The Data Persistence Test *(Clause 7)*.

Each Test must be completed and reported in an audited SPC-1C Result. Each Test will contain one or more Test Runs, each of which will generate required SPC-1C test results. The Test Runs within a Test may be organized into one or more Test Phases. Figure 6-3 illustrates the flow of the SPC-1C Tests as well as the required sequence of Test Runs within a Test or Test Phase.

6.4.2 SPC-1C Benchmark Test Sequence

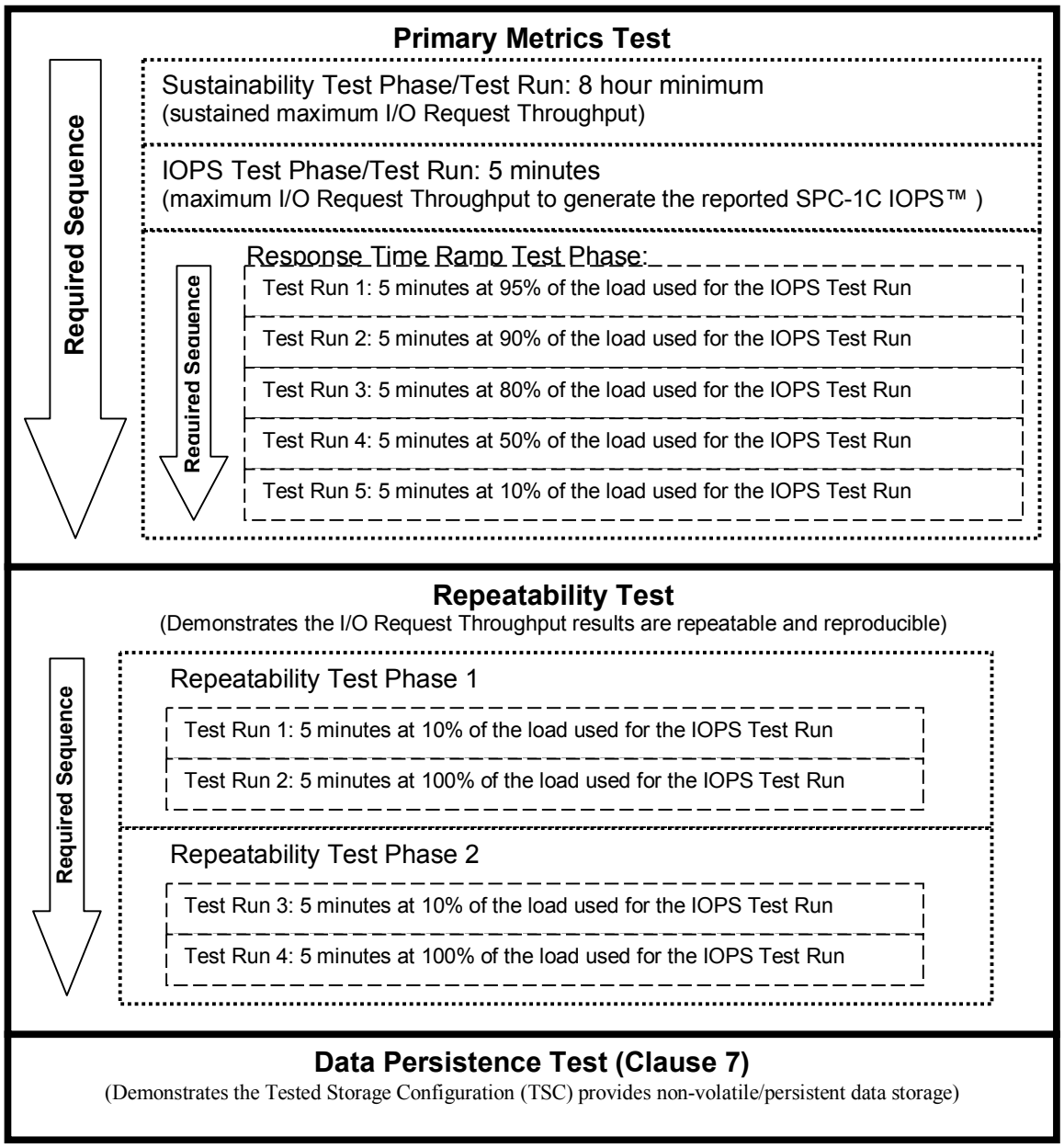
The Tests must be executed in the following sequence: Primary Metrics, Repeatability, and Data Persistence. That required sequence must be uninterrupted from the start of Primary Metrics to the completion of Persistence Test Run 1.

Uninterrupted means the Benchmark Configuration shall not be power cycled, restarted, disturbed, altered, or adjusted during the selected Test sequence. If the selected Test sequence is interrupted, the SPC-1C measurement is invalid. This does not apply to the interruption caused by the Host System/TSC power cycle between Persistence Test Run 1 and Persistence Test Run 2.

The Test Sponsor is not limited in the number of attempts to complete the selected, uninterrupted Test sequence.

An exception may be made by the auditor to the above requirement for an uninterrupted Test sequence. If such an exception is made, it will be documented in the "Audit Notes" portion of the SPC-1C Audit Certification Report.

Figure 6-3: Summary of SPC-1C Tests



6.4.3 Primary Metrics Test

6.4.3.1 Overview

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

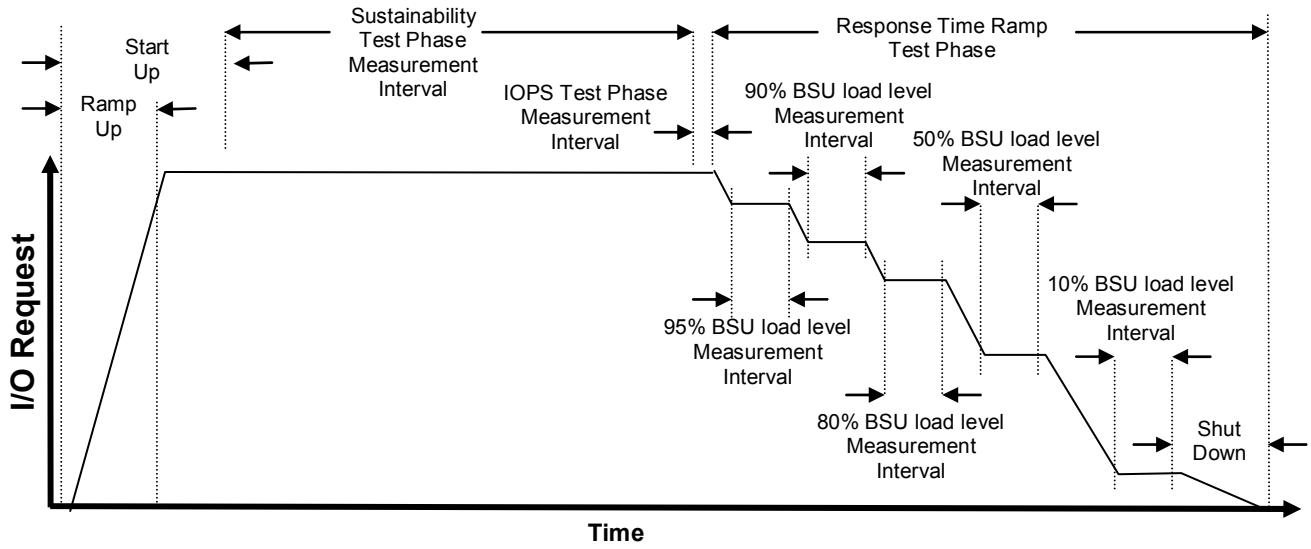
1. Sustainability
2. IOPS (I/Os per second)

3. Response Time Ramp

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

The components of the Primary Metrics Test and their relationship to each other are illustrated in Figure 6-4. The illustration is not to scale.

Figure 6-4: Primary Metrics Test



6.4.3.2 Sustainability Test Phase

6.4.3.2.1 The Sustainability Test Phase has exactly one Test Run and shall demonstrate the maximum sustainable I/O Request Throughput within at least a continuous eight (8) hour Measurement Interval.

Comment: *The intent of the eight hour Measurement Interval is to demonstrate that the maximum reported SPC-1C IOPS™ rate can be consistently maintained over an extended period, which would be required by a component in a storage configuration with requirements for sustained maximum throughput.*

6.4.3.2.2 The Sustainability Test Run will have a Start-Up, Ramp-Up, Steady State, Ramp-down, and Shutdown period as well as a Measurement Interval.

6.4.3.2.3 The duration of the Measurement Interval for the Sustainability Test Run is a minimum of eight hours (480 minutes).

6.4.3.2.4 The Measured Intensity Multiplier for each I/O stream in the Sustainability Test Run must satisfy the I/O mix requirements defined in Clause 6.3.14.3.

6.4.3.2.5 The reported metric resulting from the Sustainability Test Run is computed as the I/O Request Throughput for the Measurement Interval of the Sustainability Test Run.

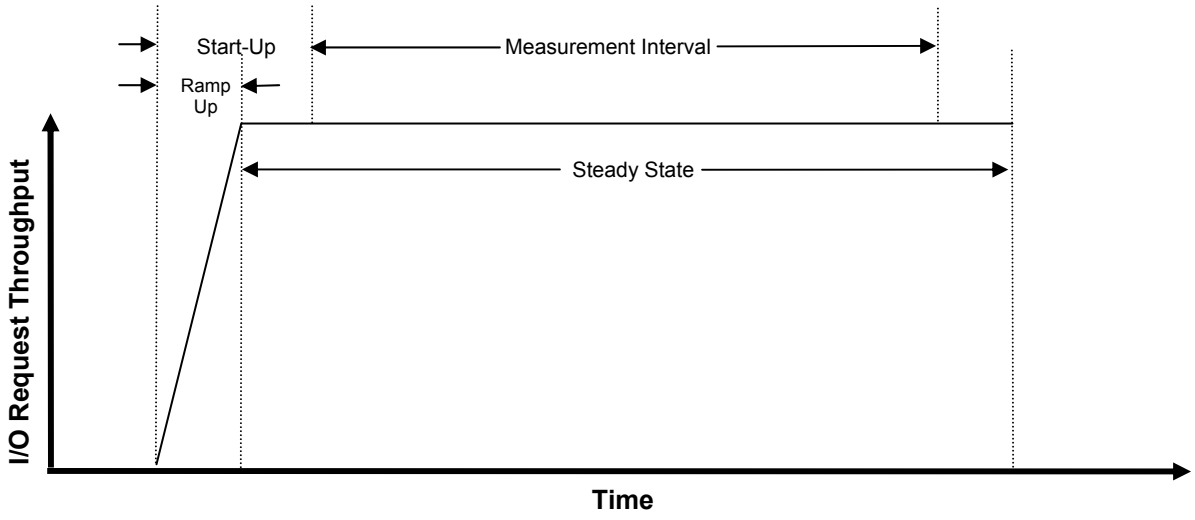
6.4.3.2.6 The computed I/O Request Throughput of the Sustainability Test Run must be no less than 95% of the reported SPC-1C IOPS™ result or the Test Run is invalid.

6.4.3.2.7 The Average Response Time, as defined in Clause 6.1.1, will be computed and reported for the Sustainability Test Run and cannot exceed 30 milliseconds. If the Average Response Time exceeds that 30-millisecond constraint, the Test Run is invalid.

6.4.3.2.8 All Sustainability Test Run data used to compute Sustainability Test Run results shall be obtained from SPC-1C Workload Generator Results Files.

6.4.3.2.9 The components of the Sustainability Test Run are illustrated in Figure 6-5. The illustration is not to scale.

Figure 6-5: Sustainability Test Phase/Test Run



6.4.3.3 IOPS Test Phase

6.4.3.3.1 The IOPS Test Phase has exactly one Test Run and shall demonstrate the maximum sustainable I/O Request Throughput after achieving sustainable and consistent I/O Request Throughput.

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

Comment: *It is the intent of this clause to insure that the Tested Storage Configuration (TSC) has demonstrated Steady State in preparation for generating the reported SPC-1C IOPS™ result.*

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

6.4.3.3.4 The IOPS Test Run is executed at the same BSU level as the Sustainability Test Run.

6.4.3.3.5 The duration of the Measurement Interval for the Sustainability Test Run is five (5) minutes.

6.4.3.3.6 The Measured Intensity Multiplier for each I/O stream in the IOPS Test Run must satisfy the I/O mix requirements defined in Clause 6.3.14.3.

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

6.4.3.3.8 The Average Response Time, as defined in Clause 6.1.1, will be computed and reported for the IOPS Test Run and cannot exceed 30 milliseconds. If the Average Response Time exceeds that 30-millisecond constraint, the Test Run is invalid.

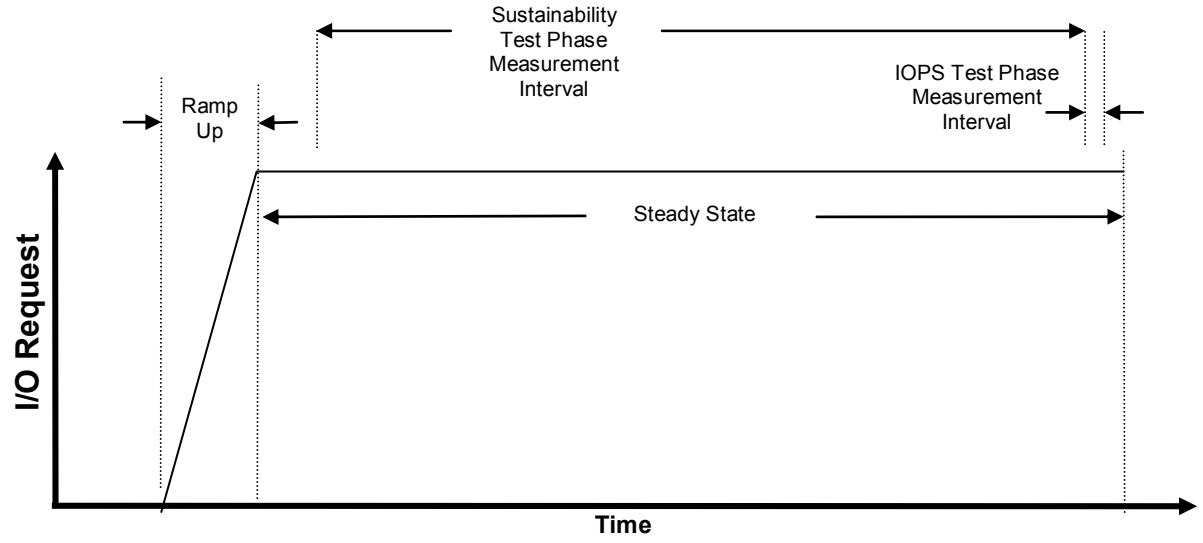
6.4.3.3.9 The Test Sponsor shall do nothing to impact the I/O Request Throughput between the end of the Sustainability Test Phase/Test Run and the beginning of the IOPS Test Phase/Test Run.

Comment: *The intent of this clause is to ensure the load presented to the TSC during the transition between the two Test Phases remains under the control of the SPC-1C Workload Generator, without any intervention from the Test Sponsor.*

6.4.3.3.10 All IOPS Test Run data used to compute IOPS Test Run results shall be obtained from SPC-1C Workload Generator Results Files.

6.4.3.3.11 The IOPS Test Phase/Test Run and its relationship to the Sustainability Test Phase/Test Run is illustrated in Figure 6-5. The illustration is not to scale.

Figure 6-6: Sustainability and IOPS Test Phases/Test Runs



6.4.3.4 Response Time Ramp Test Phase

6.4.3.4.1 The Response Time Ramp Test Phase consists of five (5) Test Runs, which measure the Average Response Time and I/O Request Throughput at 10%, 50%, 80%, 90%, and 95% of the BSU level used in the IOPS Test Run. The objectives of this Test Phase are to demonstrate:

- The relationship between Average Response Time and I/O Request Throughput for a Test Sponsor's Tested Storage Configuration (TSC) via a complete response time/throughput curve.
- The *(optimal)* Average Response Time of a lightly loaded TSC (SPC-1C LRT™).

6.4.3.4.2 The Response Time Ramp Test Phase immediately follows the IOPS Test Phase.

6.4.3.4.3 The BSU level required for a given Test Run in this Test Phase shall be the integer value resulting from truncating the product of the BSU level used in the IOPS Test Run and the BSU percentage for the Test Run.

6.4.3.4.4 The sequence of Test Runs in this Test Phase shall be:

1. 95% BSU level.
2. 90% BSU level.
3. 80% BSU level.
4. 50% BSU level.
5. 10% BSU level

6.4.3.4.5 Each Test Run in this Test Phase shall have a Start-Up, Ramp-Up, Steady State, Ramp-down, and Shutdown period as well as a Measurement Interval.

6.4.3.4.6 The duration for each Test Run's Measurement Interval shall be equal to 5 minutes.

6.4.3.4.7 The Measured Intensity Multiplier for each I/O stream in each Test Run must satisfy the I/O mix requirements defined in Clause 6.3.14.3.

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

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

6.4.3.4.10 All Test Run data used to compute Test Run results shall be obtained from SPC-1C Workload Generator Results Files.

6.4.3.4.11 The Benchmark Configuration or Tested Storage Configuration may not be restarted between the IOPS Test Phase and the Response Time Ramp Test Phase. In addition, the Test Sponsor shall do nothing to impact the I/O Request Throughput between the end of the IOPS Test Phase and the beginning of the Response Time Ramp Test Phase.

6.4.3.4.12 The Test Sponsor shall do nothing to impact the I/O Request Throughput between Test Runs of this Test Phase.

6.4.3.4.13 The components of the Response Time Ramp Test Phase and their relationship to each other, as well the IOPS Test Phase, are illustrated in Figure 6-4. The illustration is not to scale.

6.4.4 Repeatability Test

The Repeatability Test demonstrates the repeatability and reproducibility of the I/O Request Throughput and Average Response Time measured in the IOPS Test Run (100% BSU level) and Test Run 5 (10% BSU level) of the Response Time Ramp Test Phase.

The Repeatability Test consists of two identical Test Phases. Each Test Phase consists of two Test Runs. The first Test Run (SPC-1C LRT™ Repeatability Test Run – 10% BSU level) produces a SPC-1C LRT™ result. The second Test Run (SPC-1C IOPS™ Repeatability Test Run – 100% BSU level) produces a SPC-1C IOPS™ result. If any Test Run in either of the two Test Phases is not compliant, both Test Phases must be repeated.

6.4.4.1 Each Test Run in the Repeatability Test will contain a Start-Up, Ramp-Up, Steady State, Ramp-down, and Shut-down period as well as a Measurement Interval.

6.4.4.2 The duration of the Start-Up, Shut-Down, and Measurement Interval will be identical for each Test Run in the Repeatability Test.

6.4.4.3 The Measurement Interval for each Repeatability Test Run shall be equal to or greater than 5 minutes.

6.4.4.4 The Measured Intensity Multiplier for each I/O stream in each Test Run must satisfy the I/O mix requirements defined in Clause 6.3.14.3.

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

6.4.4.6 Steady State for the first Test Run in each Test Phase is attained at the same BSU level used in the Primary Metrics Test to produce the final reported SPC-1C LRT™ metric.

6.4.4.7 Steady State for the second Test Run in each Test Phase is attained at the same BSU load used in the Primary Metrics Test for the IOPS Test Run.

6.4.4.8 The final reported SPC-1C LRT™ metric is deemed reproducible and repeatable if the Average Response Time for each of the two SPC-1C LRT™ Repeatability Test Runs is less than the reported SPC-1C LRT™ metric plus 5%. As such, the LRT Repeatability Test will constrain the final reported SPC-1C LRT™ metric.

6.4.4.9 The final reported SPC-1C IOPS™ metric is deemed reproducible and repeatable if the I/O Request Throughput for each of the two SPC-1C IOPS™ Repeatability Test Runs is greater than the reported SPC-1C IOPS™ metric minus 5%. As such, the Repeatability Test will constrain the final reported SPC-1C IOPS™ metric.

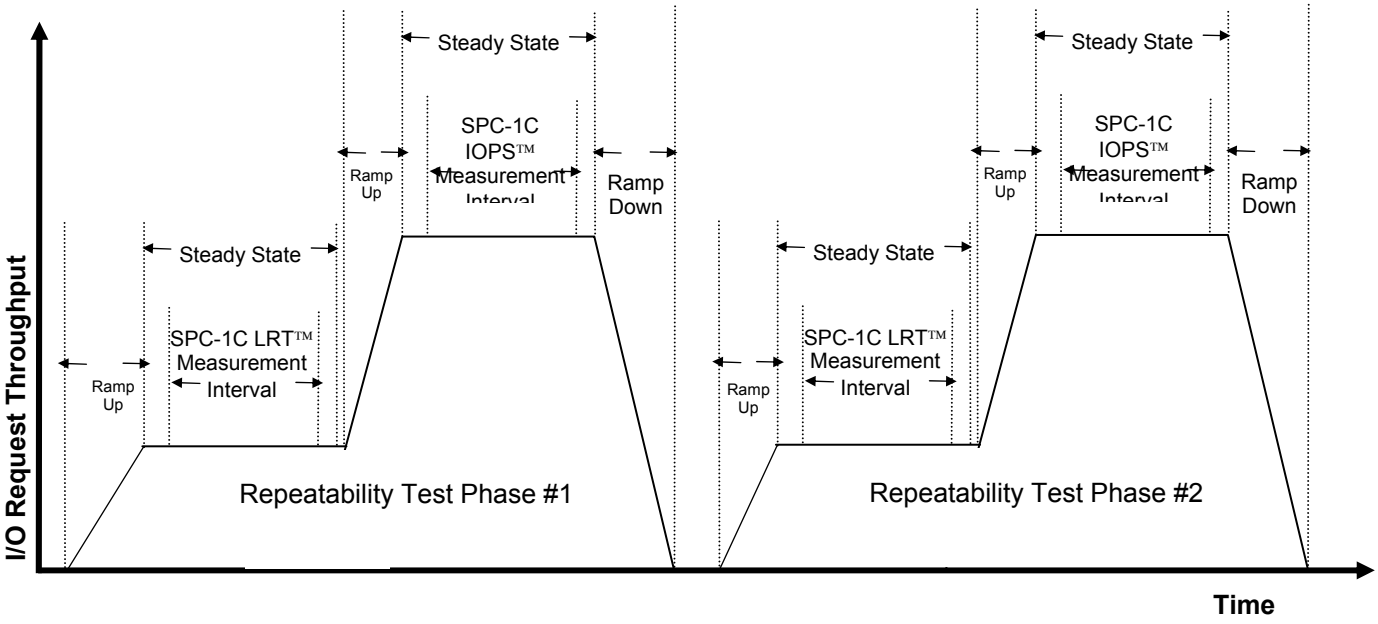
6.4.4.10 The Average Response Time, as defined in Clause 6.1.1, will be computed and reported for each of the two SPC-1C IOPS™ Test Runs and cannot exceed 30 milliseconds. If the Average Response Time exceeds that 30-millisecond constraint, the measurement is invalid.

6.4.4.11 The Test Sponsor shall do nothing to impact the performance of the Benchmark Configuration between Test Runs of the Repeatability Test.

6.4.4.12 All Repeatability Test data used to compute Repeatability Test results shall be obtained from SPC-1C Workload Generator Results Files.

6.4.4.13 Figure 6-7 illustrates the sequence of events and components of the Repeatability Test.

Figure 6-7: Repeatability Test



Clause 7: Data Persistence Requirements and Test

7.1 Introduction

Logical Volumes and the related Application Storage Unit (ASU) must demonstrate the ability to preserve data across extended periods of power loss without corruption or loss. To provide this "Persistence" capability, the Tested Storage Configuration (TSC) must use Logical Volumes and related 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-1C Persistence Test completed successfully is provided by the SPC Audit Service, attesting to the fact that the test has been satisfactorily completed on the BC per the test requirements below.

7.3 SPC-1C Persistence Test Requirements

7.3.1 The SPC-1C Persistence Test consists of two Test Runs that are performed by the SPC-1C Workload Generator in isolation from other SPC-1C Tests.

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

7.3.3 The physical and logical configuration of the BC shall not be changed between the successful execution of the Persistence Test and any other SPC-1C Test.

7.3.4 No other work shall be performed on the BC between the successful execution of the Persistence Test and the execution of other SPC-1C Tests, Test Phases, or Test Runs.

7.3.5 Success or failure of the Persistence Test shall be determined solely by information obtained from an SPC-1C Workload Generator Results File.

7.3.6 All I/O Requests initiated during any part of the Persistence Test in the SPC-1C 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.

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

7.5 Data Persistence Test Substitution

The Test Sponsor may request that the SPC-2 Persistence Test substituted for the SPC-1C Persistence Test. In most cases, such requests will be due to the limited capacity of the current SPC-1 Workload Generator to test very large storage configuration.

If the auditor grants a request to use the SPC-2 Persistence Test, the Test Sponsor will be given the appropriate details and requirements to ensure the SPC-2 Persistence Test provides the appropriate test coverage for the Tested Storage Configuration.

Clause 8: Reported Data

8.1 SPC-1C Reported Data

SPC-1C Reported Data consists of two groups of information:

- SPC-1C Primary Metrics.
- Associated data, which in conjunction with the SPC-1C Primary Metrics, characterizes the SPC-1C Result.

8.2 SPC-1C Primary Metrics

The SPC-1C Primary Metrics consist of an I/O Request Throughput and storage capacity metric. The details of each SPC-1C Primary Metric are listed below.

8.2.1 SPC-1C IOPS™ *(I/O request throughput)*

8.2.1.1 The SPC-1C-IOPS™ primary metric is defined as the I/O Request Throughput *(Clause 6.1.7)* measured in the IOPS Test Run *(Clause 6.4.3.3)*.

8.2.1.2 All public references to this data rate metric must be labeled as "SPC-1C IOPS™".

8.2.2 Total ASU (Application Storage Unit) Capacity *(storage capacity)*

8.2.2.1 Total ASU Capacity is defined in Clause 2.6.8.

8.2.2.2 All public references to the ASU Total Capacity primary metric must be labeled as "Capacity of xxx GB" or "xxx GB".

8.3 SPC-1C Associated Data

SPC-1C Associated Data consists of the following

- Data Protection Level used in the benchmark measurement *(Clause 2.7)*
- Total price of the Tested Storage Configuration (TSC) *(Clause 9.1.6)*
- SPC-1C Submission Identifier *(Clause 11.4.3)*

8.4 SPC-1C Reported Data – Public Use Requirements

Section 11.2.1 of the SPC Policies and Guidelines defines the requirements for public use of SPC Results. The following clauses present public use requirements in the context of SPC-1C Results. 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.

8.4.1 Referencing Non-Local Currency Reported Data

A public reference, which includes SPC-1C Total Price, for an SPC-1C Result that uses non-local currency pricing *(Clause 9.2.4.2)* must include a clear statement of the currency used and the "target country" *(Clause 9.2.3)*. For example, "SPC-1C Pricing is in U.S. dollars for product availability, sales, and support in People's Republic of China".

8.4.2 Referencing a Single SPC-1C Result

8.4.2.1 A public reference to an SPC-1C Result is required include one of the following:

1. A complete URL (hyperlink) to the SPC-1C Result's entry on the "SPC-1C Results" page of the SPC website.
2. The complete set of SPC-1C Reported Data, which consists of SPC-1C IOPS, Total ASU Capacity, total price of the Priced Storage Configuration, formal currency name used in pricing, "target country", data protection level, and SPC-1C Submission Identifier. This set of information must use the same font style, font size, and text clarity for 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.

8.4.2.2 Any of the SPC-1C Reported Data may be used in a public reference without stating the complete set of SPC-1C Reported Data as long as the following requirements are met:

1. The URL defined in Clause 8.4.1.1 is included in the public reference.
2. The public reference includes the "current as of" date.

8.4.3 Referencing Two or More SPC-1C Results

If a public reference of two or more SPC-1C Results does not include any comparison of SPC-1C Reported Data from the results, the requirement in Clauses 8.4.1 and 8.4.2 are applicable.

8.4.4 Comparing Two or More SPC-1C Results

Any one of the SPC-1C Reported Data items (Primary Metrics or Associated Data) may be used in public reference to compare two or more SPC-1C Results under the following conditions:

1. In addition to the SPC-1C Reported Data used in the comparison, each referenced SPC-1C Result must include either the complete set of SPC-1C Reported Data or the URL defined in Clause 8.4.1.1.
2. If the complete set of SPC-1C Reported Data is included for one of the referenced SPC-1C Results, the complete set of reported data must be included for all of the referenced results.
3. The public reference must include the "current as of" date.
4. If the public reference consists of printed or displayed materials, the required items in #1, #2 and #3 for each SPC-1C Result must use the same font style, font size, and text clarity.
5. The pricing currency and "target country" must both be identical when a comparison includes the SPC-1C Total Price.

Clause 9: Pricing

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

9.1 Priced Components

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

9.1.1 Tested Storage Configuration (TSC)

The TSC represents the physical configuration that is physically present during the benchmark measurement as defined in Clause 4.4. The TSC must be comprised of individually customer orderable components or a complete customer orderable configuration. To allow the use of a valid measurement configuration that may not represent a customer orderable configuration, the customer orderable configuration documented in the Full Disclosure Report may differ, as described in Clause 9.1.2, from the TSC.

9.1.2 Priced Storage Configuration

The Priced Storage Configuration represents a customer orderable configuration or a collection of individually customer orderable components. If the TSC, without modification, is customer orderable, it is also the Priced Storage Configuration.

In some cases the TSC is a valid measurement configuration but is not identical to a customer orderable configuration or a complete set of customer orderable components. In those cases the Priced Storage Configuration will be comprised of the TSC with the appropriate components added or deleted to create a customer orderable configuration or a complete set of customer orderable components.

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

9.1.3 Host System

If the Host System is included as a TSC component based on Clause 4.4.2, the Host System is considered a part of the Priced Storage Configuration and must be priced.

9.1.4 Additional Operational Components

9.1.4.1 Additional products explicitly required for the operation and administration of the Priced Storage Configuration must be included.

9.1.4.2 Copies of the software used by the TSC, on appropriate media, and a software load device, if required for initial load, must be included.

9.1.4.3 The price of all cables used to connect components of the TSC must be included.

9.1.5 Hardware Maintenance/Software Support

Pricing for hardware maintenance/software support is not required, but may be included at the Test Sponsor's option.

9.1.5.1 Hardware maintenance and software support must be configured using standard pricing.

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

9.1.6 Calculation of Priced Storage Configuration Total System Price

Calculation of the Total System Price includes:

- The cost of the Priced Storage Configuration as defined in Clauses 9.1.2 and 9.1.3.
- The cost of additional products (software or hardware) required for customary operation and administration of the TSC as described in Clause 9.1.4.
- All applicable tariffs, duties, and import fees, when appropriate, if those costs are not included in the listed product prices.

Specifically excluded from the pricing calculation are components that are necessary for the execution of the benchmark but do not provide any storage functionality and do not enhance the measured performance of the Tested Storage Configuration. An example of such a component would be a server or host system where the Workload Generator executes.

9.2 Pricing Methodology

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

9.2.1 Packages and Discounts

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

9.2.1.1 Generally available discounts for the priced configuration are allowed.

9.2.1.2 Generally available packaged pricing is allowed.

9.2.1.3 Assumptions of other purchases, other sites with similar systems, or any other assumption that relies on the principle that the customer has made any other purchase from the vendor are specifically prohibited.

9.2.1.4 For all hardware components used in the priced system, the cost must be the price of a new component (i.e., not reconditioned or previously owned).

9.2.1.5 For a Test Sponsor who only has indirect sales channels, pricing must be actual generally available pricing from indirect channels that meet all other requirements of Clause 9.

9.2.2 Product Availability

9.2.2.1 The Priced Storage Configuration is the actual configuration the customer would purchase. However, vendors may announce new products and disclose benchmark results before new products have actually shipped. This is allowed, but any use of benchmark-special implementations is specifically disallowed (see Clause 0.2).

9.2.2.2 Clause 0.2 requirements must be fulfilled with respect to the set of possible customers in the specified "target country" (Clause 9.2.3).

9.2.2.3 All hardware and software used in the calculations must be announced and generally orderable by customers.

9.2.2.4 Each product or collection of products that comprise the priced configuration must have an Availability Date, which is a date such that it is committed that by that date all requirements of Clause 0.2 will be fulfilled for that product or collection, including delivery for general availability.

9.2.2.5 The Priced Storage Configuration Availability Date (Clause 9.2.2.4) must not exceed three months beyond the SPC-1C Full Disclosure Report submittal date.

> ***Comment:*** *The essence of the Priced Storage Configuration Availability Date is the ability to take physical delivery of an integrated configuration that is identical to the Priced Storage Configuration, achieves the reported SPC-1C performance, and demonstrates fulfillment of all the requirements of Clause 0.2.*

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

9.2.3 "Target Country" Requirements

9.2.3.1 The "target country" is the country in which the Priced Storage Configuration is available for sale no later than the Priced Storage Configuration Availability Date *(Clause* 9.2.2.4*)*

9.2.3.2 Priced Storage Configuration pricing, as well as any included discounts, must be available to all customers in the "target country".

9.2.4 Pricing Currency

9.2.4.1 Local Currency

SPC-1C pricing may be in the currency of the "target country" where the SPC-1C Priced Storage Configuration product availability and sales requirements would be met *(Clause* 9.2.2.4*)*.

9.2.4.2 Non-Local Currency

SPC-1 pricing may be in a currency other that the currency of the "target country" if all of the following requirements are met.

9.2.4.2.1 The "target country" requirements *(Clause 9.2.3)* must be met.

9.2.4.2.2 The Test Sponsor must disclose the country that is the source of the non-local currency used in the SPC-1 pricing.

9.2.4.2.3 Public statement requirements that include SPC-1C Total Price are listed in Clause 8.4.4.

9.2.5 Third-Party Pricing

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

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

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

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

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

9.3 Required Reporting

9.3.1 Pricing Spreadsheet

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

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

9.3.1.3 The pricing spreadsheet must be included in the Full Disclosure Report *(Clause 10)* and must include the following items for each component in the Priced TSC:

- Part name or brief description
- Part number
- Source of the component, whether from a Test Sponsor or a third party (note: this can be a index into a list of component sources provided that list is included in the pricing spreadsheet)
- Reference price of the component *(Clause 9.3.1.2)*
- Quantity of the component used in the priced configuration
- The extended price of the component, based on the reference price of the component, the quantity included in the priced configuration and any component-level discounting

- If the component is a bundle/package of parts, as allowed by Clause 9.2.1, the above items apply to the bundle but each item in the bundle/package must be clearly identified in the description of bundle/package.
- Components required to configure the Priced Storage Configuration that have an aggregate price less than 0.1% of the Priced Storage Configuration may be listed as a single line item with a description of the collection of components, e.g., "Miscellaneous Cables."

9.3.1.4 The total price of the Priced Storage Configuration, must be included in the pricing spreadsheet. The total price must be stated in the minimum level of negotiable detail for the pricing currency, e.g. U.S. dollars and cents.

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

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

9.3.1.6 While package pricing is allowed, the level of discount obtained through such packages shall be disclosed by reporting the individual reference price for each component in the pricing spreadsheet (see Clause 9.3.1.2).

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

Clause 10: Full Disclosure Report (FDR)

10.1 Required Graphs and Data Tables

10.1.1 Response Time Frequency Distributions

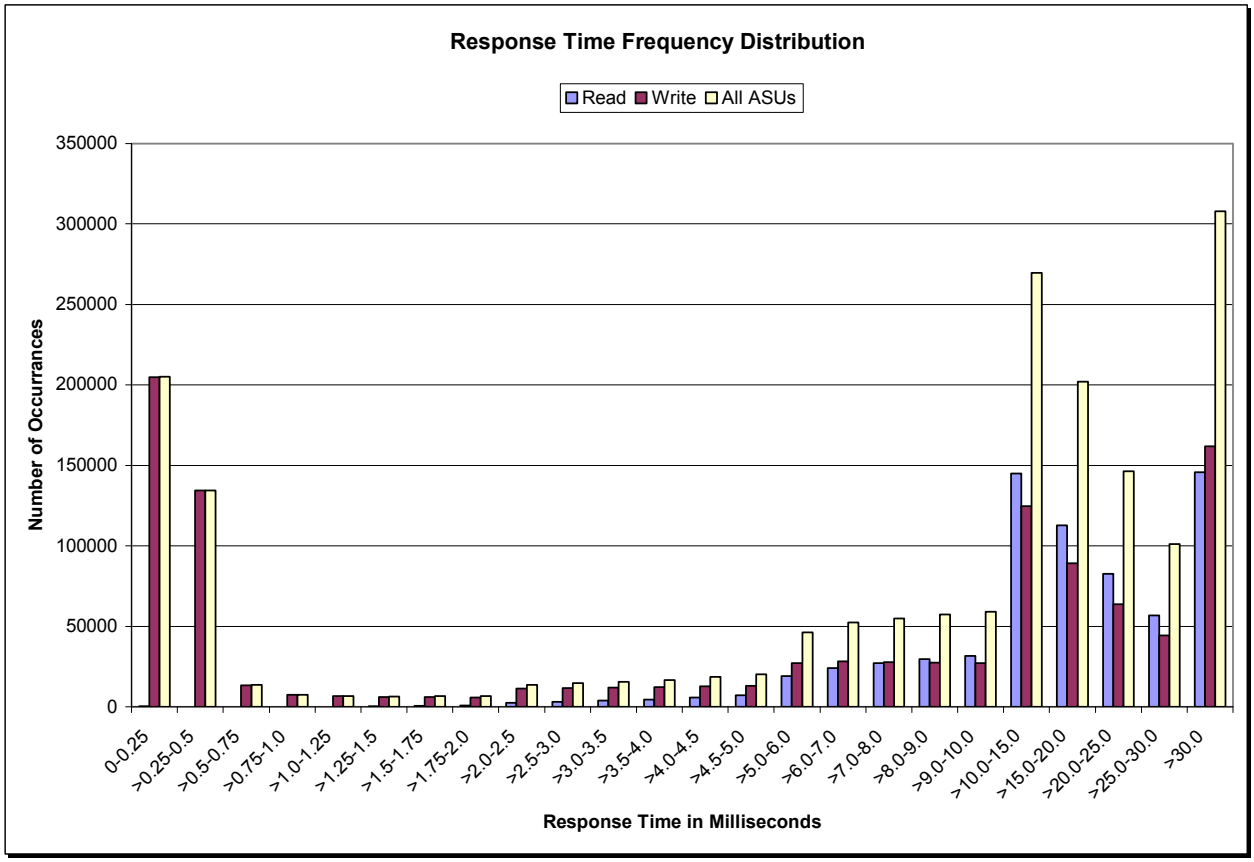
This consists of one graph and supporting table that clearly illustrates the frequency distribution of response times that occurred during an SPC-1C Test Run. The graph *(Figure 10-1)* illustrates the number of occurrences for each Response Time range.

Each Response Time Frequency Distribution graph and table shall have the format, content, and appearance illustrated in Figure 10-1 and Table 10-1. Data used to compute or construct the Response Time Frequency Distribution graph and table shall be obtained from SPC-1C Workload Generator Results Files.

Table 10-1: Response Time Frequency Distribution

Response Time (ms)	0-0.25	>0.25-0.5	>0.5-0.75	>0.75-1.0	>1.0-1.25	>1.25-1.5	>1.5-1.75	>1.75-2.0
Read	245	20	19	39	119	261	632	925
Write	204,919	134,415	13,430	7,440	6,516	6,217	6,105	5,821
All ASUs	205,164	134,435	13,449	7,479	6,635	6,478	6,737	6,746
ASU1	113,623	53,771	5,451	3,517	3,200	3,184	3,504	3,685
ASU2	23,186	11,576	1,182	686	643	630	667	625
ASU3	68,355	69,088	6,816	3,276	2,792	2,664	2,566	2,436
Response Time (ms)	**>2.0-2.5**	**>2.5-3.0**	**>3.0-3.5**	**>3.5-4.0**	**>4.0-4.5**	**>4.5-5.0**	**>5.0-6.0**	**>6.0-7.0**
Read	2,368	3,055	3,755	4,533	5,721	7,330	19,017	24,078
Write	11,341	11,537	11,880	12,192	12,788	13,009	27,164	28,329
All ASUs	13,709	14,592	15,635	16,725	18,509	20,339	46,181	52,407
ASU1	7,769	8,562	9,242	10,071	11,374	13,063	30,594	34,511
ASU2	1,126	1,158	1,209	1,276	1,410	1,428	3,695	5,396
ASU3	4,814	4,872	5,184	5,378	5,725	5,848	11,892	12,500
Response Time (ms)	**>7.0-8.0**	**>8.0-9.0**	**>9.0-10.0**	**>10.0-15.0**	**>15.0-20.0**	**>20.0-25.0**	**>25.0-30.0**	**>30.0**
Read	27,149	29,772	31,697	144,864	112,699	82,651	56,749	145,789
Write	27,669	27,522	27,207	124,653	89,253	63,651	44,286	161,954
All ASUs	54,818	57,294	58,904	269,517	201,952	146,302	101,035	307,743
ASU1	36,372	37,893	39,167	174,531	129,591	93,409	63,340	173,192
ASU2	6,481	7,070	7,509	35,861	29,114	21,387	14,672	41,959
ASU3	11,965	12,331	12,228	59,125	43,247	31,506	23,023	92,592

Figure 10-1: Response Time Frequency Distribution (by occurrence)



10.1.2 I/O Request Throughput Distribution

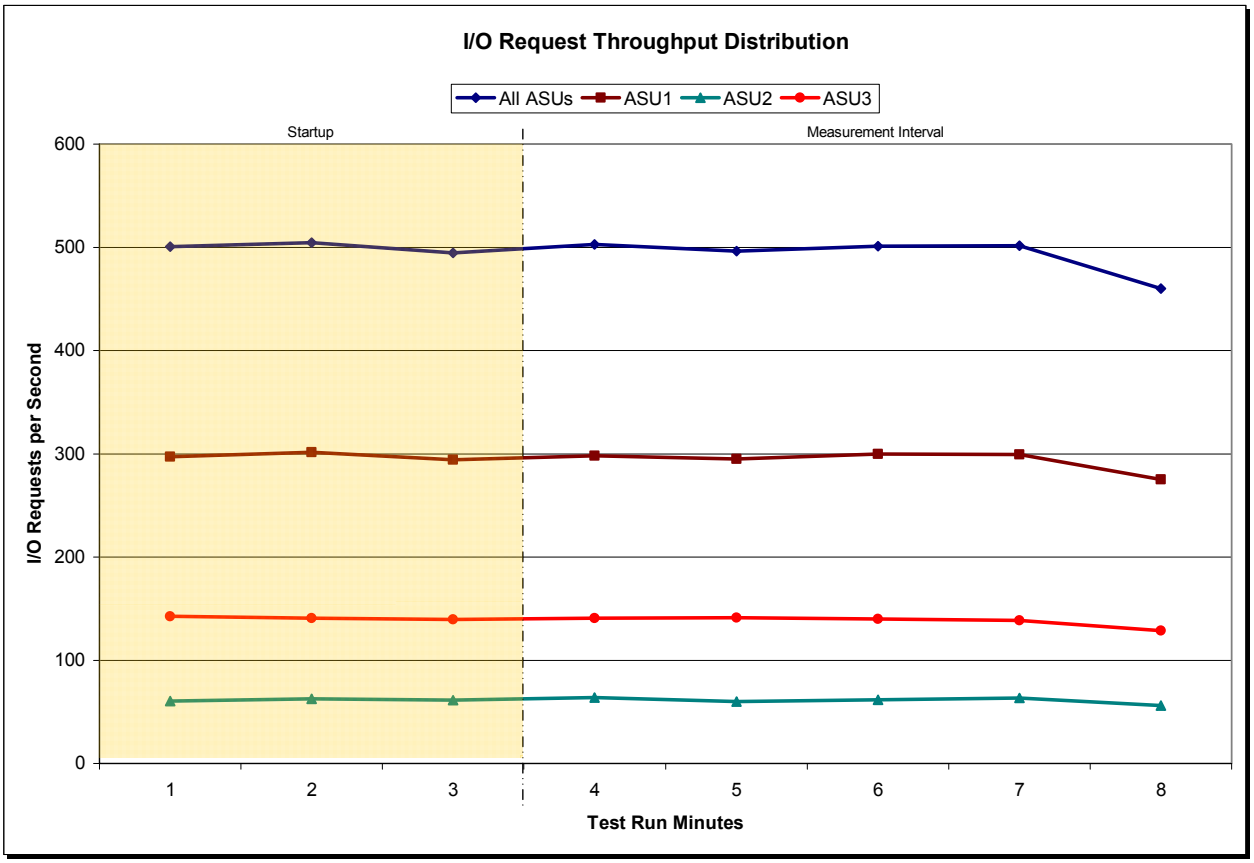
This consists of a graph and supporting table that clearly illustrates the I/O Request Throughput that occurred in each 60-second interval of an SPC-1C Test Run.

Each I/O Request Throughput Distribution graph and table shall have the format, content, and appearance illustrated in Figure 10-2 and Table 10-2, respectively. Every 60 second interval in a Test Run shall have its data presented in the graph and table. Data used to compute or construct the I/O Request Throughput Distribution graph and table shall be obtained from SPC-1C Workload Generator Results Files.

Table 10-2: I/O Request Throughput Distribution

100 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	1:59:27	2:02:27	0-2	0:03:00
Measurement Interval	2:02:27	2:07:27	3-7	0:05:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	500.48	297.35	60.67	142.47
1	504.73	301.37	62.65	140.72
2	494.63	294.00	61.27	139.37
3	502.98	298.10	63.85	141.03
4	496.43	295.07	60.02	141.35
5	501.20	299.65	61.75	139.80
6	501.60	299.27	63.62	138.72
7	460.05	275.05	56.20	128.80
Average	492.45	293.43	61.09	137.94

Figure 10-2: I/O Request Throughput Distribution



10.1.3 Average Response Time Distribution

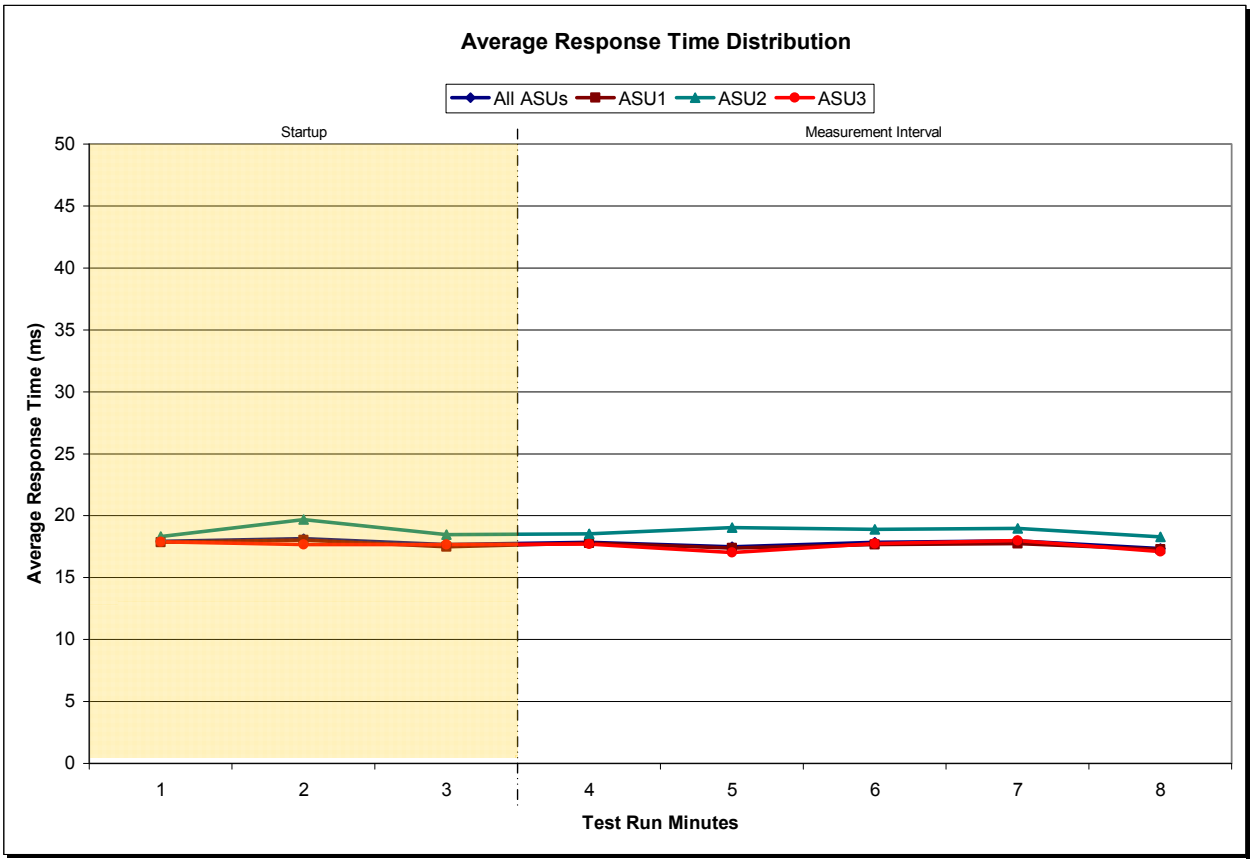
This consists of a graph and supporting table that clearly illustrates the Average Response Time Distribution that occurred in each 60-second interval of an SPC-1C Test Run.

Each Average Response Time Distribution graph and table shall have the format, content, and appearance illustrated in Figure 10-3 and Table 10-3, respectively. Every 60 second interval in a Test Run shall have its data presented in the graph and table. Data used to compute or construct the Average Response Time Distribution graph and table shall be obtained from Workload Generator Results Files.

Table 10-3: Average Response Time Distribution

100 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	1:59:27	2:02:27	0-2	0:03:00
Measurement Interval	2:02:27	2:07:27	3-7	0:05:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	17.92	17.86	18.32	17.88
1	18.13	18.03	19.69	17.66
2	17.68	17.51	18.48	17.67
3	17.86	17.79	18.54	17.70
4	17.49	17.40	19.05	17.04
5	17.84	17.67	18.90	17.74
6	17.97	17.74	18.98	18.00
7	17.35	17.27	18.30	17.08
Average	17.70	17.58	18.75	17.51

Figure 10-3: Average Response Time Distribution



10.1.4 Data Rate Distribution

This consists of a graph and supporting table that clearly illustrates the Data Rate Distribution that occurred in each 60-second interval of an SPC-1C Test Run.

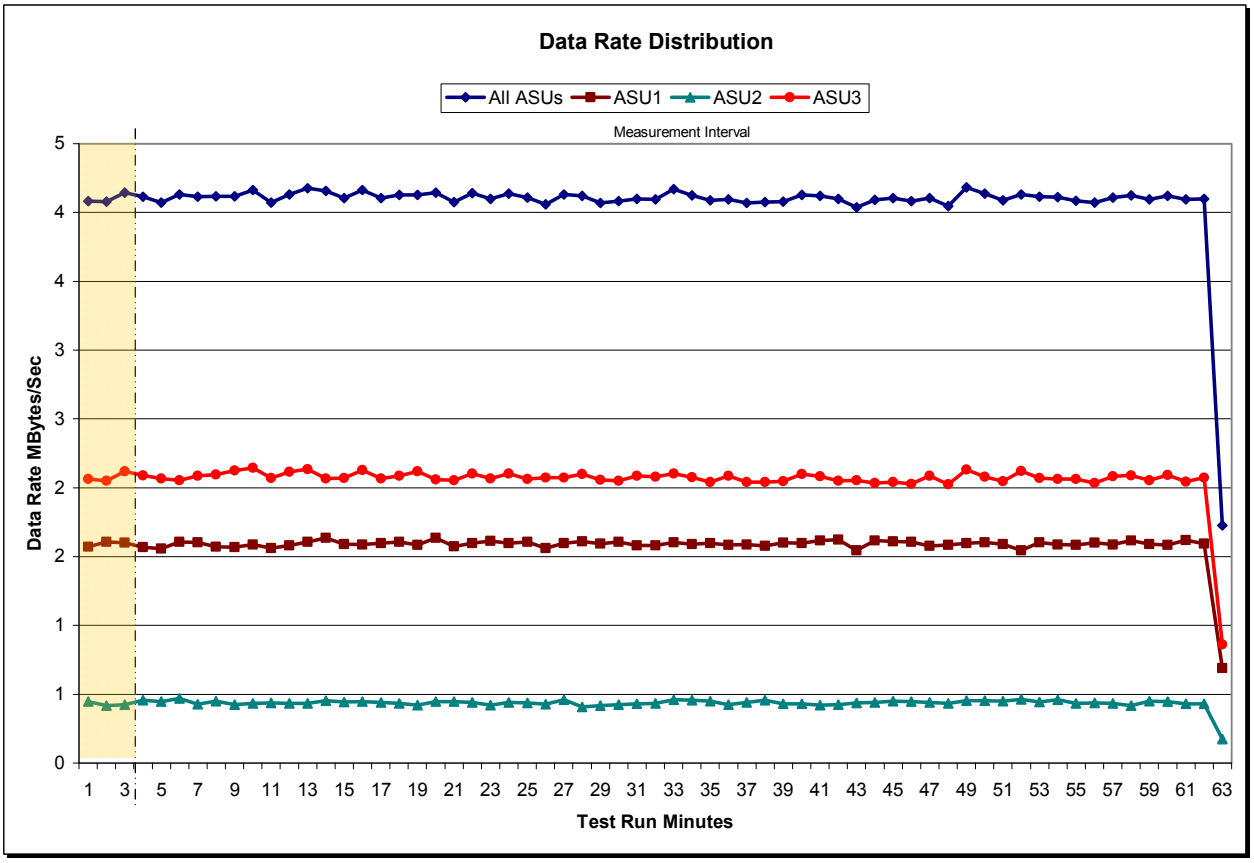
Each Data Rate Distribution graph and table shall have the format, content, and appearance illustrated in Figure 10-4 and Table 10-4, respectively. Every 60 second interval in a Test Run shall have its data presented in the table and graph Data used to compute or construct the Data Rate Distribution shall be obtained from SPC-1C Workload Generator Results Files.

Table 10-4: Data Rate Distribution

	Start	Stop	Interval	Duration
Ramp-Up/Start-Up	0:56:23	0:59:23	0-2	0:03:00
Measurement Interval	0:59:23	1:59:23	3-62	1:00:00

Interval	All ASUs	ASU1	ASU2	ASU3	Interval	All ASUs	ASU1	ASU2	ASU3
0	4.08	1.57	0.45	2.07	32	4.17	1.61	0.46	2.10
1	4.08	1.61	0.42	2.05	33	4.12	1.59	0.46	2.08
2	4.14	1.60	0.42	2.12	34	4.09	1.60	0.45	2.04
3	4.11	1.57	0.46	2.09	35	4.09	1.59	0.42	2.09
4	4.07	1.56	0.45	2.07	36	4.07	1.59	0.44	2.04
5	4.13	1.61	0.47	2.06	37	4.07	1.58	0.46	2.04
6	4.12	1.60	0.43	2.09	38	4.08	1.60	0.43	2.05
7	4.12	1.57	0.45	2.10	39	4.13	1.60	0.43	2.10
8	4.12	1.57	0.42	2.13	40	4.12	1.62	0.42	2.08
9	4.16	1.59	0.43	2.14	41	4.10	1.62	0.42	2.05
10	4.07	1.56	0.44	2.07	42	4.04	1.55	0.44	2.05
11	4.13	1.58	0.44	2.11	43	4.09	1.62	0.44	2.03
12	4.18	1.61	0.44	2.14	44	4.10	1.61	0.45	2.04
13	4.16	1.64	0.45	2.07	45	4.08	1.61	0.45	2.03
14	4.10	1.59	0.44	2.07	46	4.10	1.58	0.44	2.09
15	4.16	1.59	0.45	2.13	47	4.05	1.58	0.43	2.03
16	4.11	1.60	0.44	2.07	48	4.18	1.60	0.45	2.13
17	4.13	1.61	0.43	2.09	49	4.14	1.61	0.45	2.08
18	4.13	1.58	0.42	2.12	50	4.09	1.59	0.45	2.05
19	4.14	1.64	0.45	2.06	51	4.13	1.54	0.46	2.12
20	4.07	1.57	0.45	2.05	52	4.12	1.60	0.44	2.07
21	4.14	1.60	0.44	2.10	53	4.11	1.59	0.46	2.06
22	4.10	1.61	0.42	2.07	54	4.08	1.58	0.44	2.07
23	4.14	1.60	0.44	2.10	55	4.07	1.60	0.44	2.03
24	4.11	1.61	0.44	2.06	56	4.11	1.59	0.44	2.08
25	4.06	1.56	0.43	2.07	57	4.12	1.62	0.42	2.09
26	4.13	1.60	0.46	2.07	58	4.10	1.59	0.45	2.06
27	4.12	1.61	0.41	2.10	59	4.12	1.58	0.45	2.09
28	4.07	1.59	0.42	2.06	60	4.09	1.62	0.43	2.04
29	4.08	1.61	0.42	2.05	61	4.10	1.59	0.43	2.07
30	4.10	1.58	0.43	2.09	62	1.73	0.69	0.18	0.86
31	4.10	1.58	0.44	2.08					

Figure 10-4: Data Rate Distribution



10.1.5 Response Time Ramp Distribution

This consists of a graph and supporting table that clearly illustrates the I/O Request Throughput that occurred in each minute of the Measurement Intervals during the SPC-1C Response Time Ramp Test Phase.

Each Response Time Ramp Distribution graph and table shall have the format, content, and appearance illustrated in Figure 10-5 and Table 10-5, respectively. Data used to compute or construct the Response Time Ramp Distribution graph and table shall be obtained from SPC-1 Workload Generator Results Files.

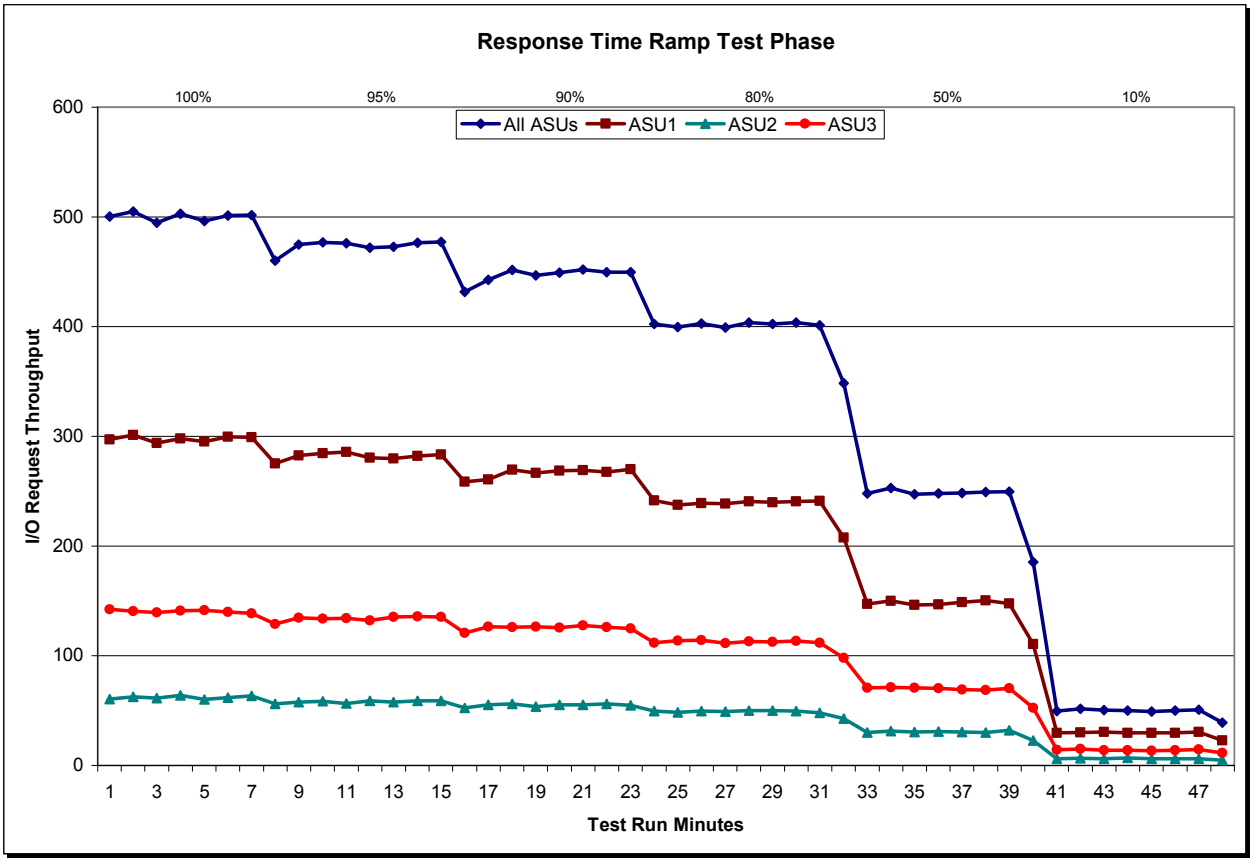
Table 10-5: Response Time Ramp Distribution

100% Load Level - 100 BSUs	Start	Stop	Interval	Duration	95% Load Level - 95 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	1:59:27	2:02:27	0-2	0:03:00	Start-Up/Ramp-Up	2:07:31	2:10:31	0-2	0:03:00
Measurement Interval	2:02:27	2:07:27	3-7	0:05:00	Measurement Interval	2:10:31	2:15:31	3-7	0:05:00
(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3	*(60 second intervals)*	All ASUs	ASU-1	ASU-2	ASU-3
0	500.48	297.35	60.67	142.47	0	474.82	282.48	57.90	134.43
1	504.73	301.37	62.65	140.72	1	476.97	284.75	58.47	133.75
2	494.63	294.00	61.27	139.37	2	476.20	285.62	56.38	134.20
3	502.98	298.10	63.85	141.03	3	471.83	280.65	59.05	132.13
4	496.43	295.07	60.02	141.35	4	472.90	279.85	57.75	135.30
5	501.20	299.65	61.75	139.80	5	476.55	282.07	58.78	135.70
6	501.60	299.27	63.62	138.72	6	477.30	283.32	58.77	135.22
7	460.05	275.05	56.20	128.80	7	431.85	258.68	52.60	120.57
Average	492.45	293.43	61.09	137.94	Average	466.09	276.91	57.39	131.78

90% Load Level - 90 BSUs	Start	Stop	Interval	Duration	80% Load Level - 80 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	2:15:35	2:18:35	0-2	0:03:00	Start-Up/Ramp-Up	2:23:39	2:26:39	0-2	0:03:00
Measurement Interval	2:18:35	2:23:35	3-7	0:05:00	Measurement Interval	2:26:39	2:31:39	3-7	0:05:00
(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3	*(60 second intervals)*	All ASUs	ASU-1	ASU-2	ASU-3
0	442.67	260.58	55.47	126.62	0	399.57	237.38	48.55	113.63
1	451.73	269.58	56.28	125.87	1	402.93	239.15	49.67	114.12
2	446.88	266.67	53.85	126.37	2	399.12	238.57	49.17	111.38
3	449.23	268.55	55.25	125.43	3	403.70	240.75	49.90	113.05
4	451.85	268.93	55.17	127.75	4	402.53	240.00	49.87	112.67
5	449.45	267.35	56.13	125.97	5	403.52	240.60	49.68	113.23
6	449.40	269.72	54.87	124.82	6	401.18	241.13	48.12	111.93
7	402.45	241.38	49.47	111.60	7	348.27	207.80	42.50	97.97
Average	440.48	263.19	54.18	123.11	Average	391.84	234.06	48.01	109.77

50% Load Level - 50 BSUs	Start	Stop	Interval	Duration	10% Load Level - 10 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	2:31:43	2:34:43	0-2	0:03:00	Start-Up/Ramp-Up	2:39:47	2:42:47	0-2	0:03:00
Measurement Interval	2:34:43	2:39:43	3-7	0:05:00	Measurement Interval	2:42:47	2:47:47	3-7	0:05:00
(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3	*(60 second intervals)*	All ASUs	ASU-1	ASU-2	ASU-3
0	247.97	147.18	30.15	70.63	0	49.62	29.58	5.93	14.10
1	252.65	150.05	31.47	71.13	1	51.72	30.03	6.57	15.12
2	247.18	146.30	30.35	70.53	2	50.50	30.38	6.18	13.93
3	248.05	146.70	30.83	70.52	3	49.98	29.60	6.73	13.65
4	248.18	148.65	30.55	68.98	4	49.27	29.70	6.13	13.43
5	249.20	150.47	29.92	68.82	5	49.90	29.62	6.27	14.02
6	249.72	147.65	31.93	70.13	6	50.88	30.45	5.98	14.45
7	185.43	110.43	22.72	52.28	7	39.03	22.85	4.75	11.43
Average	236.12	140.78	29.19	66.15	Average	47.81	28.44	5.97	13.40

Figure 10-5: Response Time Ramp Distribution



10.1.6 Response Time/Throughput

Graphs and a supporting table that clearly illustrate the relationship of Response Time to I/O Request Throughput during an SPC-1C Response Time Ramp Test Phase and IOPS Test shall be provided in the Full Disclosure Report.

The graphs shall have the format, content, and appearance illustrated in Figure 10-6, Figure 10-7, and Table 10-6, respectively. Data used to compute or construct the Response Time/Throughput graphs and table shall be obtained from SPC-1Workload Generator Results Files.

Table 10-6: Response Time/Throughput

	10% Load	50% Load	80% Load	90% Load	95% Load	100% Load
I/O Request Throughput	47.81	236.12	391.84	440.48	466.09	492.45
Average Response Time (ms):						
All ASUs	6.03	11.05	14.42	16.64	17.18	17.70
ASU-1	6.08	11.40	14.49	16.65	17.05	17.58
ASU-2	6.78	11.32	15.18	16.89	18.42	18.75
ASU-3	5.59	10.17	13.95	16.50	16.89	17.51
Reads	7.77	13.17	17.86	19.54	20.38	21.38
Writes	4.89	9.65	12.17	14.76	15.12	15.28

Figure 10-6: Response Time versus Load Level

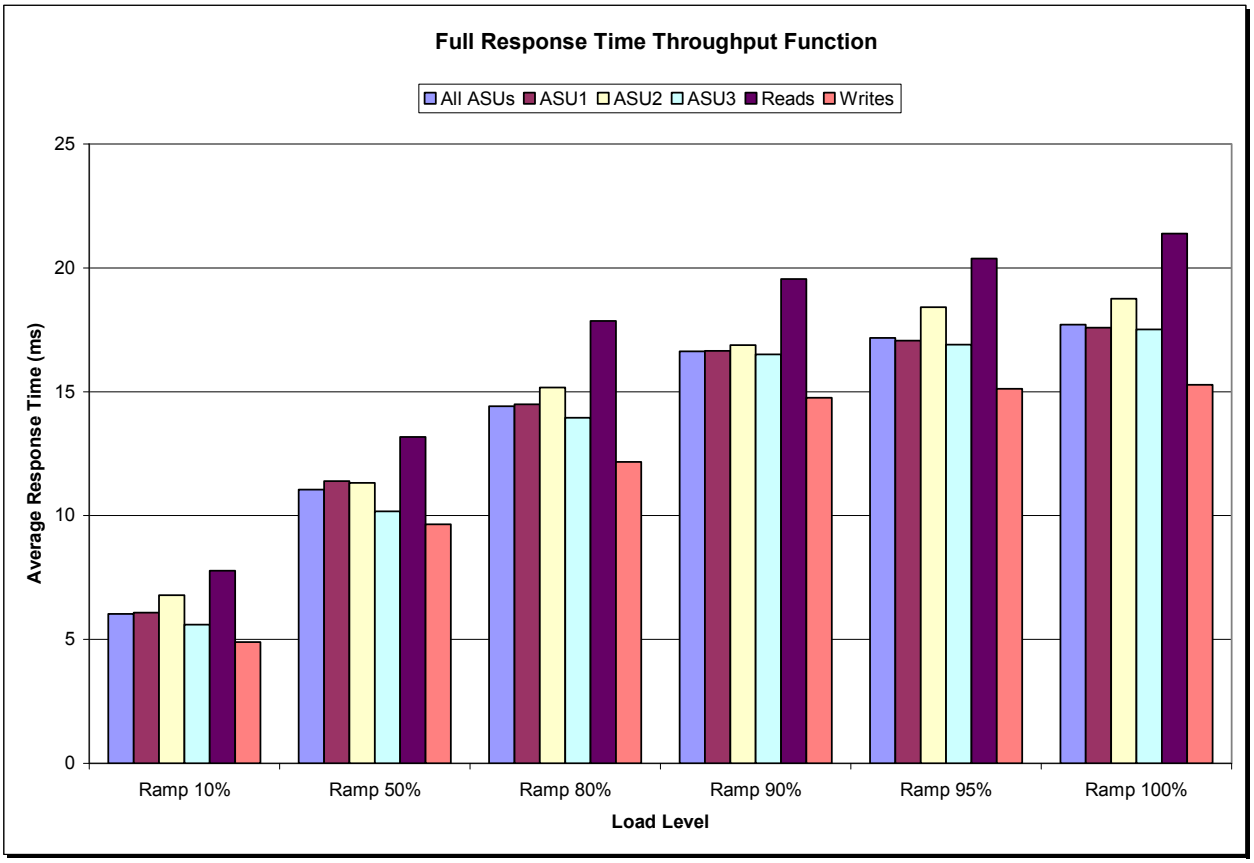
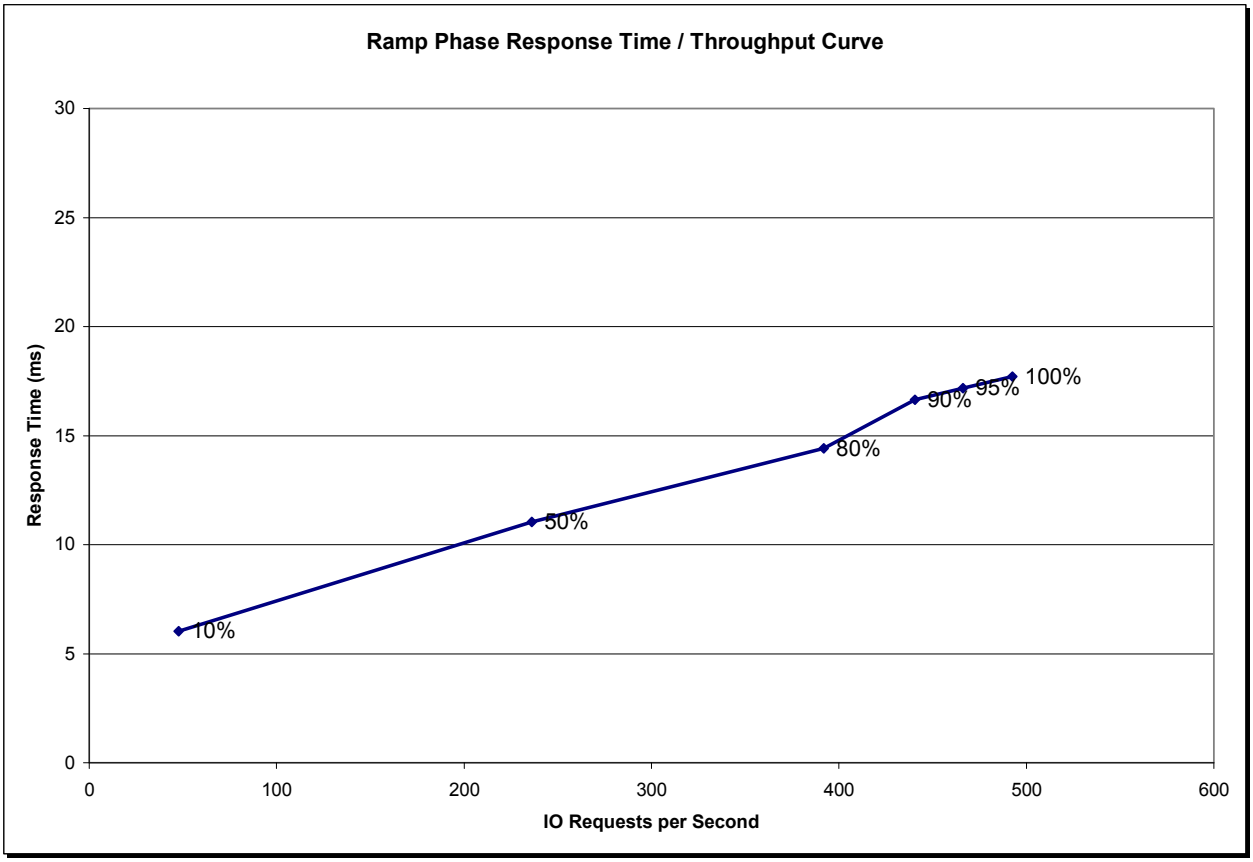


Figure 10-7: Response Time Throughput Curve



10.2 Full Disclosure Report Requirements

A Full Disclosure Report (FDR), submitted to the SPC Administrator, is required for each SPC-1C Result.

10.2.1 Electronic PDF Format

The FDR must be submitted electronically as an Adobe PDF file after successful completion of the required SPC-1C Audit and prior to any public use of the benchmark information *(Clause 11.4.1)*.

10.2.2 Document Format

The FDR will consist of the content described in Clause 10.4.

The FDR will be written in the English language. Each page of the FDR will be formatted with a minimum of one inch side and top margins, one-half inch bottom margins, and each page will be numbered.

Graphs, tables, and illustrations will use a minimum of 8-point sans serif font such as Arial. The text of the FDR will use a minimum of 10-point serif font such as Century Schoolbook.

10.3 Full Disclosure Report Availability

The Full Disclosure Report must be readily available to the public at a reasonable charge, similar to charges for similar documents by that Test Sponsor. The Test Sponsor must have on file with the SPC, submit with the FDR, or include as a part of the FDR, a release that allows public disclosure of the FDR content.

10.4 Full Disclosure Report Content

Clauses 10.4.1 – 10.4.10 describe the required content of the FDR. The FDR content will follow that same order as the above clauses and be organized under a hierarchy of headings that correspond to those clauses.

10.4.1 Title Page

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

- Title: "SPC-1C Benchmark Full Disclosure Report"
- The applicable SPC-1C Benchmark Specification version
- The Test Sponsor's name 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-1C Result and the start of the 60-day Peer Review.
- The SPC-1C Submission Identifier assigned to the SPC-1C benchmark result.

When a SPC-1C benchmark result successfully completes the required 60-day Peer Review *(Clause 11.5)*, the Title Page of its FDR may be updated with the following information:

- The "Accepted" notation and date that the SPC-1C benchmark result successfully completed its 60-day Peer review and transitioned from "Submitted for Review" to "Accepted".
- The "Certified SPC Result" logo.

10.4.2 Table of Contents

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

10.4.3 Audit Certification

This section of the FDR shall contain a copy of the certification letter issued by the SPC Audit Service to the Test Sponsor for this execution of the SPC-1C Benchmark. If the FDR is a revision to an existing FDR and contains changes to the original Priced Storage Configuration, the revised FDR shall contain an amended certification letter that includes auditor review and approval of those changes.

10.4.4 Letter of Good Faith

This section of the FDR shall contain a copy of the Letter of Good Faith issued by the Test Sponsor to the SPC Audit Service for this execution of the SPC-1C Benchmark. The Letter of Good Faith is required to be identical in format and content to the template in Appendix A on page 100 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 Auditor prior to the benchmark submission.

10.4.5 Executive Summary

The Executive Summary will consist of the content described in Clauses 10.4.5.1 – 10.4.5.12.

10.4.5.1 Contact Information

This table will contain contact information for the Test Sponsor and the SPC Auditor. The required content and format of the table is specified in Table 10-7.

Table 10-7: Test Sponsor and Auditor Contact Information

Test Sponsor and Contact Information	
Test Sponsor Primary Contact (1)	Company, Company Web Address, Individual Name – Email Address Postal Address Phone, FAX
Test Sponsor Alternate Contact (2)	Company, Company Web Address, Individual Name – Email Address Postal Address Phone, FAX
Auditor (4)	Company, Company Web Address, Individual Name – Email Address Postal Address Phone, FAX

Footnotes to Table 10-7*:*

1. *The Test Sponsor contact responsible for the submitted FDR. The primary Test Sponsor contact will be the first point of contact for any issues that may arise during the Peer Review Process.*
2. *The alternate Test Sponsor contact to be contacted only if the primary contact is not available.*
3. *Contact information for the SPC Auditor who certified the SPC-1C benchmark measurements and submission.*

10.4.5.2 Revision Information and Key Dates

This table will contain key dates and revision numbers associated with the SPC-1C result. The required content and format of the table is specified in Table 10-8.

Where appropriate in both the Executive Summary and Full Disclosure Report, the revised details will be highlighted. For example, revised pricing line items.

Table 10-8: Revision Information and Key Dates

Revision Information and Key Dates	
SPC-1C Specification revision number (1)	nn.nn.nn
SPC-1C Workload Generator revision number (2)	nn.nn.nn
Date Results were first used publicly (3)	mmmm dd, yyyy
Date FDR was submitted to the SPC (4)	mmmm dd, yyyy
Date revised FDR was submitted to the SPC (5) Current revision text: **Revision History:** dd/mm/yyyy – revision text dd/mm/yyyy – revision text	mmmm dd, yyyy
SPC-1C Availability Date(6)	mmmm dd, yyyy
Date of completed audit certification (7)	mmmm dd, yyyy

Footnotes to Table 10-8*:*

1. *The revision number of the SPC-1C Specification used to produce the results reported in this FDR.*
2. *The revision number of the SPC-1C Workload Generator used to produce the results reported in this FDR.*
3. *The calendar date that the results reported in this FDR were made public (i.e., used outside the Test Sponsors and Co-Sponsors companies).*
4. *The calendar date that the results reported in this FDR were submitted to the SPC.*
5. *The calendar date that a revised FDR was submitted to the SPC. The Revision History is a brief description of each revision.*
6. *The Priced Storage Configuration Availability Date defined in Clause 9.2.2.4.*
7. *The calendar date that the SPC-1C Audit was successfully completed as documented by the Audit Certification Letter issued to the Test Sponsor.*

10.4.5.3 Tested Storage Product (TSP) Description

The Executive Summary shall contain a brief description of the Tested Storage Product (TSP). Features used in the benchmark by the TSP may be included in the description. For example, if the TSP is a software product that provides virtualization functionality used in the benchmark but does not include Storage Devices; the description should contain that information. Features available in the TSP, but not used in the benchmark cannot be included in the description.

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

10.4.5.4 Summary of Results

The executive summary shall contain a table of key results reported by the Test Sponsor. The content, appearance, and format of this table is specified in Table 10-9.

Table 10-9: Summary of Results

SPC-1C Reported Data	
Tested Storage Product: AAAAAAAAAAAAAAAA (1)	
Title	**Value**
SPC-1C Submission Identifier (2)	Cnnnnn
SPC-1C IOPS™ (3)	NNNNNN
Total ASU Capacity (4)	XX,XXX GB
Data Protection Level (5)	Protected 1/Protected 2/Unprotected
Price (6)	$XXX,YYY,ZZZ
Pricing Currency (7)	formal currency name
"Target Country" for availability and sales (8)	"target country" name

Footnotes to Table 10-9*:*

1. *The formal name of the Tested Storage Product as defined in Clause 4.5.*
2. *The assigned SPC-1C Submission Identifier*
3. *Computed per Clause 6.1.7.*
4. *Computed per Clauses 2.6.7, and 2.6.8 (Total ASU Capacity).*
   Must be stated in gigabytes (GB) as a truncated integer or a truncated value with three significant digits, using the method that produces the more precise value.
5. *The Data Protection Level that was selected per Clause 2.7.2. If a* ***Protected*** *level is specified, a brief description of the data protection mechanism must be included.*
6. *Computed per Clause 9.1.6*
7. *If non-local currency (Clause 9.2.4.2) was used, the name of the "target country".*

10.4.5.5 Storage Capacities and Relationship Diagram

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

10.4.5.6 Pricing

The Executive Summary shall contain a pricing spreadsheet as documented in Clause 9.3.1.

10.4.5.7 Discounts

The Executive Summary shall describe the basis, including type and justification, of any discounts *(Clause 9.2.1)* included in the pricing spreadsheet.

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

The Executive Summary will contain a list of all differences between the Tested Storage Configuration (TSC) and Priced Storage Configuration. See Clauses 9.1.1 and 9.1.2 for definitions of TSC and Priced Storage Configuration.

10.4.5.9 Priced Storage Configuration Component Changes

10.4.5.9.1 New SPC-1C Result based on an existing SPC-1C Result *(Clause 11.7)*

The Executive Summary must list all hardware and/or software component differences if the Priced Storage Configuration of the new SPC-1C Result is not identical to the Priced Storage Configuration of the existing SPC-1C Result upon which it is based. The list shall contain the name of the original component, the new component, and a brief description of the difference(s) between the two components.

10.4.5.9.2 Revised SPC-1C Result *(Clause 11.8)*

The Executive Summary of a revised SPC-1C Result that contains changes to the Priced Storage Configuration is required to list of all Priced Storage Configuration component changes between the original and revised results. The list shall contain the name of the original component, the new component, and a brief description of the difference(s) between the two components.

10.4.5.10 Response Time/Throughput Curve

The Executive Summary shall contain a Response Time/Throughput curve *(Figure 10-7)* as well as a table *(Table 10-6)* containing the data used to generate the Response Time/Throughput curve.

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

The Executive Summary will contain a one page BC/TSC diagram that illustrates all major components of the BC/TSC. Examples of the major components that must be included in the diagram include:

1. All Host Systems and Management Appliances in the BC. Each Host System and Management Appliance contained in the diagram will include the following information:
    - CPU information that includes number of CPUs, model of each CPU, clock speed of each CPU, and cache configuration for each CPU.
    - The amount of main memory configured.
    - The operating system and version.
    - The type of system I/O interconnect.

- The type of physical connections between adapters that are connected to the system I/O interconnect and any storage controllers, domain controllers, or storage devices.

2. All storage controllers and domain controllers in the TSC. Each storage controller and domain controller contained in the diagram will include the following information:
   - The model and/or name.
   - The amount of memory and cache.
   - The number of front-end physical connections and the type of each front-end connection.
   - The number of back-end physical connections and the type of each back-end connection.
   - The type of physical connections between adapters that are connected to the system I/O interconnect and the storage controller or domain controller.
3. The number of storage devices and their individual formatted storage capacities.

Comment: *Configurations vary widely and it is impossible to provide exact guidelines suitable for all configurations. The intent of this clause is to describe the system components and connections in sufficient detail to allow independent reconstruction of the BC environment.*

An example of the required diagram is illustrated in Figure 10-8.

Figure 10-8: Benchmark Configuration/Tested Storage Configuration Diagram

10.4.5.12 Host System and Tested Storage Configuration (TSC) T

The Executive Summary will contain a table that lists the major components of each Host System and the Tested Storage Configuration (TSC). Table 10-10 specifies the content, format, and appearance of the table.

Table 10-10: Host System(s) and Tested Storage Configuration

Host System:	Tested Storage Configuration (TSC):
Host System name/model *(1)*	Host Bus Adapter (HBA) information *(7)*
CPU information *(2)*	TSP product name *(8)*
Main Memory configuration *(3)*	Storage/Domain Controller information *(9)*
Operating system name and version *(4)*	Front-end interconnection information *(10)*
TSC System Software *(5)*	Back-end interconnection information *(11)*
	Storage device information *(12)*
	All other major TSC components *(13)* *(e.g. switches, enclosures, etc.)*

Footnotes to Table 10-10:

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 and cache configuration/capacity.*
3. *The amount of main memory configured in each Host System.*
4. *The operating system, version, and any specific patches/updates installed on each Host System.*
5. *Any System Software, other than the operating system, installed on the Host System that provided TSC functionality such as a volume manager.*
6. *The number, product/model name and description of all Host Bus Adapters installed on each Host System.*
7. *The Tested Storage Product name and model.*
8. *The model/name and description of each storage/domain controller in the TSC. The description will include:*
    - *The amount of memory and cache.*
    - *The type and total number of front-end physical connections.*
    - *The type and total number of back-end physical connections.*
    - *The type of physical connection between the Host System and storage/domain controller*
    - *The number of configured Storage Devices (12) accessible by the storage/domain controller.*
9. *The number of physical front-end connections used in the benchmark.*
10. *The number of physical back-end physical connections used in the benchmark and the number of Storage Devices accessible by each connection.*
11. *The number of Storage Devices in the TSC and a description of each type of Storage Device. The description will include:*
    - *The type of device (disk drive, solid state device, etc.).*
    - *The formatted capacity of each Storage Device type.*
    - *The rotation speed, if appropriate, of each Storage Device type.*
    - *The amount of cache in each Storage Device type.*
12. *All other major TSC components such as switches, enclosures, etc.*

Note: The above clause concludes the Executive Summary portion of the Full Disclosure Report.

10.4.6 Benchmark Configuration – Tested Storage Configuration

The intent of Clauses 10.4.6.1 – 10.4.6.3 is to require disclosure of the detailed information necessary to recreate the Benchmark Configuration, including the Tested Storage Configuration, so that the SPC-1C benchmark results submitted by the Test Sponsor may be independently reproduced.

10.4.6.1 Customer Tuning Parameters and Options

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

Examples of customer tunable parameters and options include:

- Host Bus Adapter Options.
- Storage controller and domain 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.

10.4.6.2 Tested Storage Configuration Creation and Configuration

The Full Disclosure Report must include sufficient information to recreate the logical representation of the Tested Storage Configuration (TSC). In addition to customer tunable parameters and options *(Clause 10.4.6.1)*, that information must include, at a minimum:

- A diagram and/or description of the following:
  - All physical components that comprise the TSC. Those components are also illustrated in the BC Configuration Diagram in Clause 10.4.5.11.
  - The logical representation of the TSC, configured from the above components that will be presented to the SPC-1C 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.

10.4.6.3 SPC-1C Workload Generator Storage Configuration

The Full Disclosure Report will include all SPC-1C Workload Generator storage configuration commands and parameters used in the SPC-1C benchmark measurements.

10.4.7 Data Repository

The intent of Clauses 10.4.7.1 – 10.4.7.1 is to require disclosure of the detailed information that fully describes and accounts for the various storage capacities and mappings used in Tested Storage Configuration.

10.4.7.1 SPC-1C Storage Capacities and Relationships

Two tables and an illustration documenting the storage capacities and relationships of the SPC-1C Storage Hierarchy *(Clause 2.1)* will be included in the FDR. The content, appearance, and format of the tables are specified in Table 10-11 and Table 10-12. The content, appearance, and format of the illustration are specified in Figure 10-9.

In addition, an annotation must be included with the table illustrated in Table 10-11 that documents the source of the value presented for Physical Storage Capacity. The source will be either formatted capacity or capacity reported as available for application use. If multiple Storage Device models are included in the Tested Storage Configuration, the annotation must detail the appropriate source for each model.

The annotation must also include the following text:

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

Table 10-11: SPC-1C Storage Capacities

SPC-1C Storage Capacities		
Storage Hierarchy Component	**Units**	**Capacity**
Total ASU Capacity (1)	GB	nnn,nnn.nn
Addressable Storage Capacity (2)	GB	n,nnn,nnn.nn
Configured Storage Capacity (3)	GB	n,nnn,nnn.nn
Physical Storage Capacity (4)	GB	n,nnn,nnn.nn
Data Protection (5)	GB	nnn,nnn.nn
Required Storage (6)	GB	nn.nn
Global Storage Overhead (7)	GB	nn.nn
Total Unused Storage (8)	GB	nn.nn

Footnotes to Table 10-11.

1. *Defined in Clause 2.6*
2. *Defined in Clause 2.4*
3. *Defined in Clause 2.3*
4. *Defined in Clause 2.2*
5. *Defined in Clause 2.7*
6. *Defined in Clause 2.3.3*
7. *Defined in Clause 2.2.3*
8. *Sum of capacities defined in Clauses 2.2.4, 2.3.2, and 2.4.3.*

Capacities must be stated in gigabytes (GB) as a value with a minimum of two digits to the right of the decimal point.

Table 10-12: SPC-1C Storage Hierarchy Ratios

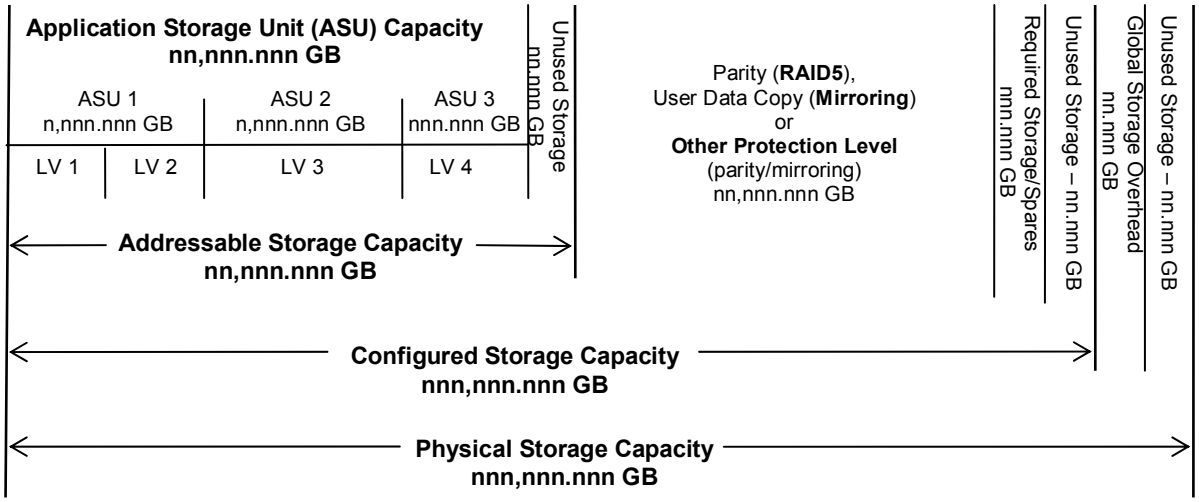
	Addressable Storage Capacity	Configured Storage Capacity	Physical Storage Capacity
Total ASU Capacity	(1)	(2)	(3)
Data Protection		(4)	(5)
Addressable Storage Capacity		(6)	(7)
Required Storage/Spares		(8)	(9)
Configured Storage Capacity			(10)
Global Storage Overhead			(11)
Unused Storage	(12)	(13)	(14)

Footnotes to Table 10-12.

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

1. *Total ASU Capacity ÷ Addressable Storage Capacity*
2. *Total ASU Capacity ÷ Configured Storage Capacity*
3. *Total ASU Capacity ÷ Physical Storage Capacity*
4. *Data Protection ÷ Configured Storage Capacity*
5. *Data Protection ÷ Physical Storage Capacity*
6. *Addressable Storage Capacity ÷ Configured Storage Capacity*
7. *Addressable Storage Capacity ÷ Physical Storage Capacity*
8. *Required Storage ÷ Configured Storage Capacity*
9. *Required Storage ÷ Physical Storage Capacity*
10. *Configured Storage Capacity ÷ Physical Storage Capacity*
11. *Global Storage Overhead ÷ Physical Storage Capacity*
12. *Unused Storage (contained in Addressable Storage Capacity) ÷ Addressable Storage Capacity*
13. *Unused Storage (contained in Configured Storage Capacity) ÷ Configured Storage Capacity*
14. *Unused Storage (total)) ÷ Physical Storage Capacity*

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


Application Storage Unit (ASU) Capacity
nn,nnn.nnn GB
ASU 1
n,nnn.nnn GB
ASU 2
n,nnn.nnn GB
ASU 3
nnn.nnn GB
Unused Storage
nn.nnn GB
LV 1
LV 2
LV 3
LV 4
Addressable Storage Capacity
nn,nnn.nnn GB
Parity (RAID5),
User Data Copy (Mirroring)
or
Other Protection Level
(parity/mirroring)
nn,nnn.nnn GB
Required Storage/Spares
nnn.nnn GB
Unused Storage – nn.nnn GB
Global Storage Overhead
nn.nnn GB
Unused Storage – nn.nnn GB
Configured Storage Capacity
nnn,nnn.nnn GB
Physical Storage Capacity
nnn,nnn.nnn GB

10.4.7.2 Logical Volume Capacity and ASU Mapping

A table illustrating the capacity of each ASU and the mapping of Logical Volumes to ASUs shall be included in the FDR. Capacity must be stated in gigabytes (GB) as a truncated integer or a truncated value with three significant digits, using the method that produces the more precise value. Logical Volumes shall be sequenced in the table from top to bottom per its position in the contiguous address space of each ASU. The capacity of each Logical Volume shall be stated. Each Logical Volume identifier in the table shall be unique within the BC. The content, appearance, and format of this table are specified in Table 10-13. In conjunction with this table, the Test Sponsor shall provide a complete description of the type of data protection *(Clause 2.7)* used on each Logical Volume.

Table 10-13: SPC-1C Logical Volume Capacity and ASU Mapping

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

10.4.8 SPC-1C Test Execution Results

Clauses 10.4.8.1 – 10.4.8.5 describe the required content and format of the Full Disclosure Report section that documents the results of the various SPC-1C Tests, Test Phases, and Test Runs.

10.4.8.1 Primary Metrics Test – Sustainability Test Phase

The FDR shall contain the following for the single Test Run in the Sustainability/IOPS Test Phase:

1. A Data Rate Distribution graph and data table *(Clause 10.1.4)*.
2. I/O Request Throughput Distribution graph and data table *(Clause 10.1.2)*.
3. A Response Time Frequency Distribution graph and table *(Clause 10.1.1)*.
4. An Average Response Time Distribution graph and table *(Clause 10.1.3)*.
5. The human readable SPC-1C Test Run Results File produced by the SPC-1C Workload Generator *(may be included in an appendix)*.
6. A listing of all input parameters supplied to the SPC-1C Workload Generator *(may be included in an appendix)*.
7. The Measured Intensity Multiplier for each I/O Stream.
8. The variability of the Measured Intensity Multiplier, as defined in Clause 6.3.14.3.

10.4.8.2 Primary Metrics Test – IOPS Test Phase

1. I/O Request Throughput Distribution graph and data table *(Clause 10.1.2)*.
2. A Response Time Frequency Distribution graph and table *(Clause 10.1.1)*.
3. An Average Response Time Distribution graph and table *(Clause 10.1.3)*.
4. The human readable SPC-1C Test Run Results File produced by the SPC-1C Workload Generator *(may be included in an appendix)*.
5. A listing of all input parameters supplied to the SPC-1C Workload Generator *(may be included in an appendix)*.
6. The Measured Intensity Multiplier for each I/O Stream.
7. The variability of the Measured Intensity Multiplier, as defined in Clause 6.3.14.3.
8. The total number of I/O Requests completed in the measurement interval as well as the number of I/O Request with a Response Time less than or equal to 30.00 milliseconds and the number of I/O Requests with a Response Time greater than 30.00 milliseconds.

10.4.8.3 Primary Metrics Test – Response Time Ramp Test Phase

The FDR shall contain the following for the Response Time Ramp Test Phase:

1. A Response Time Ramp Distribution graph *(Clause 10.1.5)*.
2. The human readable Test Run Results File produced by the SPC-1C C Workload Generator for each Test Run within the Response Time Ramp Test Phase *(may be included in an appendix*).
3. An Average Response Time Distribution graph and table *(Clause 10.1.1)* for the 10% BSU Level Test Run *(the SPC-1C LRT™ metric)*
4. A listing of all input parameters supplied to the SPC-1C Workload Generator *(may be included in an appendix*).

10.4.8.4 Repeatability Test

The FDR shall contain the following for the Repeatability Test:

1. A table containing the results of the Repeatability Test. The content, appearance, and format of the table are specified in Table 10-14.
2. I/O Request Throughput Distribution graph and table for each Repeatability Test Run *(Clause 10.1.2)*.
3. An Average Response Time Distribution graph and table for each Repeatability Test Run *(Clause 10.1.2)*.
4. The human readable Test Run Results File produced by the SPC-1C C Workload Generator *(may be included in an appendix*).
5. A listing of all input parameters supplied to the SPC-1C Workload Generator *(may be included in an appendix*).

Table 10-14: Repeatability Test Results

	IOPS	LRT
Reported Metrics	*n,nnn.nn*	*n.nn*
Repeatability Test Phase 1	n,nnn.nn	n.nn
Repeatability Test Phase 2	n,nnn.nn	n.nn

10.4.8.5 Data Persistence Test

The FDR shall contain the following for the Data Persistence Test:

1. A listing of the SPC-1C Workload Generator commands and parameters used to execute each of the Test Runs in the Persistence Test *(may be included in an appendix*).
2. The human readable SPC-1C Test Results File for each of the Test Runs in the Data Persistence Test *(may be included in an appendix*).
3. 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 10-15.

Table 10-15: Data Persistence Test Results

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

Footnotes to Table 10-15:

1. *Within the set of Data Persistence Test Runs executed to pass the Data Persistence Requirement, the Test Run Number. Tables in this section of the FDR shall be presented in the same sequence as the Test Runs performed by the Test Sponsor. Test Run Number shall be integer values beginning with the number one (1).*
2. *The total number of Logical Blocks written for this Test Run in step #1 of Clause 7.4.*
3. *The total number of Logical Blocks that passed verification in step #5 of Clause 7.4.*
4. *The total number of Logical Blocks that failed verification in step #5 of Clause 7.4.*

5. *Wall clock time in minutes and seconds required to complete step #1 of Clause 7.4.*
6. *The number of bytes per logical block in the TSC.*
7. *For all I/O Requests issued during the course of the Persistence Test the number of Failed I/O Requests per the definition in Clause 6.1.6*
8. *If the Host System(s) were shutdown and power cycled enter 'Yes'. If the Host System(s) were not shutdown and power cycled, per Clause 7.4 #3, enter 'No'.*

10.4.9 Priced Storage Configuration Availability Date

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

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

10.4.10 Anomalies or Irregularities

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

10.4.11 Disclosure Requirements – New SPC-1C Result based on an existing SPC-1C Result

The following table is required in the FDR of a new SPC-1C Result that is based on an existing SPC-1C Result *(referred to below as 'Basis')*. The required content and format of the table is specified in Table 10-16.

Table 10-16: Basis SPC-1C Result Information

Test Sponsor and Contact Information	
Basis Test Sponsor Primary Contact (1)	Company, Company Web Address, Individual Name – Email Address Postal Address Phone, FAX
Basis SPC-1C Submission Identifier (2)	ZZZ-N
Submission Date of Basis SPC-1C Result (3)	mmmm dd, yyyy
Status of the Basis SPC-1C Result (4)	{Submitted for Review/Accepted}
Date the Basis SPC-1C Result completed or will complete Peer Review (5)	mmmm dd, yyyy
Auditor for the Basis SPC-1C Result (6)	Company, Company Web Address, Individual Name – Email Address Postal Address Phone, FAX

Footnotes to Table 10-16:

1. *The Test Sponsor contact responsible for the Basis SPC-1C Result.*
2. *The SPC-1C Submission Identifier of the Basis SPC-1C Result.*
3. *The date the Basis SPC-1C Result was submitted to the SPC.*
4. *The current Peer Review status of the Basis SPC-1C Result.*
5. *The date the Basis SPC-1C Result successfully completed Peer Review and transitioned to "Accepted" status or the scheduled date for that to occur.*
6. *The Auditor for the Basis SPC-1C Result.*

Clause 11: Measurement, Audit, and Result Submission

11.1 Introduction

A new SPC-1C Result may either be generated from an execution of the complete set of SPC-1C Tests *(Clause 6.4)*, which has not been used in any other SPC-1C Result, or the new SPC-1C Result may be based on an existing SPC-1C result. In addition under certain conditions, an existing SPC-1C Result may be revised.

11.1.1 New, Original SPC-1C Result

The creation of a new, original SPC-1C Result requires completion of the SPC-1C Result Validation process, which consists of the following:

- Creation of a complete set of SPC-1C Results Files resulting from the execution of the complete set of SPC-1C Tests *(SPC-1C Measurement)*, which are defined in Clause 6.4.
- Successful completion of an SPC-1C Audit, which is defined in Clause 11.3.
- Submission of the required materials, as defined in Clause 11.4, to the SPC.
- Successful completion of the required SPC Peer Review, which is described in Clause 11.5.

While it is not possible to preclude the possibility of an erroneous SPC-1C Result, the SPC-1C Validation process is designed to minimize the possibility that an SPC-1C Result could lead a consumer of that benchmark data to an erroneous or misleading conclusion about the Test Storage Product.

11.1.2 New SPC-1C Result based on an existing SPC-1C Result

In addition to creating a new SPC-1C Result as described above, an existing SPC-1C Result, under certain conditions, may be the basis of a submission to create a new SPC-1C Result for a Tested Storage Product other than the original Tested Storage Product.

The SPC-1C Result Validation process for this type of new SPC-1C Result consists of the following:

- Successful completion of an SPC-1C Audit *(Clause 11.3)*.
- Submission of the required materials *(Clause 11.4)*.
- Successful completion of the required SPC Peer Review *(Clause 11.5)*.

Additional details for creating this type of SPC-1C Result appear in Clause 11.7.

11.1.3 Revision to an existing SPC-1C Result

An existing SPC-1C Result may be revised under the conditions defined in Clause 11.8.

11.2 SPC-1C Measurement

The execution of the complete set of SPC-1C Tests *(Clause 6.4)* to create a complete set of SPC-1C Results Files, which will form the basis of an SPC-1C Result, is performed in the SPC Audit facility by SPC Audit personnel or may be performed at a Test Sponsor's site in an On-Site Audit.

Clause 11.2.1 describes the Benchmark Configuration (BC) components and documentation that are required to be supplied by the Test Sponsor to the SPC Audit facility. Clause 11.2.2 describes the BC components at the SPC Audit facility, which are available for use in the SPC-1C measurement. Clause 11.2.3 defines the level of Test Sponsor participation allowed during the SPC-1C measurement.

Additional details, if needed, will be supplied to the Test Sponsor when an SPC-1C measurement is scheduled with the SPC Audit Service.

11.2.1 SPC-1C Tested Storage Configuration (TSC) and Documentation

The Test Sponsor is required to provide the following at the SPC Audit facility for the SPC-1C measurement:

- A complete TSC.
- A complete set of documentation for the hardware/software installation and configuration of the supplied TSC
- SPC-1C-specific documentation required to configure the TSC for the required SPC-1C Test Runs.
- Contact information for a Test Sponsor designee who will address questions, issues, etc.

11.2.2 SPC-1C Host System(s)

The SPC Audit facility will provide one or more Host Systems for use in the SPC-1C Measurement except in the case where the Host System is a TSC component. In that case, the Host System will be supplied by the Test Sponsor as part of the TSC *(Clause 11.2.1)*.

Use of a Host System supplied by the Test Sponsor, which is not a TSC component, must be requested and agreed upon when an SPC-1C measurement is scheduled with the SPC Audit Service.

11.2.3 Test Sponsor Participation

The Test Sponsor is allowed to be onsite at the SPC Audit facility during their SPC-1C measurement and may assist in the installation and configuration of the TSC, as well as the SPC-1C-specific configuration process for the TSC. The Test Sponsor is not allowed to participate in the execution of the SPC-1C Test Runs.

11.3 SPC-1C Audit

An SPC-1C Audit will be executed by SPC Audit personnel in conjunction with the SPC measurement conducted at the SPC Audit facility (*Clause 11.2)* or at a Test Sponsor's site in an On-Site Audit. The purpose of an SPC-1C Audit is to verify an SPC-1C measurement is eligible for submission to the SPC as part of the SPC-1C Result Validation process. The SPC-1C Audit includes:

- Verification of the compliant execution of the complete set of SPC-1C Tests and generation of the resultant complete set of SPC-1C Results Files.
- Verification that the required SPC-1C Full Disclosure Report (FDR) is complete, accurate, and compliant with the appropriate version of the SPC-1C specification.

The SPC-1C Audit procedures are defined in Clause 11.6.

11.3.1 SPC-1C On-Site Audit

11.3.1.1 A Test Sponsor may elect to satisfy the SPC-1C Audit requirements by means of an SPC-1C On-Site Audit and are responsible for the costs of the SPC-1C On-Site Audit.

11.3.1.2 The SPC Audit Service will provide an SPC Auditor who is responsible for the execution of the SPC-1C On-Site Audit.

11.3.2 SPC-1C Audit Certification

11.3.2.1 The SPC Audit personnel will, in the course of the SPC-1C Audit, determine if the SPC-1C Measurement is eligible for submission to the SPC.

11.3.2.2 If the SPC Audit personnel determine the SPC-1C Measurement is eligible for submission, the SPC Audit personnel will produce an SPC-1C Audit Certification report attesting to the successful completion of the SPC-1C Audit and issue that report to the Test Sponsor.

11.3.2.3 The SPC-1C Audit Certification report will document execution of the SPC-1C Audit procedures defined in Clause 11.6. The SPC-1C Audit Certification report for a successful SPC-1C Audit will contain any anomalous or inconsistent element encountered during the audit. While those elements did not prevent successful completion of the audit, their presence warranted documentation.

11.3.2.4 If the SPC-1C measurement is eligible for submission to the SPC, the Test Sponsor may then submit the required materials to the SPC to establish a new SPC-1C Result *(Clause 11.4)* and begin the SPC Peer Review *(Clause 11.5)*.

11.3.2.5 If the SPC Audit personnel determine the SPC-1C measurement is not eligible for submission to the SPC, the Test Sponsor may request an SPC-1C Audit Report that documents the compliance issues encountered during the audit. In addition, the SPC-1C Audit Report will include recommendations to address those compliance issues.

11.3.2.6 If the Test Sponsor disagrees with the SPC Audit personnel's determination of eligibility, the Test Sponsor may submit an appeal to the SPC Compliance Review Committee.

11.4 SPC-1C Measurement Submission

A Test Sponsor may submit to the SPC an SPC-1C measurement that has successfully completed an SPC-1C Audit.

11.4.1 SPC-1C Submission Materials

A complete SPC-1C measurement submission consists of the following items submitted to the SPC by the Test Sponsor:

- A PDF version of the audited SPC-1C Full Disclosure Report (FDR) and Executive Summary.
- Payment to the SPC of all SPC-1C Audit costs and SPC-1C Result filing fee.
- A release, if not previously submitted, allowing public disclosure of the SPC-1C Result and FDR.

11.4.2 SPC-1C Result

When the SPC-1C measurement submission is successfully completed:

- A unique SPC-1C Submission Identifier is created for the submitted SPC-1C measurement.

- The submitted SPC-1C measurement becomes a new SPC-1C Result that is in "Submitted For Review" status.
- A copy of both the SPC-1C Full Disclosure Report and Executive Summary are placed on the SPC website in the "Benchmark Results" section.
- A notification email is sent to the SPC membership announcing the new SPC-1C result.
- The SPC Peer Review begins *(Clause 11.5)*.

11.4.3 SPC-1C Submission Identifier

An SPC-1C Submission Identifier takes the following format: **ZZZ-N**. Where:

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

11.5 SPC Peer Review

The SPC Peer Review of a new SPC-1C Result begins when the result is created *(Clause 11.4.2)* and encompasses all the information contained in the SPC-1C Full Disclosure Report submitted for the result.

SPC Peer Review of revisions to an existing SPC-1C Result begins when the revised SPC-1C Full Disclosure Report (FDR) is submitted to the SPC. The peer review, in this case, is limited to the revised information in the newly submitted FDR, which includes any component changes in the Priced Storage Configuration.

The SPC Peer Review is the final step to certify the SPC-1C Result's compliance with this specification. The details of the SPC Peer Review are described in the SPC Policies and Procedures.

11.6 SPC-1C Audit Procedures

The following SPC-1C audit procedures address the requirements previously stated in each clause of this specification. The audit procedures are organized to follow the order in which each clause appears in this specification.

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, TSP name, date, etc.). Any other changes in content and format must be approved by the SPC Auditor 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.
2. Verify the Configured Storage Capacity and requirements stated in Clause 2.3.
3. Verify the Addressable Storage Capacity and requirements stated in Clause 2.4.
4. Verify the capacity of each Logical Volume and requirements stated in Clause 2.5.
5. Verify the capacity of the Application Storage Unit (ASU) and requirements stated in Clause 2.6.

The Test Sponsor is required to provide documentation of tools/utilities available with the TSC to generate to appropriate listings to complete the above verification.

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 *Figure 10-8: Benchmark Configuration/Tested Storage Configuration Diagram* and *Table 10-10: Host System(s) and Tested Storage Configuration*. Confirm the presence of the components illustrated in the figure and listed in the table.
2. Obtain a listing of all customer tunable parameters and options that have been altered from their default values (Clause 10.4.6.1). The listing must contain the name of each component with an altered parameter/option, the name of the parameter/option, and the altered value.
3. Obtain information that is sufficient to recreate the logical representation of the TSC (Clause 10.4.6.2). That information must include, at a minimum:
   - A diagram and/or description of the following:
     - All physical components that comprise the TSC.
     - The logical representation of the TSC, configured from the above components, which was presented to the SPC-1C Workload Generator.
   - Listing 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.
4. Verify the required configuration information for each Host System *(Clause 10.4.5.12)*.
5. 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, Figure 4-2, and Figure 4-3.

Verification of items #1 – #3 is done using the required documentation supplied by the Test Sponsor as part of the SPC-1C measurement *(Clause 11.2)*. Verification of item #4 is done using documentation supplied by the Test Sponsor if the Host System is supplied by the Test Sponsor.

11.6.6 Clause 5: SPC-1C Workload Generator – Audit Items

1. Verify the presence and version number of the SPC-1C Workload Generator on each Host System in the BC.
2. In a multi-host configuration, verify that the execution of multiple SPC-1C Workload Generators on the multiple Host Systems was synchronized in time (Clause 5.2).

Verification of items #1 and #2 are done using the appropriate Test Results files.

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

1. Observe the execution of each SPC-1C Test, Test Phase, and Test Run and determine compliance with the requirements and constraints of Clause 6.
2. Obtain the SPC-1C Results Files for each Test Run.
3. Authenticate the Results Files obtained in #2.
4. Inspect each authenticated Results File to determine compliance with all the constraints and requirements of Clause 4, Clause 5, and Clause 6.

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

1. Observe the successful Persistence Test and determine its compliance with the requirements and constraints of Clause 7.
2. Obtain the Persistence Test Results file from each Test Run.
3. Authenticate the successful Persistence Test Results file obtained in #1.
4. 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 Data – Audit Items

None

11.6.10 Clause 9: Pricing – Audit Items

1. If the Tested Storage Configuration (TSC) and Priced Storage Configuration are not identical, verify that the differences between the two configurations are disclosed and that the Priced Storage Configuration would be capable of providing at least the same level of reported performance as the TSC.
2. Review a preliminary copy of the pricing spreadsheet, described in Clause 9.3.1, and verify that it meets all the requirements and constraints of Clause 9. It is not required to review the final pricing prior to issuing the audit certification letter.

11.6.11 Clause 10: Full Disclosure Report (FDR) – Audit Items

Verify the SPC-1C Full Disclosure Report (FDR) is complete and accurate based on the requirements in Clause 10.

11.7 Creating a new SPC-1C Result based on an existing SPC-1C Result

An existing SPC-1C Result may be the basis of a submission to create a new SPC-1C Result if the following requirements are met:

a) The Tested Storage Product (TSP) for the new SPC-1C Result is not the same as the TSP in the existing SPC-1C Result.

b) The hardware and software components that comprise the Priced Storage Configuration (9.1.2) in the new SPC-1C Result are materially the same as those used in the existing SPC-1C Result.

c) Any hardware and/or software differences between the existing and new Priced Storage Configurations do not impact the performance-related primary metrics.

d) All performance data disclosed in the new SPC-1C Full Disclosure Report is identical to that which is contained in the original FDR.

e) The existing SPC-1C Result is either in "Submitted for Review" or "Accepted" status.

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

11.7.1 Audit Requirements

The SPC-1C Audit for a new SPC-1C Result based on an existing SPC-1C Result may not follow the complete set of procedures defined in Clause 11.6.

11.7.2 Full Disclosure Report Requirements

11.7.2.1 A new SPC-1C Result based on an existing SPC-1C Result must include in its Full Disclosure Report the table of required information described in Clause 10.4.11, which will contain key information about the existing SPC-1C Result.

11.7.2.2 All differences in hardware and software products that comprise the original and new Priced Storage Configurations must be listed in the Full Disclosure Report *(Clause 10.4.5.9.1)*.

11.7.3 Withdrawal of the existing SPC-1C Result

If an SPC-1C Result successfully completes Peer Review and is subsequently withdrawn with no compliance issue outstanding, SPC-1C Results based on the withdrawn SPC-1C Result are not required to be withdrawn.

11.8 SPC-1C Result Revisions

Revisions to an existing SPC-1C Result can occur only under the following conditions:

- Fully documented pricing changes to the Priced Storage Configuration.
- A change in the SPC-1C Availability Date.
- As directed by the SPC Policies.

In all cases, the resulting revised SPC-1C Full Disclosure Report is required to be reviewed and approved by an SPC Auditor prior to submission to the SPC *(Clause 11.6.11)*.

11.8.1 SPC-1C Pricing Revisions

Priced Storage Configuration pricing of an existing SPC-1C Result may be revised based on fully documented price changes (decreases and increases). If the cumulative price changes result in an increase of 5% or more from the reported SPC-1C Total Price *(Clause 9.1.6)*, the Test Sponsor must submit a revised FDR with the new pricing information to the SPC within 30 days of the effective date of the price changes for the SPC-1C Result to remain compliant. Pricing changes below the 5% increase threshold are submitted at the discretion of the Test Sponsor. In either case, the SPC-1C measurement need not be re-executed to remain compliant if there are no changes in the Priced Storage Configuration components resulting from the revised pricing.

Comment: *The intent of this clause is that published the SPC-1C Total Price- reflects the actual, current SPC-1C Total Price.*

11.8.2 SPC-1C Availability Date Revisions

The original SPC-1C Availability Date for the Priced Storage Configuration may be revised consistent with the Availability requirement specified in Clause 9.2.2.5. The SPC-1C measurement need not be re-executed to remain compliant if there are no changes in the Priced Storage Configuration resulting from the revised SPC-1C Availability Date.

11.8.3 SPC Policies Directed Revisions

Revisions to an SPC-1C Result may result from provisions in the SPC Policies and Procedures such as in the case of a compliance issue identified during the SPC Peer Review.

11.8.4 Component Substitution in a revised SPC-1C Result

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

Examples of component substitutions include:

- Replacement of a now obsolete component that was included in the existing Priced Storage Configuration.
- Replacement of a component when a change in the component's availability would extend the SPC-1C Availability Date beyond the period allowed by the specification (Clause 9.2.2.5).

If the Priced Storage Configuration component changes are approved by the SPC Auditor, an amended SPC-1C Audit Certification report will be issued to the Test Sponsor for inclusion in a revised FDR, which will contain a list of all changes *(Clause 10.4.5.9.2)*. If the auditor does not approve the component changes, the Test Sponsor may appeal that decision to the SPC Compliance Review Committee.

Clause 12: Energy Extension

12.1 Overview

The ENERGY EXTENSION is an optional extension of the SPC-1C benchmark specification as described in the following clauses. By performing ENERGY EXTENSION measurements, the Test Sponsor will augment the SPC-1C Reported Data as described in Clause 8. The ENERGY EXTENSION measurement and reporting may only be performed as part of the SPC-1C benchmark execution.

The purpose of the ENERGY EXTENSION measurements is to record data on the power consumption of the Tested Storage Configuration (TSC). An Idle Test is included as part of the ENERGY EXTENSION measurements, to determine TSC power consumption under idle conditions. Following the Idle Test, power consumption is also recorded throughout the Primary Metrics and Repeatability Tests.

12.2 Apparatus

The instruments or apparatus used to record power consumption must belong to the list "Power extension apparatus" that is provided on the SPC web site. Instruments shall be included in the "Power extension apparatus" list only after being recommended by the SPC Auditor and approved by vote of the SPC Council. The use of instruments during ENERGY EXTENSION tests shall conform to any electrical or other restrictions, as stated in the documentation provided with each instrument.

All power supplies present in the TSC must be active. Concurrent power measurements must be taken at each active AC input, such that the total power requirement of the TSC is recorded.

12.3 Disclosure Requirements

When ENERGY EXTENSION measurements are taken, the test sponsor must disclose the following characteristics of the TSC:

- Number of AC input(s) used for powering the TSC.
- Voltage, amperage, and phase characteristics of the AC input(s) used for powering the TSC.
- Number of power supplies present and active in the TSC.
- Mutual failover capabilities of the configured power supplies, if any.

12.4 Measurements

12.4.1 Timekeeping

For the purpose of timekeeping, the system clock whose timekeeping is reflected in the workload generator output is considered to be the master clock. The time of each POWER EXTENSION measurement must be reported by providing a complete time stamp, including both the date and the time of day. The reported times must agree with the timekeeping of the master clock to within +- 1 second.

12.4.2 Idle Test

12.4.2.1 When ENERGY EXTENSION tests are performed, the test sequence begins with a test of power use under idle conditions (Idle Test). If an SPC-1C test is performed without the ENERGY EXTENSION, the Idle Test is not needed and is not performed.

12.4.2.2 RMS power data (in watts) are collected at 5 second intervals during the Idle Test.

12.4.2.3 The Idle Test permits power data to be captured for either a single idle state, or multiple idle states. The intent of permitting measurements of multiple, distinct idle states is to reflect progressive reductions of power use that may occur after prolonged inactivity. For example, if a small storage system has the capability to spin down its disk drives after an extended period of idle conditions, then the system supports two idle states and both can be measured during the Idle Test.

The number of idle states is determined by the test sponsor. The operational states measured during the Idle Test are called Idle-0, Idle-1, Idle-2, …, Idle-L, where L>=0 is the number of the last (assumed to be deepest) idle state.

12.4.2.4 If it is desired to measure more than one idle state, the transitions between states must not require manual intervention. Such transitions may, however, be requested via the execution of a preprogrammed script, or can occur automatically as part of the routine operation of the TSC.

12.4.2.5 The Idle Test consists of the following phases, performed in sequence:

1. Conditioning Phase (duration: 10 minutes). The workload generator applies a number of BSU's equal to that applied during the IOPS phase of the Primary Metrics test.
2. Phases Idle-0, Idle-1, … Idle-(L-1) (duration: specified by the test sponsor, but the same for all affected Idle phases and no less than 10 minutes). No work is applied by the workload generator.
3. Phase Idle-L (duration and start: specified by the test sponsor, but no less than 30 minutes). No work is applied by the workload generator.
4. Recovery Phase (duration: 10 minutes). The workload generator applies a number of BSU's equal to that applied during the 10% BSU level run of the Response Time Ramp Test Phase.

The test sponsor may optionally include a transition period prior to each phase as just listed in (2) through (4). The transition period, if included, must be the same length prior to each phase, not to exceed 3 minutes.

12.4.3 Primary Metrics and Repeatability Tests

12.4.3.1 When ENERGY EXTENSION measurements are performed, the Primary Metrics Test, followed by the Repeatability Test, begins immediately after completion of the Idle Test.

12.4.3.2 When ENERGY EXTENSION measurements are performed, RMS power data (in watts) are collected at 5 second intervals during the Primary Metrics and Repeatability Tests

12.4.4 Temperature

The ambient temperature must be recorded at the following times:

- During the first one minute of the Idle Test.
- During the last one minute of the Primary Metrics Test.

These measurements are referred to as the initial and final ENERGY EXTENSION temperatures respectively. The temperature measurements must have a precision of at least +/- 0.1 °C, and must be taken in near proximity to the TSC.

12.5 Power Profiles

12.5.1 For the purpose of developing the reported data associated with the ENERGY EXTENSION, three power profiles are defined. The three profiles are referred to as PPLOW, PPMED, and PPHIGH. The intent of the three profiles is to describe anticipated conditions in environments that respectively impose light, moderate, or heavy demands upon the TSC.

12.5.2 Each power profile is a triplet of three numbers, as follows:

PPLOW = (0, 8, 16)

PPMED = (4, 14, 6)

PPHIGH = (18, 6, 0)

The interpretation of the three numbers is that they represent anticipated hours of heavy, moderate, or idle operation respectively during a given day. For example, PPMED_1 (the first member of the PPMED triplet) is 4. This means that in environments that impose moderate overall demand, we anticipate 4 hours per day of heavy operation.

For the purpose of applying the energy profiles, heavy operation is associated with measurements taken at the 80% BSU level run of the Response Time Ramp Test Phase; moderate operation is associated with measurements taken at the 50% BSU level run of the Response Time Ramp Test Phase; and idle operation is associated with measurements taken in the Idle-L test phase. The average number of watts observed in each of the measurement intervals just identified will be referred to respectively as W_heavy, W_mod, and W_idle. Similarly, the corresponding IOPS results observed in the first two of these measurement intervals will be referred to respectively as IOPS_heavy and IOPS_mod.

12.5.3 Nominal Operating Power (watts). The Nominal Operating Power is intended to reflect the average power draw computed across three selected environments, over the course of a day, taking into account hourly load variations. When ENERGY EXTENSION measurements are performed, the test result called Nominal Operating Power is defined to be: (PPLOW_1*W_heavy + PPLOW_2*W_mod + PPLOW_3*W_idle + PPMED_1*W_heavy + PPMED_2*W_mod + PPMED_3*W_idle + PPHIGH_1*W_heavy + PPHIGH_2*W_mod + PPHIGH_3*W_idle) / 72.

12.5.4 Nominal Traffic (IOPS). The Nominal Traffic is intended to reflect the average level of I/O traffic computed across three selected environments, over the course of a day, taking into account hourly load variations. When ENERGY EXTENSION measurements are performed, the test result called Nominal Traffic is defined to be: (PPLOW_1*IOPS_heavy + PPLOW_2*IOPS_mod + PPMED_1*IOPS_heavy + PPMED_2*IOPS_mod + PPHIGH_1*IOPS_heavy + PPHIGH_2*IOPS_mod) / 72.

12.5.5 Operating IOPS/watt. The Operating IOPS/watt assesses the overall efficiency with which I/O traffic can be supported, by taking the ratio of the Nominal Traffic versus the Nominal Operating Power. When ENERGY EXTENSION measurements are performed, the test result called Operating IOPS/watt is defined to be: (Nominal Traffic) / (Nominal Operating Power).

12.5.6 Annual Energy Use (kWh). The Annual Energy Use estimates the average energy use computed across three selected environments, over the course of a year. When ENERGY EXTENSION measurements are performed, the test result called Annual Energy Use is defined to be: 0.365*24*(Nominal Operating Power).

12.6 Naming Convention

All references to an SPC-1C Result that includes the SPC-1C Energy Extension shall use the terms SPC Benchmark 1C/Energy™ or SPC-1C/E™, as appropriate, rather than SPC Benchmark 1C™ or SPC-1C™.

12.7 SPC-1C/E Reported Data

12.7.1 SPC-1C/E Post-Processing Tool

SPC-1C/E Reported Data can only be generated by the SPC-1C/E Post-Processing Tool approved by the SPC-C Technical Subcommittee.

12.7.1.1 The required input to generate SPC-1C/E Reported Data consists of:

1. The data collected during the Idle Test as defined in Clause 12.4.2.
2. The data collected during the Primary Metrics and Repeatability Tests as defined in Clause 12.4.3.2.
3. The official performance results files from the Idle Test Conditioning Phase *(Clause 12.4.2.5#1)*, the Idle Test Recovery Phase *(Clause 12.4.2.5, #4)*, and each of the Test Runs that comprise the Primary Metrics and Repeatability Tests *(Clauses 6.4.3 and 6.4.4)*.

12.7.1.2 SPC-1C/E Reported Data consists of:

1. A required graph produced by the SPC-1C/E Post Processing Tool, which reports and illustrates the performance in SPC-1C/E IOPS and average power consumption in RMS watts for Idle Test Conditioning Phase *(Clause 12.4.2.5#1)*, Idle Test Recovery Phase *(Clause 12.4.2.5, #4)*,, and each of the Test Runs that comprise the Primary Metrics and Repeatability Tests *(Clauses 6.4.3 and 6.4.4)*. An example of that required graph appears below in Figure 12-1.
2. A required table produced by the SPC-1C/E Post-Processing Tool, which reports the calculated power profile data *(Clause 12.5)*. An example of that required table appears below in Table 12-1.
3. A required table produced by the SPC-1C/E Post-Processing Tool, which reports the power data collected during the Idle Test *(Clause 12.4.2.2)* and the Primary Metrics Test *(Clause 12.4.3.2)*. An example of a portion of that required table appears below in Table 12-2.

Figure 12-1: Power / Performance Profile Data

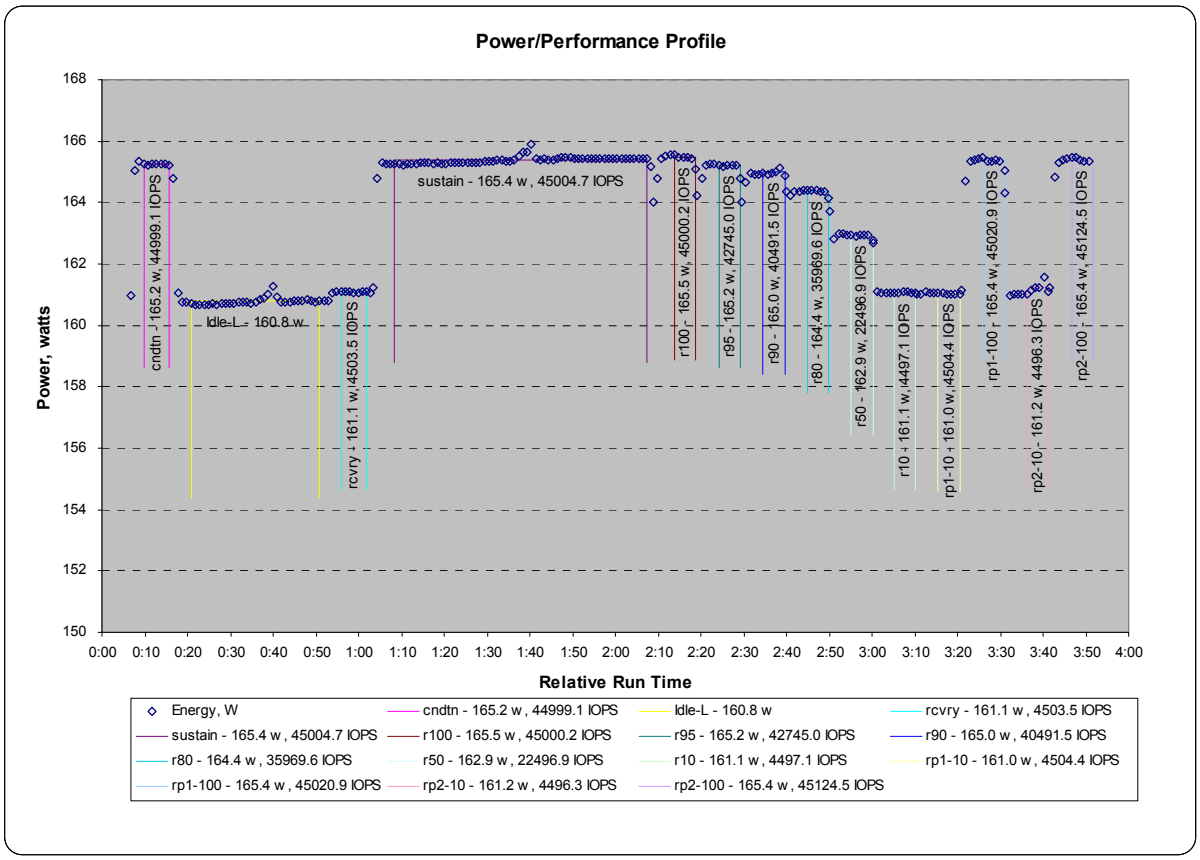


Table 12-1: Power Profile Data

	Usage Profile					
	Hours of Use per Day			Nominal	Nominal	Nominal
	Heavy	Moderate	Idle	Power, W	Traffic, IOPS	IOPS/W
Low Daily Usage:	0	8	16	**161.50**	**7498.96**	**46.43**
Medium Daily Usage:	4	14	6	**162.64**	**19118.11**	**117.55**
High Daily Usage:	18	6	0	**164.01**	**32601.39**	**198.77**
			Composite Metrics:	**162.72**	**19,739.49**	**121.31**

Annual Energy Use, kWh:	**1,425.41**		
Energy Cost, $/kWh:	$ 0.12	**Annual Energy Cost, $:**	**$ 171.05**

Table 12-2: Power Consumption Data

Relative Time	Time	Run Name	Energy, W	Voltage, V	Current, A
0:06:44	16:46:44	Conditioning	160.97	202.52	0.9057
0:07:44	16:47:44	Conditioning	165.02	202.51	0.9246
0:08:44	16:48:44	Conditioning	165.33	202.67	0.9255
0:09:44	16:49:44	Conditioning	165.25	202.67	0.9251
0:10:44	16:50:44	Conditioning	165.23	202.58	0.9253
0:11:44	16:51:44	Conditioning	165.25	202.57	0.9255
0:12:44	16:52:44	Conditioning	165.26	202.63	0.9254
0:13:44	16:53:44	Conditioning	165.26	202.60	0.9254
0:14:44	16:54:44	Conditioning	165.24	202.62	0.9252
0:15:44	16:55:44	Conditioning	165.23	202.65	0.9251
0:16:44	16:56:44	Startup Idle-L	164.77	202.72	0.9228
0:17:44	16:57:44	Startup Idle-L	161.06	202.77	0.9056
0:18:44	16:58:44	Startup Idle-L	160.76	202.65	0.9046
0:19:44	16:59:44	Startup Idle-L	160.77	202.43	0.9052
0:20:51	17:00:51	Idle-L	160.72	203.50	0.9016
0:21:51	17:01:51	Idle-L	160.67	203.84	0.9002
0:22:51	17:02:51	Idle-L	160.69	203.81	0.9003
0:23:51	17:03:51	Idle-L	160.68	203.74	0.9005
0:24:51	17:04:51	Idle-L	160.69	203.70	0.9006
0:25:51	17:05:51	Idle-L	160.70	203.64	0.9007
0:26:51	17:06:51	Idle-L	160.67	203.59	0.9006
0:27:51	17:07:51	Idle-L	160.70	203.60	0.9007
0:28:51	17:08:51	Idle-L	160.70	203.66	0.9005
0:29:51	17:09:51	Idle-L	160.72	203.77	0.9003
0:30:51	17:10:51	Idle-L	160.73	203.76	0.9005
0:31:51	17:11:51	Idle-L	160.76	203.68	0.9008
0:32:51	17:12:51	Idle-L	160.76	203.68	0.9008
0:33:51	17:13:51	Idle-L	160.75	203.63	0.9009
0:34:51	17:14:51	Idle-L	160.72	203.66	0.9007
0:35:51	17:15:51	Idle-L	160.75	203.69	0.9008
0:36:51	17:16:51	Idle-L	160.86	203.66	0.9013
0:37:51	17:17:51	Idle-L	160.89	203.65	0.9015
0:38:51	17:18:51	Idle-L	161.00	203.72	0.9020
0:39:51	17:19:51	Idle-L	161.28	203.78	0.9031
0:40:51	17:20:51	Idle-L	160.92	203.70	0.9017
0:41:51	17:21:51	Idle-L	160.76	203.64	0.9011
0:42:51	17:22:51	Idle-L	160.77	203.60	0.9012
0:43:51	17:23:51	Idle-L	160.78	203.55	0.9013
0:44:51	17:24:51	Idle-L	160.80	203.56	0.9015
0:45:51	17:25:51	Idle-L	160.79	203.63	0.9015
0:46:51	17:26:51	Idle-L	160.79	203.58	0.9015
0:47:51	17:27:51	Idle-L	160.82	203.55	0.9018
0:48:51	17:28:51	Idle-L	160.82	203.52	0.9019
0:49:51	17:29:51	Idle-L	160.78	203.44	0.9019
0:50:51	17:30:51	RunOut	160.78	203.48	0.9018
0:51:51	17:31:51	RunOut	160.79	203.50	0.9018
0:52:51	17:32:51	Recovery	160.80	203.46	0.9019
0:53:51	17:33:51	Recovery	161.04	203.39	0.9033
0:54:51	17:34:51	Recovery	161.09	203.36	0.9036
0:55:51	17:35:51	Recovery	161.11	203.34	0.9036
0:56:51	17:36:51	Recovery	161.09	203.35	0.9036
0:57:51	17:37:51	Recovery	161.09	203.38	0.9036
0:58:51	17:38:51	Recovery	161.08	203.37	0.9035
0:59:51	17:39:51	Recovery	161.06	203.33	0.9035
1:00:51	17:40:51	Recovery	161.08	203.26	0.9038
1:01:51	17:41:51	Recovery	161.08	203.17	0.9041
1:02:51	17:42:51	RunOut	161.06	203.12	0.9041
1:03:24	17:43:24	Startup Sustainabiltiy	161.24	203.12	0.9049
1:04:24	17:44:24	Startup Sustainabiltiy	164.80	203.18	0.9213
1:05:24	17:45:24	Startup Sustainabiltiy	165.29	203.27	0.9234
1:06:24	17:46:24	Startup Sustainabiltiy	165.26	203.22	0.9233
1:07:24	17:47:24	Startup Sustainabiltiy	165.26	203.13	0.9235
1:08:24	17:48:24	Sustainability	165.26	203.19	0.9233
1:09:24	17:49:24	Sustainability	165.25	203.27	0.9232
1:10:24	17:50:24	Sustainability	165.23	203.31	0.9230
1:11:24	17:51:24	Sustainability	165.28	203.27	0.9233
1:12:24	17:52:24	Sustainability	165.25	203.28	0.9232

12.8 SPC-1C/E Full Disclosure Report (FDR) Requirements

In addition to the requirements and content defined in Clause 10, the SPC-1C/E FDR shall include the content described in the following clauses.

12.8.1 Configuration Diagram

The FDR shall include a diagram of the electrical metering, illustrating the measurement apparatus used and the relationship between active AC inputs and the associated measurement apparatus inputs.

12.8.2 SPC-1C/E Reported Data

All SPC-1C/E Reported Data defined in Clause 12.7 shall be included in the FDR.

12.8.3 Temperature

The ambient temperature measurement data, defined in Clause 12.4.4, shall be included in the FDR.

12.9 SPC-1C/E Audit Requirements

Execution of the complete set of SPC-1C/E Tests *(Clauses 6.4., 12.4.2, and 12.4.3)*, which will form the basis of an SPC-1C/E Result, are performed during the SPC-1C/E audit.

In the case of a successful audit, the SPC-1C/E Audit Certification report *(Clause 11.3.2.3)* will enumerate and document the audit procedures used in the audit, which include the requirements and process defined in Clause 11 as well as the process used to ensure compliance with the Clauses 12.2– 12.8.

Eligibility for SPC-1C/E measurement submission to the SPC, the submission process for an SPC-1C/E measurement submission to the SPC, disposition in the case of an unsuccessful audit, and Test Sponsor appeal process in the case of an unsuccessful audit are defined in Clauses 11.3.2 – 11.4.

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 SPC Audit Service***

From: ***Test Sponsor Name and Contact Information***

To: ***SPC Auditor Name and Contact Information***

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

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

Signed: Date:

_____ _____

Name and title of an appropriate Test Sponsor senior executive

Date of Signature

Appendix B: The Hierarchical Reuse Random Walk

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

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

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

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

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

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

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