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Information technology — Power efficiency measurement specification for data center storage

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National foreword

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Foreword

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This document was prepared by SNIA (as SNIA Emerald™ Power Efficiency Measurement Specification V3.0.3) and drafted in accordance with its editorial rules. It was adopted, under the JTC 1 PAS procedure, by Joint Technical Committee ISO/IEC JTC 1, *Information technology*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

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1 Introduction

There is a growing awareness of the environmental impact of IT equipment use. This impact takes several forms: the energy expended in equipment manufacture and distribution, the impact of materials reclamation, and the energy consumed in operation and cooling of the equipment. IT equipment users of all kinds now wish to make their IT operations as energy efficient as possible. This new priority can be driven by one or more of several requirements:

- Rising energy costs have made power and cooling expenses a more significant percentage of total cost of ownership of server and storage equipment;
- Some data centers are physically unable to add more power and cooling load, which means that new applications and data can only be brought on if old ones are retired or consolidated onto new, more efficient configurations;
- Increased regulatory and societal pressures provide incentives for companies to lower their total energy footprints. For many companies, IT is a significant portion of overall energy consumption, and corporate Green goals can only be achieved by reducing IT's energy needs or by making operations more efficient.

IT equipment users will seek advice on the most energy efficient approach to getting their work done. It is not practical for customers to test a wide range of storage products and architectures for themselves. A more effective approach is to create a collection of standard metrics that allow IT architects to objectively compare a range of possible solutions. This objective, metric-based approach has a dual impact:

- Users can select the mode of storage usage that accomplishes their work objectives with the lowest overall energy consumption;
- Companies will be driven to innovate and compete in the development of energy efficient products as measured by the standard yardsticks.

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2 Scope

2.1 Abstract

This document describes a standardized method to assess the energy efficiency of commercial storage products in both active and idle states of operation. A taxonomy is defined that classifies storage products in terms of operational profiles and supported features. Test definition and execution rules for measuring the power efficiency of each taxonomy category are described; these include test sequence, test configuration, instrumentation, benchmark driver, IO profiles, measurement interval, and metric stability assessment. Qualitative heuristic tests are defined to verify the existence of several capacity optimization methods. Resulting power efficiency metrics are defined as ratios of idle capacity or active operations during a selected stable measurement interval to the average measured power.

2.2 Introduction

This document defines methodologies and metrics for the evaluation of the related performance and energy consumption of storage products in specific active and idle states.

Storage products and components are said to be in an “active” state when they are processing externally initiated, application-level requests for data transfer between host(s) and the storage product(s). For purposes of this document, idle is defined as “ready idle”, in which storage systems and components are configured, powered up, connected to one or more hosts and capable of satisfying externally initiated, application-level initiated IO requests within normal response time constraints, but no such IO requests are being submitted.

2.3 Current Revision

This document addresses storage products supporting block or file data access. Block access and file access refer to the type of service provided typically by Storage Area Network (SAN) and Network Attached Storage (NAS) systems, respectively. It is not appropriate to use this document to ascertain power efficiency for anything other than these two access modes. This document includes:

- A generalized taxonomy for storage products (clause 5);
- An assessment mechanism for software-based Capacity Optimization Methods (clause 6);
- Measurement and data collection guidelines for assessing the power efficiency of block- and file-based storage products in both active and ready idle states (clause 7);
- Metrics describing storage product power efficiency (clause 8);
- Required disclosures for a test result published as a SNIA Emerald™[1] Power Efficiency Measurement test result (clause 9).

2.4 Purpose

The purpose of a SNIA Emerald™ Power Efficiency Measurement is to provide a reproducible and standardized assessment of the energy efficiency of commercial storage products in both active and ready idle states.

1. Tested systems shall be comprised of commercially released products and components;
2. Tested systems shall employ settings, parameters, and configurations that would allow end-users to achieve power efficiency levels equivalent to the published result;
3. All data published as an SNIA Emerald™ Power Efficiency Measurement test result shall be gathered from test execution conducted according to this document;

[1] SNIA Emerald™ is a trademark of the Storage Networking Industry Association. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO of the product named.

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4. Test execution shall complete in its entirety and without test failure or test error messages;
5. Software features which invoke, generate, or use software designed specifically for the test shall not be used. Configuration options chosen for test execution shall be options that are generally recommended for the customer;
6. Energy for powering the equipment shall be provided by the power mains that are being monitored (not by an internal UPS).

A SNIA Emerald™ Power Efficiency Measurement shall be a good faith effort to accurately characterize the power requirements of the tested system. The precise configuration used in a SNIA Emerald™ Power Efficiency Measurement is left to the sponsor of a test. Any commercially released components may be used, and a focus on new or emerging components or technologies is encouraged.

2.5 Disclaimer

A SNIA Emerald™ Power Efficiency Measurement test result provides a high-level assessment of the energy efficiency of the tested system in specific ready idle and active states. It is not an attempt to precisely model or reproduce any specific installation.

Actual performance and energy consumption behavior is highly dependent upon precise workload, environmental and usage parameters. While a SNIA Emerald™ Power Efficiency Measurement test result is intended to provide a realistic and reproducible assessment of the relative power efficiency of a system across a broad range of configurations and usage patterns, it cannot completely match the precise needs of any one specific installation.

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3 Normative References

The following documents are referred to in the text in a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

Table 1 lists these documents.

Table 1 – Normative References

Author/Owner	Title	Revision	URL
ISO/IEC	*ISO/IEC Directives Part II*	Eighth edition, 2018	https://www.iso.org/directives-and-policies.html

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4 Definitions, Symbols, Abbreviations, and Conventions

4.1 Overview

For the purposes of this document, the terms and definitions given in The SNIA Dictionary[2] and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

• ISO Online browsing platform: available at https://www.iso.org/obp

• IEC Electropedia: available at http://www.electropedia.org/

The terms and definitions defined in this document are based on those found in The SNIA Dictionary[2]. They have been extended, as needed, for use in this document. In cases where the current definitions in the SNIA dictionary conflict with those presented in this document, the definitions in this document shall apply.

4.2 Definitions

4.2.1

auto-tiering

policy-based system that automatically places and moves data across tiers to optimize performance service levels, cost targets, and overall energy consumption

Note 1 to entry: Each storage tier may comprise different storage technologies, offering varying performance, cost, and energy consumption characteristics.

4.2.2

cache

temporary storage used to transparently store data for expedited access to or from slower media, and not directly addressable by end-user applications

4.2.3

capacity optimization method (COM)

subsystem, whether implemented in hardware or software, which reduces the consumption of space required to store a data set

4.2.4

committed data

data that has been written to stable storage

4.2.5

compression

the process of encoding data to reduce its size

4.2.6

count-key-data (CKD)

disk data organization model in which the disk is assumed to consist of a fixed number of tracks, each having a maximum data capacity

Note 1 to entry: The CKD architecture derives its name from the record format, which consists of a field containing the number of bytes of data and a record address, an optional key field by which particular records can be easily recognized, and the data itself.

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4.2.7

data deduplication

replacement of multiple copies of data—at variable levels of granularity—with references to a shared copy in order to save storage space and/or bandwidth

4.2.8

dedupable

property that a collection of data is said to possess if the needed storage capacity for the data is reduced significantly by data deduplication

4.2.9

delta snapshot

type of point in time copy that preserves the state of data at an instant in time, by storing only those blocks that are different from an already existing full copy of the data

4.2.10

direct-connected

storage designed to be under the control of a single host, or multiple hosts in a non-shared environment

4.2.11

efficiency

ratio of useful work to the power required to do the work

4.2.12

file

abstract data object made up of a) an ordered sequence of data bytes stored on a disk or tape, b) a symbolic name by which the object can be uniquely identified, and c) a set of properties, such as ownership and access permissions that allow the object to be managed by a file system or backup manager

4.2.13

file system

software component that imposes structure on the address space of one or more physical or virtual disks so that applications may deal more conveniently with abstract named data objects of variable size (files)

4.2.14

fixed block architecture (FBA)

model of disks in which storage space is organized as linear, dense address spaces of blocks of a fixed size

Note 1 to entry: Fixed block architecture is the disk model on which SCSI is predicated.

4.2.15

fixed content addressable storage (FCAS)

storage optimized to manage content addressable data that is not expected to change during its lifetime

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4.2.16

formatted capacity

total number of bytes available to be written after a system or device has been formatted for use, e.g., by an object store, file system or block services manager

Note 1 to entry: Formatted capacity, also called usable capacity, is less than or equal to raw capacity. It does not include areas set aside for system use, spares, RAID parity areas, checksum space, host- or file system-level remapping, "right sizing" of disks, disk labeling and so on. However, it may include areas that are normally reserved—such as snapshot set-asides—if they can alternatively be configured for ordinary data storage by the storage administrator.

4.2.17

free space

amount of additional irreducible data that can be written to the product under test as configured

4.2.18

hot band

simulation of naturally occurring hot spots

4.2.19

hot spot

area of storage more frequently accessed across the addressable space

4.2.20

IO intensity

measure of the number of IOPS requested by a load generator

Note 1 to entry: IO intensity is phrased as a percentage of selected maximum IOPS level that satisfies the timing requirement(s) for a taxonomy category.

4.2.21

irreducible data

data that is neither compressible nor dedupable

4.2.22

load generator

hardware and software environment executing the workload generator to drive the product under test during measurements

4.2.23

Logical Unit (LU)

entity within a SCSI target that executes IO commands

4.2.24

Logical Unit Number (LUN)

synonym for logical unit

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4.2.25

Maximum Time to First Data (MaxTTFD)

maximum time required to start receiving data from a storage system to satisfy a read request for arbitrary data

4.2.26

network-connected

storage designed to be connected to a host via a network protocol (e.g., TCP/IP, IB, and FC)

4.2.27

non-disruptive serviceability

support for continued availability of data during all FRU service operations, including break/fix, code patches, software/firmware upgrades, configuration changes, data migrations, and system expansion

Note 1 to entry: Service operations may impact performance, but shall not result in a loss of access.

4.2.28

parity RAID

collective term used to refer to Berkeley RAID Levels 3, 4, 5 and 6

4.2.29

permanent storage

data storage media which can retain data indefinitely without a power source

4.2.30

product under test

customer-orderable system or component that is the subject of a SNIA Emerald™ Power Efficiency Measurement

4.2.31

raw capacity

sum of the raw, unformatted, uncompressed capacity of each storage device in the product under test

4.2.32

ready idle

operational state in which a system is capable of satisfying an arbitrary IO request within the response time and MaxTTFD constraints of its selected taxonomy category, but no user-initiated IO requests are being submitted to the system. In the ready idle state, background I/O activity, autonomously initiated by the solution under test, may take place

4.2.33

sequential read

IO load consisting of consecutively issued read requests to logically adjacent data

4.2.34

sequential write

IO load consisting of consecutively issued write requests to logically adjacent data

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4.2.35

Single Point of Failure (SPOF)

one component or path in a system, the failure of which would make the system inoperable or data inaccessible

4.2.36

SNIA Emerald™ Power Efficiency Measurement

test performed according to this document

4.2.37

SNIA Emerald™ Power Efficiency Measurement test result

result of a test performed according to this document

4.2.38

solution under test

All hardware and software components that are exercised during a test to verify functional behavior or determine performance characteristics, including all of the hardware and software components involved in a test

Note 1 to entry: It includes the physical and virtual components of the load generator, storage media, and the entire data path between the load generator and the storage media.

4.2.39

stable storage

storage that retains its content over power failures

Note 1 to entry: See Annex C.

4.2.40

storage controller

device for handling storage requests that includes a processor or sequencer programmed to autonomously process a substantial portion of IO requests directed to storage devices

4.2.41

storage device

collective term for disk drives, solid state drives and modules, tape cartridges, and any other mechanisms providing non-volatile data storage

Note 1 to entry: This definition is specifically intended to exclude aggregating storage elements such as RAID array subsystems, robotic tape libraries, filers, and file servers. Also excluded are storage devices which are not directly accessible by end-user application programs, and are instead employed as a form of internal cache.

4.2.42

storage protection

any combination of hardware and software (e.g., RAID, NVRAM, disk sparing and background disk scrubbing or media scan) that assures that all IO operations will be preserved in the event of power loss or storage device failure

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4.2.43

system crash

hardware or software failure which causes data to no longer be available, at least temporarily, and which requires a reboot of one or more hardware components and/or re-initialization of one or more software components in order for data access to be restored

4.2.44

test sponsor

individual, company, or agent that performs a test according to this document

4.2.45

thin provisioning

technology that allocates the physical capacity of a volume or file system as applications write data, rather than pre-allocating all the physical capacity at the time of provisioning

4.2.46

virtual drive

removable media storage device (e.g., tape drive) that is emulated using other storage devices

4.2.47

workload generator

software used in the load generator to drive the product under test during measurement

4.3 Symbols and Abbreviated Terms

CKD	Count-Key-Data
COM	Capacity Optimization Method
FBA	Fixed Block Architecture
FCAS	Fixed Content Addressable Storage
FRU	Field-Replaceable Unit
IT	Information Technology
LU	Logical Unit
LUN	Logical Unit Number
MAID	Massive Array of Idle Disks
MaxTTFD	Maximum Time to First Data
NVRAM	Non-Volatile Random Access Memory
RAS	Reliability, Availability, and Serviceability
SCSI	Small Computer System Interface
SNIA	Storage Networking Industry Association
SPOF	Single Point of Failure
UPS	Uninterruptible Power Supply

4.4 Expression of Provisions

This document uses the verbal forms for expressions of provisions as defined by ISO/IEC Directives Part 2 (Eighth edition, 2018). These verbal forms include shall, shall not, should, should not, may, may not, can, cannot, and must.

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4.5 Conventions

Certain words and terms used in this document have a specific meaning beyond their normal English meaning. These words and terms are defined either in subclause 4.2 or in the text where they first appear.

Storage capacities are represented in base-10. IO transfer sizes and offsets are represented in base-2.

The associated units and abbreviations used in this document are:

- A kilobyte (KB) is equal to 10^3 B.
- A megabyte (MB) is equal to 10^6 B.
- A gigabyte (GB) is equal to 10^9 B.
- A terabyte (TB) is equal to 10^{12} B.
- A petabyte (PB) is equal to 10^{15} B.
- An exabyte (EB) is equal to 10^{18} B.
- A kibibyte (KiB) is equal to 2^{10} B.
- A mebibyte (MiB) is equal to 2^{20} B.
- A gibibyte (GiB) is equal to 2^{30} B.
- A tebibyte (TiB) is equal to 2^{40} B.
- A pebibyte (PiB) is equal to 2^{50} B.
- An exbibyte (EiB) is equal to 2^{60} B.

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5 Taxonomy

5.1 Introduction

This clause defines a market taxonomy that classifies storage products or subsystems in terms of operational profile and supported features.

While this taxonomy is broad and defines a framework for products that range from consumer solutions to enterprise installations, it is not intended to address all storage devices. For example, this taxonomy does not address storage devices that rely on a Universal Serial Bus (USB) connection for their power.

Further, while this document includes definitions for its entire taxonomy, it does not include testing methodologies for the entire taxonomy. Both individual sections of the taxonomy (e.g., Near-Online-1) and broader and more general groups of sections are not addressed beyond taxonomy definition in this document. Their cells in Table 2 are shaded to make it clear that this omission in intentional.

Table 2 – Taxonomy Overview

Level	**Category**			
	Online (see 5.5)	**Near-Online (see 5.6)**	**Removable Media Library (see 5.7)**	**Virtual Media Library (see 5.8)**
Consumer/ Component[a]	Online 1	Near-Online 1	Removable 1	Virtual 1
Low-end	Online 2	Near-Online 2	Removable 2	Virtual 2
Mid-range	Online 3	Near-Online 3	Removable 3	Virtual 3
	Online 4			
High-end	Online 5	Near-Online 5	Removable 5	Virtual 5
Mainframe	Online 6	Near-Online 6	Removable 6	Virtual 6

[a] Entries in this level of taxonomy include both consumer products and data-center components (e.g., stand-alone tape drives)

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5.2 Taxonomy Categories

5.2.1 General

Taxonomy categories define broad market segments that can be used to group products that share common functionality or performance requirements, and within which meaningful product comparison can be undertaken. This document defines four broad taxonomy categories (summarized in Table 2):

- Online, defined in subclause 5.5;
- Near-Online, defined in subclause 5.6;
- Removable Media Library, defined in subclause 5.7;
- Virtual Media Library, defined in subclause 5.8.

Within a taxonomy category, a specific model or release of a product will support different feature sets, whether focused on capacity, reliability, performance, functionality, or another differentiator. Feature and functionality differences within a category are addressed with attributes. Each taxonomy category defines a set of attributes that are common to all products within the category.

5.2.2 Category Attributes

Where a taxonomy category requires a specific, fixed setting or range for a given attribute, that setting is summarized in Table 3 to assist a test sponsor in initial category selection. The full set of attributes for each category is provided in subclauses 5.5 through 5.8.

Table 3 – Common Category Attributes

Attribute	Category			
	Online	Near-Online	Removable Media Library	Virtual Media Library
Access Pattern	Random/ Sequential	Random/ Sequential	Sequential	Sequential
MaxTTFD (t)	t < 80 ms	t > 80 ms	t > 80 ms t < 5 min	t < 80 ms

The attribute Consumer/Component refers to either

- Any of a wide array of manufactured goods which are purchased primarily for personal, family and/or household purposes;
- A data-center component (e.g., a stand-alone tape drive or an individual hard disk drive) that is a part of a data-center storage product.

5.3 Taxonomy Classifications

Classifications define combinations of settings or values for the attributes within a category.

5.4 Taxonomy Rules

A product shall satisfy all the attributes for its designated category and designated classification. If a product satisfies the attributes of multiple classifications, the product may be considered to be in any or all of these classifications. In cases where storage devices within a product fall within more than one category or classification, the product shall be considered a member of the category and classification whose requirements can be met by all of its storage devices.

Maximum Supported Configuration bounds the number of storage devices that the product is capable of supporting.

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A product shall be considered to be of a taxonomy category and classification if, in the Classification Table for the category (Table 4, Table 5. Table 6, or Table 7):

1. The product has each of the features and functionalities listed as ***required*** or described in a table entry;
2. The product has no feature or functionality listed as ***prohibited.***

Note1: The presence or absence of attributes label as Optional has no impact on the category and classification of a product.

Note 2: The nature of features and functionalities listed as Not Specified is not material to the categorization of a product.

Note 3: Based on these rules, it is possible that a product is considered to be of multiple taxonomy categories and/or multiple taxonomy classifications of a category.

5.5 Online Category

This category defines the features and functionalities for an online, random-access storage product. Products in this profile may provide any combination of block, file, or object interfaces. Table 4 defines the requirements for the taxonomy classifications defined in this category.

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Table 4 – Online Classifications

Attribute	Classification					
	Online 1	**Online 2**	**Online 3**	**Online 4**	**Online 5**	**Online 6**
Access Pattern	Random/ Sequential	Random/ Sequential	Random/ Sequential	Random/ Sequential	Random/ Sequential	Random/ Sequential
MaxTTFD (t)	t < 80 ms	t < 80 ms	t < 80 ms	t < 80 ms	t < 80 ms	t < 80 ms
Connectivity	Not Specified	Direct-connected to single or multiple hosts	Network-connected	Network-connected	Network-connected	Network-connected
Consumer/ Component	Yes	No	No	No	No	No
Integrated Storage Controller	Optional	Optional	Required	Required	Required	Required
Storage Protection	Optional	Optional	Required	Required	Required	Required
No SPOF	Optional	Optional	Optional	Required	Required	Required
Stable storage support	Optional, unless Required by protocol	Optional, unless Required by protocol	Required	Required	Required	Required
Non-Disruptive Serviceability	Optional	Optional	Optional	Optional	Required	Required
FBA/CKD Support	Optional	Optional	Optional	Optional	Optional	Required
Maximum Supported Configuration[a]	≥ 1	≥ 4	≥ 12	> 100	> 400	> 400

[a] Maximum Supported Configuration does not apply to an all solid-state system that is not based on replaceable storage devices.

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5.6 Near-Online Category

This category defines the features and functionalities for a near-online, random-access storage product. Products in this profile employ MAID or FCAS architectures as well as any combination of block, file, or object interfaces. Table 5 defines the requirements for this taxonomy classifications defined in this category.

Table 5 – Near-Online Classifications

Attribute	Classification					
	Near-Online 1	**Near-Online 2**	**Near-Online 3**	**Near-Online 4**	**Near-Online 5**	**Near-Online 6**
Access Pattern	Random/ Sequential	Random/ Sequential	Random/ Sequential		Random/ Sequential	Random/ Sequential
MaxTTFD (t)	t > 80 ms	t > 80 ms	t > 80 ms		t > 80 ms	t > 80 ms
Connectivity	Not Specified	Network connected	Network connected		Network connected	Network connected
Consumer/ Component	Yes	No	No		No	No
Integrated Storage Controller	Optional	Optional	Required		Required	Required
Storage Protection	Optional	Optional	Required		Required	Required
No SPOF	Optional	Optional	Optional		Optional	Required
Non-Disruptive Serviceability	Optional	Optional	Optional		Optional	Required
FBA/CKD Support	Optional	Optional	Optional		Optional	Optional
Maximum Supported Configuration	≥ 1	≥ 4	≥ 12		> 100	> 1 000

5.7 Removable Media Library Category

This category defines the features and functionalities for storage products that rely on automated or manual media loaders (e.g., tape or optical libraries). Table 6 defines the requirements for the taxonomy classifications defined in this category.

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