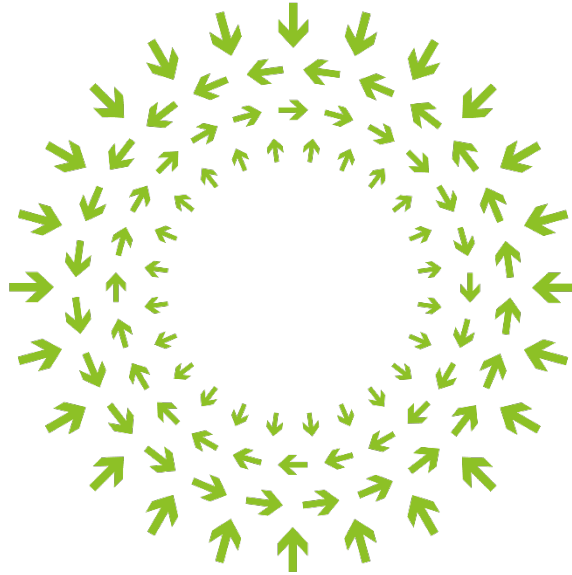




OPEN
Compute Project

Datacenter SAS-SATA Device Specification

Version 1.0 (03282023)

Author: Ross Stenfort, Madhavan Ravi, Meta

Author: Lee Prewitt, Microsoft

Author: Paul Kaler, HPE

Table of Contents

1	License OWF Option.....	5
2	Overview	5
3	Scope.....	5
4	Common Interface Requirements	5
4.1	SMR Requirements	6
4.2	Device Profile	6
4.3	Volatile Write Cache Enabled Behavior	6
5	SATA Requirements	7
5.1	SATA and ATA Requirements	7
5.2	SATA PHY Layer Requirements	14
5.3	SATA LINK Layer Requirements.....	15
5.4	SATA Command Layer Requirements	15
5.4.1	Identify Device (Command code: ECh)	15
5.4.2	Read Log Ext (Command code: 2Fh)	16
5.4.3	Request Sense Data Ext (Command Code: 0Bh)	18
5.4.4	Sanitize Device Commands	18
5.4.5	Set Features (Command code: EFh).....	19
5.4.6	Sleep (Command code: E6h).....	20
5.4.7	Standby (Command code: E2h).....	20
5.4.8	Write DMA FUA Ext (Command code: 3Dh)	20
5.4.9	Write Uncorrectable Ext (Command code: 45h).....	21
6	SAS Requirements.....	21
6.1	SAS Requirements.....	21
6.2	SAS PHY Layer Requirements.....	22
6.3	SAS LINK Layer Requirements.....	22
6.4	SAS Command Layer Requirements.....	22
6.4.1	Supported Commands	22
6.4.2	Sanitize Device Commands	26
6.4.3	VPD Pages	27
6.4.4	Mode Pages.....	27
6.4.5	Log Pages.....	29
6.5	Dual port Requirements.....	30

7	Power	32
8	Reliability.....	35
8.1	MTBF / AFR Requirements	35
8.2	Load / Unload Cycles	36
8.3	EPO / Sudden Power Loss	37
8.4	Data Integrity / End to End Data Protection	37
8.5	UBER.....	37
8.6	ORT Requirement.....	38
8.7	Behavior on Assert / Firmware Crash	38
8.8	Head Wear-out / Degradation	38
8.9	Shelf Life	38
9	Performance Requirements.....	38
9.1	Time to Ready	38
9.2	Sequential Performance Requirements.....	39
9.3	Random Read Performance Requirements	39
9.4	Random Write Performance Requirements	39
9.5	Latency Requirements	40
9.6	Maximum Command Timeout	40
9.7	Power Mode Transition Times	40
9.8	Write Cache Flushing Latency	40
9.9	Multi-actuator Specific Considerations.....	41
10	Environmental.....	41
10.1	Thermal	41
10.2	Altitude.....	41
10.3	Humidity.....	42
10.4	Mechanical	42
10.4.1	Form Factor Requirements	42
10.4.2	Weight.....	43
10.4.3	Shock and Vibration	43
11	Sustainability Requirements	44
12	Security	44
12.1	Basic Security Requirements.....	44
12.2	Secure Boot.....	48

13	Labeling	49
13.1	Top Cover Label Requirements	49
13.2	Edge Label Requirements	54
14	Compliance	54
14.1	ROHS Compliance	54
14.2	ESD Compliance	54
15	Appendix A	55

1 License OWF Option

Contributions to this Specification are made under the terms and conditions set forth in Open Web Foundation Contributor License Agreement (“OWF CLA 1.0”) (“Contribution License”) by:

HPE

Meta

Microsoft

Usage of this Specification is governed by the terms and conditions set forth in the Open Web Foundation Final Specification Agreement (“OWFa 1.0”).

Note: The following clarifications, which distinguish technology licensed in the Contribution License and/or Specification License from those technologies merely referenced (but not licensed), were accepted by the Incubation Committee of the OCP:

NONE

2 Overview

This document is to define the requirements for HDDs and SSDs for use in data centers.

3 Scope

This document covers HDDs and SSDs using the SAS and SATA interface.

4 Common Interface Requirements

Requirement ID	Description
COMM-1	From the factory, the firmware revision field shall match the firmware revision on the label. See LABL-1.
COMM-2	The device shall have volatile write cache disabled by default from the factory.
COMM-3	The device shall have non-volatile (e.g., power loss protected) write cache enabled by default from the factory.
COMM-4	Device vendors shall support standard and vendor unique diagnostic information to be extracted for failure analysis and telemetry monitoring.
COMM-5	The device shall support firmware update without power cycling the devices.
COMM-6	The device shall have default maximum I/O command error recovery time out of 10 seconds.
COMM-7	The device shall support FW download and activation within 10 seconds when idle.
COMM-8	The device shall support FW download and activation within 20 seconds with any workload.
COMM-9	HDDs shall support the logical depopulation feature.

Requirement ID	Description
COMM-10	Any optional features supported by the device not described in this document shall be clearly documented and disclosed to the customer.
COMM-11	Any vendor unique features supported by the device not described in this document shall be clearly documented and disclosed to the customer.
COMM-12	The vendor shall provide a SATA/ SAS compliance report (e.g., ULINK or equivalent) depending on the device type.
COMM-13	The device shall report capacity values with IDEMA established guidelines for devices less than 8 TB and SFF-8447 for 8TB and greater.
COMM-14	For HDDs, the vendor shall provide a single firmware binary that includes both device microcode and servo firmware.

4.1 SMR Requirements

If the device supports SMR, the following requirements shall be met.

Requirement ID	Description
SMR-1	SMR HDDs shall comply with ZAC-2 SATA / ZBC-2 SAS specifications.
SMR-2	SMR HDDs shall reserve 0.8% of total drive capacity as CMR zone for journaling and logging purposes.
SMR-3	Each SMR zone shall be 128MB in size.
SMR-4	Host Managed drives shall always return the last LBA of the Conventional space after successfully processing the READ CAPACITY (16) command i.e., the RC_BASIS field shall always be 00b.
SMR-5	A Host Managed device processing a SECURITY ERASE UNIT command shall comply with the following: • If the ZAC SECURITY OPTION bit=0b, then all write pointer zones shall become EMPTY. • If the ZAC SECURITY OPTION bit=1b, the device shall ABORT the SECURITY ERASE UNIT command.

4.2 Device Profile

The following are device profiles. This section is intended to be firmware-based configuration settings configured by device suppliers when manufacturing a device. A device may be configured with a mix of A and/or B settings. Each customer shall provide their A/B preference for each configuration setting.

Requirement ID	Description	Configuration Setting	
		A	B
DP-CFG-1	Default Supported Sector Size	4096 Native	512/ 512e

4.3 Volatile Write Cache Enabled Behavior

This section specifies how the device shall behave with regards to Write Cache operations if it is enabled.

Requirement ID	Description
WCH-1	If write cache is enabled and the device has returned a write command completion status, then any cached data that has not yet been written to the medium shall be preserved through any “reset event” and written to the medium. “Reset event” refers to any HW/SW/LINK reset.
WCH-2	Any link associated protocol (valid or invalid), any disparity issue, any PHY operation issue (PHY reset), any elasticity buffer issue, any port mode or port mode operations change (power management or speed change), or any interface signal timing or amplitude problem shall not prevent cached write data of completed write commands from being written to the medium. Assuming power delivery is correct and has been properly maintained with the proper operational environmental conditions, ANY issue with deviations or changes shall not cause data loss or corruption when write caching is enabled.
WCH-3	The device shall flush cached write data to the medium prior to: • Acknowledging a power management command (STANDBY, SLEEP, etc.) that may cause the media to be inaccessible, or • Transitioning into any device maintenance or self-test routine either scheduled or non-scheduled (e.g., idle time functions such as head sweeps, BGMS, etc.), or • Transitioning into any power reduction state or mode, or • Returning successful completion on the disable write cache command.
WCH-4	The device is responsible for: • Invoking auto write reallocation in error recovery to successfully write cached data if needed. • Either temporarily or permanently disabling write caching if current operating conditions indicate normal writes are at risk.
WCH-5	In the event an error occurs preventing the device from writing any cached data to the medium the device shall report a Device Fault error in the Status register on the next (earliest subsequent) command.
WCH-6	The write cache flushing commands shall take no more than 10 seconds at any conditions if write cache is enabled. The write cache flushing commands refer to FLUSH CACHE / FLUSH CACHE EXT for SATA device and SYNCHRONIZE CACHE for SAS device.

5 SATA Requirements

If the device supports SATA, the following requirements shall be met.

5.1 SATA and ATA Requirements

Requirement ID	Description
SATA-1	The device shall comply with Serial ATA Revision 3.5a or newer.
SATA-2	The device shall comply with ATA Command Set - 5 (ACS-5) or newer.
SATA-3	The device shall follow the table below regarding support for ATA Feature Sets. • M = Mandatory. Command shall be supported. • P = Prohibited. Command shall not be supported (command rejected with ABRT).

Requirement ID	Description	
	O = Optional. Command support is optional.	
	ATA Feature Set	Support
	48-bit Address feature set	M
	Accessible Max Address Configuration feature set	P
	Advanced Background Operation feature set	P
	Advanced Power Management (APM) feature set	P
	CompactFlash Association (CFA) feature set	P
	Device Statistics Notifications (DSN) feature set	P
	Extended Power Conditions (EPC) feature set	M ¹
	Free-fall Control feature set	P
	General feature set	M
	General Purpose Logging (GPL) feature set	M
	Hybrid Information feature set	P
	Long Logical Sector (LLS) feature set	P
	Long Physical Sector (LPS) feature set	P
	Native Command Queuing (NCQ) feature set	M ²
	Power Management feature set	M
	Power-Up In Standby (PUIS) feature set	M ¹
	Rebuild Assist feature set	P
	Sanitize Device feature set	M ³
	SATA Hardware Feature Control feature set	P
	Security feature set	M
	Self-Monitoring, Analysis, and Reporting Technology (SMART) feature set (Include SMART self-test, SMART error logging)	M
	Sense Data Reporting feature set	Yes ¹
	Software Settings Preservation (SSP) feature set	M ²
	Streaming feature set	P
	Trusted Computing feature set	M (for devices that support TCG Opal)
	Write-Read-Verify feature set	M ¹
	Guaranteed In-order Data Delivery feature set	P
	Non-zero buffer offset in DMA Setup FIS feature set	P

Requirement ID	Description	
	Device Sleep feature set	M ¹
	Read look-ahead feature set	M ²
	Free-fall Control feature set	P
	Optional ATA device 28-bit commands feature set	P
	NCQ priority information feature set	M
	Notes: 1. Shall be disabled by default. 2. Shall be enabled by default. 3. The SANITIZE FREEZE LOCK EXT and the SANITIZE ANTIFREEZE LOCK EXT commands of the Sanitize Device feature set shall both be supported.	
SATA-4	The device shall support a negotiated link speed of up to 6Gbps	
SATA-5	The following SMART attributes shall be included in the device’s SMART log:	
	Attribute ID	Description
	1	Read Error Rate
	3	Spin Up Time
	4	Start/Stop Count
	5	Reallocated Sector Count
	7	Seek Error Rate
	9	Power-On Hours
	10	Spin Retry Count
	12	Device Power Cycle Count
	184	End-to-End error / IOEDC
	187	Reported unrecoverable read errors
	188	Command Timeout
	189	High Fly Writes
	192	Power-Off Retract Count
	193	Load/Unload Cycle Count
	194	Temperature
	197	Current Pending Sector Count
	198	Off-Line Scan Uncorrectable Sector Count
	199	CRC Error/Frame Error Count
	241	Total LBAs Written
	242	Total LBAs Read
SATA-6	The device shall follow the table below regarding support for log pages: • M = Mandatory. Log Page shall be supported. • P = Prohibited. Log Page shall not be supported (command rejected with ABRT). • O = Optional. Log Page support is optional.	

Requirement ID	Description		
	Log Address	Log Name	Support
	00h	Log directory	M
	01h	Summary SMART error log	P
	02h	Comprehensive SMART error log	P
	03h	Extended comprehensive SMART error log	M
	04h	Device statistics	M
	06h	SMART Self-test log	M
	07h	Extended SMART self-test log	M
	08h	Power conditions	M
	09h	SMART Selective self-test	P
	0Ah	Device Statistics Notification	P
	0Ch	Pending defects	M
	0Dh	LPS Misalignment	P
	0Fh	Sense data for successful NCQ commands	P
	10h	NCQ error log	M
	11h	SATA PHY event counters	M
	12h	SATA NCQ Non-Data log	P
	13h	SATA NCQ Send and Receive log	P
	14h	Hybrid Information	P
	15h	Rebuild Assist log	P
	19h	LBA Status	P
	21h	Write Stream Error log	P
	22h	Read Stream Error log	P
	24h	Current Device Internal Status Data log	M
	25h	Saved Device Internal Status Data log	P
	2Fh	Set Sector Configuration log	P
	30h	Identify device data	M
	80h..9Fh	Host specific logs	P
	E0h	SCT Command/Status log	M
	E1h	SCT Data Transfer log	M
SATA-7	The device shall support the following statistics logs:		
	Log Page	Description	
	00h	List of supported log pages	
	01h	General Statistics	
	03h	Rotating Media Statistics ¹	
	04h	General Error Statistics	
	05h	Temperature Statistics	

Requirement ID	Description																									
	06h	Transport Statistics																								
	07h	Solid State Device Statistics ²																								
	Notes: 1. Not required for SSD. 2. Not required for HDD.																									
SATA-8	The device shall support host-initiated power management (HIPM).																									
SATA-9	Host-initiated power management (HIPM) shall be disabled by default.																									
SATA-10	The device shall not support Host Automatic Partial to Slumber transitions.																									
SATA-11	The device shall not support device-initiated power management (DIPM).																									
SATA-12	The device shall not support Device Automatic Partial to Slumber transitions.																									
SATA-13	The device shall implement the set feature command to support the power disable feature.																									
SATA-14	The device shall implement the set feature command to support modification of maximum I/O command error recovery timeout. Subcommand code D6h shall be used with the definitions below for the count field: - Count [15:8] Reserved. Clear to zero. - Count [7:0] Command timeout in seconds. A value of 00h disables the command timeout¹. The value shall be preserved across power cycles and resets. ¹ Supplier shall document the minimum timeout value supported by warranty in drive specification and the drive label. See LABL-22.																									
SATA-15	AC coupling is required at both physical transmitter and receiver interfaces.																									
SATA-16	The device shall follow the table below regarding support for optional T13 commands. - M = Mandatory. Command shall be supported. - P = Prohibited. Command shall not be supported (command rejected with ABRT). - O = Optional. Command support is optional. All mandatory commands shall be enabled by default. <table border="1"> <thead> <tr> <th>Command</th><th>Command / Feature Code</th><th>Support</th></tr> </thead> <tbody> <tr> <td>DATA SET MANAGEMENT</td><td>06h</td><td>M (SSD only)</td></tr> <tr> <td>DATA SET MANAGEMENT XL</td><td>07h</td><td>M (SSD only)</td></tr> <tr> <td>DOWNLOAD MICROCODE</td><td>92h</td><td>M</td></tr> <tr> <td>DOWNLOAD MICROCODE DMA</td><td>93h</td><td>P</td></tr> <tr> <td>SLEEP</td><td>E6h 99h</td><td>M P</td></tr> <tr> <td>FLUSH CACHE</td><td>E7h</td><td>M</td></tr> <tr> <td>FLUSH CACHE EXT</td><td>EAh</td><td>M</td></tr> </tbody> </table>		Command	Command / Feature Code	Support	DATA SET MANAGEMENT	06h	M (SSD only)	DATA SET MANAGEMENT XL	07h	M (SSD only)	DOWNLOAD MICROCODE	92h	M	DOWNLOAD MICROCODE DMA	93h	P	SLEEP	E6h 99h	M P	FLUSH CACHE	E7h	M	FLUSH CACHE EXT	EAh	M
Command	Command / Feature Code	Support																								
DATA SET MANAGEMENT	06h	M (SSD only)																								
DATA SET MANAGEMENT XL	07h	M (SSD only)																								
DOWNLOAD MICROCODE	92h	M																								
DOWNLOAD MICROCODE DMA	93h	P																								
SLEEP	E6h 99h	M P																								
FLUSH CACHE	E7h	M																								
FLUSH CACHE EXT	EAh	M																								

Requirement ID	Description		
	NOP	00h	M
	READ BUFFER	E4h	M
	READ DMA (w/retry)	C8h	M
	READ DMA EXT	25h	M
	READ DMA QUEUED	C7h	P
	READ DMA QUEUED EXT	26h	P
	READ FPDMA QUEUED	60h	M
	READ LOG DMA EXT	47h	M
	READ SECTOR(S) (w/retry)	20h	M
	READ SECTOR(S) EXT	24h	M
	READ VERIFY SECTOR(S) (w/retry)	40h	M
	READ VERIFY SECTOR(S) EXT	42h	M
	NCQ—ABORT NCQ QUEUE	63h/00h	P
	NCQ—DEADLINE HANDLING	63h/01h	P
	SET FEATURES (APM Sub-command only)	63h/05h	P
	ZERO EXT	63h/06h	P
	RECEIVE FPDMA QUEUED	65h	M
	REQUEST SENSE DATA EXT	0Bh	M
	BLOCK ERASE EXT	B4h/0012h	M (SSD only)
	CRYPTO SCRAMBLE EXT	B4h/0011h	M
	OVERWRITE EXT	B4h/0014h	M (HDD only)
	SANITIZE ANTIFREEZE LOCK EXT	B4h/0040h	M
	SANITIZE FREEZE LOCK EXT	B4h/0020h	M
	SANITIZE STATUS EXT	B4h/0000h	M
	SET DATE & TIME EXT	77h	M
	SMART EXECUTE OFF-LINE IMMEDIATE	B0h/D4h	M
	SMART READ DATA	B0h/D0h	M
	SMART READ LOG	B0h/D5h	M
	SMART RETURN STATUS	B0h/DAh	M

Requirement ID	Description		
	SMART WRITE LOG	B0h/D6h	M
	TRUSTED NON-DATA	5Bh	M (TCG only)
	TRUSTED RECEIVE	5Ch	M (TCG only)
	TRUSTED RECEIVE DMA	5Dh	M (TCG only)
	TRUSTED SEND	5Eh	M (TCG only)
	TRUSTED SEND DMA	5Fh	M (TCG only)
	WRITE BUFFER	E8h	M
	WRITE DMA (w/retry)	CAh	M
	WRITE DMA EXT	35h	M
	WRITE DMA FUA EXT	3Dh	M
	WRITE DMA QUEUED	CCh	P
	WRITE DMA QUEUED EXT	36h	P
	WRITE DMA QUEUED FUA EXT	3Eh	P
	WRITE FPDMA QUEUED	61h	M
	WRITE LOG DMA EXT	57h	M
	WRITE SAME – SCT command	Action/Function	M
	Repeat write pattern in background	0002h/0001h	M
	Repeat write data block in background	0002h/0002h	M
	Repeat write pattern in foreground	0002h/0101h	M
	Repeat write data block in foreground	0002h/0102h	M
	WRITE SECTOR(S) (w/retry)	30h	M
	WRITE SECTOR(S) EXT	34h	M
	WRITE UNCORRECTABLE EXT	45h	M
	CLOSE ZONE EXT	9Fh/01h	M (SMR only)
	FINISH ZONE EXT	9Fh/02h	M

Requirement ID	Description																		
	(SMR only)																		
	OPEN ZONE EXT 9Fh/03h M (SMR only)																		
	REPORT ZONES EXT 4Ah/00h M (SMR only)																		
	RESET WRITE POINTER EXT 9Fh/04h M (SMR only)																		
SATA-17	The device shall support the following features and default settings: <table> <tr> <th>Feature</th><th>Default Setting</th></tr> <tr> <td>Spread Spectrum Clocking (SSC) receive from host</td><td>Enabled</td></tr> <tr> <td>Spread Spectrum Clocking (SSC) transmit to host at 6Gbps</td><td>Enabled</td></tr> <tr> <td>Spread Spectrum Clocking (SSC) transmit to host at 1.5Gbps or 3.0Gbps</td><td>Disabled</td></tr> <tr> <td>Pin 11 delay spin</td><td>Enabled</td></tr> <tr> <td>Hot-plug capable</td><td>Enabled</td></tr> <tr> <td>Off-line read scan</td><td>Enabled</td></tr> <tr> <td>SCT</td><td>Enabled</td></tr> <tr> <td>Segmented DOWNLOAD MICROCODE</td><td>Enabled</td></tr> </table>	Feature	Default Setting	Spread Spectrum Clocking (SSC) receive from host	Enabled	Spread Spectrum Clocking (SSC) transmit to host at 6Gbps	Enabled	Spread Spectrum Clocking (SSC) transmit to host at 1.5Gbps or 3.0Gbps	Disabled	Pin 11 delay spin	Enabled	Hot-plug capable	Enabled	Off-line read scan	Enabled	SCT	Enabled	Segmented DOWNLOAD MICROCODE	Enabled
Feature	Default Setting																		
Spread Spectrum Clocking (SSC) receive from host	Enabled																		
Spread Spectrum Clocking (SSC) transmit to host at 6Gbps	Enabled																		
Spread Spectrum Clocking (SSC) transmit to host at 1.5Gbps or 3.0Gbps	Disabled																		
Pin 11 delay spin	Enabled																		
Hot-plug capable	Enabled																		
Off-line read scan	Enabled																		
SCT	Enabled																		
Segmented DOWNLOAD MICROCODE	Enabled																		
SATA-18	Download Microcode shall support modes 03h, 0Eh, and 0Fh.																		
SATA-19	If the SSD device has Power Loss Protection (PLP) (e.g., battery back-up, capacitor bank, or super cap), then the SSD device shall periodically initiate tests of the PLP, even if power is never removed from the device. The PLP shall have sufficient charge to back up all user data and/or metadata in the cache. If it fails or degrades to a point that it cannot guarantee sufficient charge to back up all user data and/or metadata in the cache, the SSD device shall do the following: • Flush all cached writes to NAND. • Disable the volatile write cache if the volatile write cache is currently enabled. • Generate a SMART trip (threshold exceeded) in response to a SMART RETURN STATUS command (Power Loss Protection Failure). • Set WCE to 0b in IDENTIFY DEVICE data word 85, bit 5. • Return an error, i.e., ABRT (ST:51h ER:40h) to host attempts to enable write cache.																		
SATA-20	The SSD device shall support the DATA SET MANAGEMENT command with the Trim bit. Every single LBA specified by the DATA SET MANAGEMENT command with the Trim bit set shall be trimmed (“deterministic zeroes data”).																		

5.2 SATA PHY Layer Requirements

Requirement ID	Description
SATA-PHY-1	The device shall include controls for setting driver strength, pre-emphasis amounts, and (if implemented) receiver equalization gains.

Requirement ID	Description
SATA-PHY-2	The HDD device shall complete spin-down within 10 seconds from: • Power removal / power loss. • Any command that causes the device to spin down from an active (spinning at speed) state.
SATA-PHY-3	The HDD device by default shall enable “staggered spin-up” regardless of pin 11 state (i.e., signal input level) after DC power is applied. The HDD device shall only spin-up after receiving a COMWAKE.
SATA-PHY-4	The device shall support all BIST modes (mandatory and optional) for loopback testing with SATA devices with proper support of the BIST Activate FIS bits F, L, T, A, S, and P.
SATA-PHY-5	All mandatory PHY Event Counter identifiers shall be supported as defined by Serial ATA Revision 3.5a, section 13.9.3. PHY Event Counter identifiers 00Bh (CRC errors within a host-to-device FIS) and 00Dh (Non-CRC errors within a host-to-device FIS) shall also be supported and updated to reflect the number of instances of that particular event. All supported PHY Event Counter identifiers shall be reported regardless of the event count.

5.3 SATA LINK Layer Requirements

Requirement ID	Description
SATA-LINK-1	If the device receives an invalid Dword (including an R_ERR primitive or a character with bad disparity) inside a frame, it shall treat the frame (if any) as having a CRC error, regardless of whether the CRC is correct. The device shall terminate a WRITE command due to any link-associated error (CRC). The bad data associated with the command shall not be written to the media, and no reduction in normal device performance shall occur due to this type of device error-handling operation.

5.4 SATA Command Layer Requirements

5.4.1 Identify Device (Command code: ECh)

Requirement ID	Description
SATA-ID-1	The device shall set the IDENTIFY DEVICE data words correctly to reflect all requirements listed in this document (e.g., supported features, default enabled/disabled, version/revision number, capacity values, etc.).
SATA-ID-2	The device shall report current negotiated Serial ATA signal speed

5.4.2 Read Log Ext (Command code: 2Fh)

Requirement ID	Description			
SATA-RLE-1	The device shall support Logs and Pages via the Read Log Ext command per the table below.			
	• M = Mandatory. Log/Page shall be supported. • P = Prohibited. Log/Page shall not be supported (command rejected with ABRT). • O = Optional. Log/Page support is optional.			
	Log Address	Support	Logs and Pages	
	00h	M	Log directory	
	01h	P	Summary SMART Error log	
	02h	P	Comprehensive SMART error log	
	03h	M	Extended Comprehensive SMART error log	
	04h	M	Device Statistics logs	
			Page	Description
			HDD	SSD
			00h	List of supported log pages
			01h	General Statistics
			02h	Free-fall Statistics
			03h	Rotating Media Statistics
			04h	General Errors Statistics
			05h	Temperature Statistics
			06h	Transport Statistics
			07h	Solid State Device Statistics
	05h	P	Reserved	
	06h	M	SMART self-test log	
	07h	M	Extended SMART self-test log	
	08h	M	Extended Power Conditions	
	09h	P	Selective Self-Test log	
	0Ah	P	Device Statistics Notification	
	0Bh	P	Reserved	
	0Ch	M	Pending Defects log	
	0Dh	P	(LPS) Long Physical Sector Mis-alignment log	
	0Eh	P	Reserved	
	0Fh	P	Sense Data for Successful NCQ Commands log	
	10h	M	Native queued (FPDMA command) error log (see Serial ATA Revision 3.4)	
	11h	M	SATA PHY Event Counters log	
	12h	P	SATA NCQ Non-data log	

Requirement ID	Description		
	13h	P	SATA NCQ Send and Receive log
	14h	P	Hybrid Information Log
	15h	P	Rebuild Assist Log
	16h-17h	P	Reserved for Serial ATA (required as development of the log(s) completed)
	18h	P	Reserved
	19h	P	LBA Status
	1Ah – 1Fh	P	Reserved
	20h	P	Obsolete
	21h	P	Write stream error log
	22h	P	Read stream error log
	23h	P	Obsolete
	24h	P	Current Device Internal Status Data Log
	25h	P	Saved Device Internal Status Data log
	26h – 2Eh	P	Reserved
	2Fh	P	Set Sector Configuration
	30h	M	IDENTIFY DEVICE data (log pages 00h – 06h, and 08h)
	31h – 7Fh	P	Reserved
	80h-9Fh	P	Host Specific
	A0h-B5h	O	Device vendor specific
	B6h	P	Reserved
	B7h-BAh	O	Device vendor specific
	BCh-CFh	O	Device vendor specific
	D0h	P	Reserved
	D1h-D6h	O	Device vendor specific
	D8h-DFh	O	Device vendor specific
	E0h	M	SCT Command/Status
	E1h	M	SCT Data Transfer
	E2h-FFh	P	Reserved
SATA-RLE-2	SATA devices shall return sense data 05/24/00 (INVALID FIELD IN CDB) for unsupported log addresses.		

5.4.3 Request Sense Data Ext (Command Code: 0Bh)

Requirement ID	Description														
SATA-RSDE-1	This 48-bit command allows the host to obtain the most recent sense data from the device if the Sense Data reporting feature set is supported and sense data reporting is enabled via SET FEATURES command (referring to below table). The sense key, additional sense code, and additional sense code qualifier fields shall be set to values defined in the table below. Otherwise, the sense key, additional sense code, and additional sense code qualifier shall be cleared to zero.														
	<table><tr><th>Condition</th><th>Required Sense Data</th></tr><tr><td>Unsupported command</td><td>05/20/00 (ILLEGAL REQUEST-INVALID COMMAND OPERATION CODE)</td></tr><tr><td>Supported command attempting to access unsupported log address or log page</td><td>05/24/00 (ILLEGAL REQUEST- INVALID FIELD IN CDB)</td></tr><tr><td>ATA NOP command w/ subcommand 00h (Return command aborted)</td><td>0B/00/00 (ABORTED COMMAND-NO ADDITIONAL SENSE INFORMATION)</td></tr><tr><td>Supported command with invalid fields (obsolete, reserved values, etc.)</td><td>05/24/00 (ILLEGAL REQUEST- INVALID FIELD IN CDB)</td></tr><tr><td>Supported command attempting to access invalid LBAs</td><td>05/21/00 (ILLEGAL REQUEST- LOGICAL BLOCK ADDRESS OUT OF RANGE)</td></tr><tr><td>Other condition</td><td>See ANSI T10 SPC-5</td></tr></table>	Condition	Required Sense Data	Unsupported command	05/20/00 (ILLEGAL REQUEST-INVALID COMMAND OPERATION CODE)	Supported command attempting to access unsupported log address or log page	05/24/00 (ILLEGAL REQUEST- INVALID FIELD IN CDB)	ATA NOP command w/ subcommand 00h (Return command aborted)	0B/00/00 (ABORTED COMMAND-NO ADDITIONAL SENSE INFORMATION)	Supported command with invalid fields (obsolete, reserved values, etc.)	05/24/00 (ILLEGAL REQUEST- INVALID FIELD IN CDB)	Supported command attempting to access invalid LBAs	05/21/00 (ILLEGAL REQUEST- LOGICAL BLOCK ADDRESS OUT OF RANGE)	Other condition	See ANSI T10 SPC-5
	Condition	Required Sense Data													
	Unsupported command	05/20/00 (ILLEGAL REQUEST-INVALID COMMAND OPERATION CODE)													
	Supported command attempting to access unsupported log address or log page	05/24/00 (ILLEGAL REQUEST- INVALID FIELD IN CDB)													
	ATA NOP command w/ subcommand 00h (Return command aborted)	0B/00/00 (ABORTED COMMAND-NO ADDITIONAL SENSE INFORMATION)													
	Supported command with invalid fields (obsolete, reserved values, etc.)	05/24/00 (ILLEGAL REQUEST- INVALID FIELD IN CDB)													
	Supported command attempting to access invalid LBAs	05/21/00 (ILLEGAL REQUEST- LOGICAL BLOCK ADDRESS OUT OF RANGE)													
Other condition	See ANSI T10 SPC-5														

5.4.4 Sanitize Device Commands

Requirement ID	Description	
SATA-SDC-1	The device shall support the Sanitize feature set commands in the table below:	
	Feature	Command
	0000h	SANITIZE STATUS EXT
	0011h	CRYPTO SCRAMBLE EXT
	0012h	BLOCK ERASE EXT
	0014h	OVERWRITE EXT
	0020h	SANITIZE FREEZE LOCK EXT
	0040h	SANITIZE ANTIFREEZE LOCK EXT
SATA-SDC-2	The device shall service READ LOG EXT, READ LOG DMA EXT, and SMART READ LOG commands during Sanitize operations.	
SATA-SDC-3	The device shall be able to provide any requested log page while a Sanitize operation is under way.	
SATA-SDC-4	Specifically, if a Sanitize operation is in progress and a READ LOG EXT command is received requesting the SCT Command/Status log (E0h) log, the device shall not return an error, but rather, shall service the command by returning all current content for the log page. All of the content of the page shall be available and be current, but most critical to the host	

Requirement ID	Description
	application, is the current most recent temperature reading (byte 200 (HDA Temp (Current device HDA temperature in deg. C) retrieved by the device's temperature sensor at the time the command is received from the host.
SATA-SDC-5	After a Sanitize operation is completed, the device shall enable reads to the sanitized LBAs without generating errors. After a CRYPTOGRAPHIC ERASE service action per SEC-52, the device shall return all zeros for host reads to LBAs that have not been written since the last Sanitize command.

5.4.5 Set Features (Command code: EFh)

Requirement ID	Description																					
SATA-SF-1	The device shall support SET FEATURES subcommand (Feature register) values 10h and 90h to facilitate the enabling or disabling of the feature items in the table below. - M = Mandatory. Feature shall be supported. - P = Prohibited. Feature shall not be supported (command rejected with ABRT). - O = Optional. Feature support is optional.																					
	<table><tr><th>Subcommand</th><th>Feature</th><th>Support</th></tr><tr><td>01h</td><td>Non-zero buffer offset in DMA Setup FIS</td><td>P</td></tr><tr><td>02h</td><td>DMA Setup FIS Auto-Activate optimization</td><td>M¹</td></tr><tr><td>03h</td><td>Device-initiated interface power state transitions</td><td>P</td></tr><tr><td>04h</td><td>Guaranteed In-order Data Delivery</td><td>P</td></tr><tr><td>05h</td><td>Asynchronous Notification</td><td>P</td></tr><tr><td>06h</td><td>Software Settings Preservation</td><td>M</td></tr></table>	Subcommand	Feature	Support	01h	Non-zero buffer offset in DMA Setup FIS	P	02h	DMA Setup FIS Auto-Activate optimization	M ¹	03h	Device-initiated interface power state transitions	P	04h	Guaranteed In-order Data Delivery	P	05h	Asynchronous Notification	P	06h	Software Settings Preservation	M
	Subcommand	Feature	Support																			
	01h	Non-zero buffer offset in DMA Setup FIS	P																			
	02h	DMA Setup FIS Auto-Activate optimization	M ¹																			
	03h	Device-initiated interface power state transitions	P																			
	04h	Guaranteed In-order Data Delivery	P																			
	05h	Asynchronous Notification	P																			
	06h	Software Settings Preservation	M																			
Notes:																						
¹ Shall be disabled by default.																						
SATA-SF-2	IDENTIFY DEVICE data words 89 and 90 shall report erase time and NOT be affected by this SET FEATURE protocol. In other words, these particular words, 89 and 90, for reporting Normal Erase time and Enhanced Erase time, shall always report the erase time regardless of the activation/deactivation status of this feature.																					
SATA-SF-3	The device shall support the subcommand codes for the Feature register of the command Set Feature task file per the table below. - M = Mandatory. Subcommand code shall be supported. - P = Prohibited. Subcommand code shall not be supported (command rejected with ABRT). - O = Optional. Subcommand codes support is optional.																					
	<table><tr><th>Subcommand</th><th>Feature Description</th><th>Support</th></tr><tr><td>02h</td><td>Enable write cache</td><td>M</td></tr><tr><td>03h</td><td>Set transfer mode based on value in Sector Count register</td><td>M</td></tr></table>	Subcommand	Feature Description	Support	02h	Enable write cache	M	03h	Set transfer mode based on value in Sector Count register	M												
	Subcommand	Feature Description	Support																			
	02h	Enable write cache	M																			
03h	Set transfer mode based on value in Sector Count register	M																				

Requirement ID	Description		
	06h	Enable Power-Up In Standby (PUIS) feature set	M
	07h	Power-Up In Standby feature set device spin-up	M
	10h	Enable use of Serial ATA feature	M
	4Ah	Extended Power Conditions	M
	66h	Disable reverting to power-on defaults	M
	82h	Disable volatile write cache	M
	86h	Disable Power-Up In Standby feature set	M
	90h	Disable use of Serial ATA feature	M
	C3h	Sense Data Reporting feature set (enable = 1h in Count field; disable = 0h in Count field)	M
	CCh	Enable reverting to power-on defaults	M
SATA-SF-4	Subcommands 06h (Enable Power-Up In Standby (PUIS) feature set), 07h (Power-Up In Standby feature set device spin-up), and 86h (Disable Power-Up In Standby feature set) shall be disabled by default from the factory.		
SATA-SF-5	All Extended Power Conditions (EPC) timers shall be disabled by default from the factory. When the Extended Power Conditions (EPC) timers are disabled, the device shall not transition to different power states based on any EPC timer expiration.		

5.4.6 Sleep (Command code: E6h)

Requirement ID	Description
SATA-SLP-1	Because host systems may not read the Status register and clear the Interrupt Pending, a device may release INTRQ and enter Sleep mode after a vendor specific time period.

5.4.7 Standby (Command code: E2h)

Requirement ID	Description
SATA-STB-1	An SSD device without rotating media shall enter the STANDBY state by transitioning to the low power state and suspending all background activities.

5.4.8 Write DMA FUA Ext (Command code: 3Dh)

Requirement ID	Description
SATA-WDFE-1	An SSD device shall cache FUA commands if the Power Loss Protection (PLP) is healthy.

5.4.9 Write Uncorrectable Ext (Command code: 45h)

Requirement ID	Description
SATA-WUE-1	There shall be no limit imposed by the device relative to the number of uncorrectable errors created by the WRITE UNCORRECTABLE EXT command with all supported modes other than the limit imposed by the total device capacity limit. The device shall support WRITE UNCORRECTABLE EXT modes 55h and AAh and be fully functional as defined in ACS-5. It is required that device suppliers validate that the performance of this command complies with the intended command functional result. This shall be validated with every supported mode. The WRITE UNCORRECTABLE EXT command with the Feature field value set to AAh (flagged error) and Count field set to one shall corrupt only one LBA, regardless of number of LBAs per physical sector.

6 SAS Requirements

If the device supports SAS, the following requirements shall be met.

6.1 SAS Requirements

Requirement ID	Description
SAS-1	The device shall comply with the following SCSI specifications: • SCSI primary commands (SPC-5) or newer • SCSI block commands (SBC-4) or newer • SAS Protocol Layer (SPL-4) or newer • SCSI Architecture Model (SAM-5) or newer
SAS-2	At a minimum, HDD devices shall support a SAS3 (12G) interface speed.
SAS-3	At a minimum, SSD devices shall support a SAS3 (24G) interface speed.
SAS-3	The device shall support self-test short and extended (long) tests in both foreground (captive) and background modes. When running the short self-test, the device shall complete the test within 2 minutes with and without outstanding I/O workload. When running extended self-test, the device shall take no more than twice the smaller time specified in: • Extended self-test completion minutes field in Extended Inquiry Data VPD page (86h) described in SPC-4/5 section 7.7.7, or • Extended self-test completion time field in Control mode page (0Ah), described in SPC-4/5 section 7.5.11
SAS-4	A dual port device shall enable both ports by default, however, for devices that only have single port requirements the secondary SAS port shall be disabled by default to reduce power draw.
SAS-5	Drives shall support sense code reporting, including but not limited to: • 00/0B/xx DST / BGMS related warnings

Requirement ID	Description
	• 00/5D/xx SMART warnings / thresholds exceeded • 00/5E/xx Power transitions • 01/xx/xx Soft errors & faults • 02/xx/xx Device not ready • 03/xx/xx Medium errors (Read errors & faults) • 04/xx/xx Miscellaneous failures • 05/xx/xx Device access/invalid command/illegal request type failures • 06/xx/xx Unit attentions • 07/xx/xx SMR / Zone related • 0B/xx/xx Aborted commands
SAS-6	Telemetry commands involving read activity only shall not block host I/O for more than 100ms.
SAS-7	Download protection shall be built into the device to recover from an incorrect microcode version being downloaded and/or power fail during download.
SAS-8	The device shall support segmented downloads with segment sizes of 32K and 64K. All other segment sizes are optional. The device shall also support Buffer ID=0 and use of the Buffer Offset field to segment data.

6.2 SAS PHY Layer Requirements

Requirement ID	Description
SAS-PHY-1	If the device detects a character with bad disparity, it shall count the Dword containing the error in the Protocol Specific Port log page (18h) and shall treat the frame (if any) as having a CRC error, regardless of whether the CRC is correct.

6.3 SAS LINK Layer Requirements

Requirement ID	Description
SAS-LINK-1	If the device receives an invalid Dword (including an ERROR primitive or a character with bad disparity) inside a frame, it shall treat the frame (if any) as having a CRC error, regardless of whether the CRC is correct.
SAS-LINK-2	If the device is dual port enabled, then the BROADCAST (ASYNCHRONOUS EVENT) primitive shall be supported. The link layer method used by the device shall provide the notification to all application clients (i.e., initiators) to indicate that the device has “cleared” or “aborted” commands in its task set (i.e., “wiped-out” the command queue).

6.4 SAS Command Layer Requirements

6.4.1 Supported Commands

Requirement ID	Description
SAS-CMD-1	The device shall support the following Commands:

Requirement ID	Description		
	- M = Mandatory. Command shall be supported. - P = Prohibited. Command shall not be supported (command rejected with 05h/20h/00h or 05h/24h/00h CHECK CONDITION). - O = Optional. Command support is optional.		
	Command	Opcode	Support
			HDD SSD
	FORMAT UNIT	04h	M M
	GET LBA STATUS (16)	9Eh/12h	P P
	GET LBA STATUS (32)	7Fh/0012h	P P
	INQUIRY	12h	M M
	LOG SELECT	4Ch	M M
	LOG SENSE	4Dh	M M
	MODE SELECT (6)	15h	M M
	MODE SENSE (6)	1Ah	M M
	MODE SELECT (10)	55h	M M
	MODE SENSE (10)	5Ah	M M
	ORWRITE (16)	8Bh	P P
	ORWRITE (32)	7Fh/000Eh	P P
	PERSISTENT RESERVE IN	5Eh	M M
	PERSISTENT RESERVE OUT	5Fh	M M
	READ (10)	28h	M M
	READ (12)	A8h	P P
	READ (16)	88h	M M
	READ (32)	7Fh/ 0009h	M M
	READ BUFFER (10)	3Ch	M M
	READ BUFFER (16)	9Bh	M M
	READ CAPACITY (10)	25h	M M
	READ CAPACITY (16)	9Eh	M M
	READ DEFECT DATA (10)	37h	M M
	READ DEFECT DATA (12)	B7h	M M
	READ LONG (10)	3Eh	M M
	REASSIGN BLOCKS	07h	M M
	RECEIVE DIAGNOSTIC RESULTS	1Ch	M M
	REPORT IDENTIFYING INFORMATION	A3h/05h	M M
	REPORT LUNS	A0h	M M

	REPORT SUPPORTED OPERATION CODES	A3h/0Ch	M	M
	REPORT SUPPORTED TASK MANAGEMENT FUNCTIONS	A3h/0Dh	M	M
	REPORT TIMESTAMP	A3h/0Fh	M	M
	REQUEST SENSE	03h	M	M
	SANITIZE	48h	M	M
	SECURITY PROTOCOL IN	A2h	M (TCG Only)	M (TCG only)
	SECURITY PROTOCOL OUT	B5h	M (TCG Only)	M (TCG Only)
	SEND DIAGNOSTIC	1Dh	M	M
	SET IDENTIFYING INFORMATION	A4h/06h	M	M
	SET TIMESTAMP	A4/0Fh	M	M
	START STOP UNIT	1Bh	M	M
	SYNCHRONIZE CACHE (10)	35h	M	M
	SYNCHRONIZE CACHE (16)	91h	M	M
	TEST UNIT READY	00h	M	M
	UNMAP	42h	P	M
	VERIFY (10)	2Fh	M	M
	VERIFY (12)	AFh	P	P
	VERIFY (16)	8Fh	M	M
	VERIFY (32)	7Fh/ 000Ah	M	M
	WRITE (10)	2Ah	M	M
	WRITE (12)	AAh	P	P
	WRITE (16)	8Ah	M	M
	WRITE (32)	7Fh/ 000Bh	M	M
	WRITE AND VERIFY (10)	2Eh	M	M
	WRITE AND VERIFY (12)	A Eh	P	P
	WRITE AND VERIFY (16)	8 Eh	M	M
	WRITE AND VERIFY (32)	7Fh/ 000Ch	M	M
	WRITE BUFFER	3Bh	M	M
	WRITE LONG (10)	3Fh	M	M
	WRITE LONG (16)	9Fh/11h	M	M
	WRITE SAME (10)	41h	M	M
	WRITE SAME (16)	93h	M	M

Requirement ID	Description
SAS-CMD-2	An INQUIRY command to a device shall return valid information to any initiator port even if a different initiator port has a reservation.
SAS-CMD-3	The EVPD bit shall be supported. An INQUIRY command requesting VPD data that is received by the device to a non-existent LUN shall cause the device to properly report a value of 7Fh (011b - PERIPHERAL QUALIFIER and 1Fh - PERIPHERAL DEVICE TYPE) in byte 0 of the VPD data.
SAS-CMD-4	After a Sanitize command, the device shall enable reads to the sanitized LBAs without generating errors. After a Block Erase (010b) or Crypto Erase (100b) per SEC-52, the device shall return all zeros for host reads to LBAs that have not been written since the last Sanitize command.
SAS-CMD-5	The UNMAP command requests that the SSD device causes one or more LBAs to be unmapped. As such, this command can provide host file system information (e.g., “deleted” or “recycle bin”/ “burn files”) to the device for purposes of enabling the device to optimize its internal operations. This can be beneficial for SSDs for identifying blocks that may be managed differently by the SSD for extended wear leveling endurance, usage, and reliability by reducing data movement operations (wear leveling) and program erase cycles. For HDD devices (if implemented) this information may be beneficial for enhancing media scan “scrubbing” operations to include write operations to non-user data block checks.
SAS-CMD-6	The UNMAP command shall be implemented by SSD devices. SSD devices shall return zeroes on reads to unmapped LBA(s) that have not been written. Every single LBA specified by the UNMAP command shall be unmapped (or mapped with zeroes as the data content for the LBAs) and clear all uncorrectable errors in the range of the command that were previously caused by a WRITE LONG command.
SAS-CMD-7	The device microcode shall be field downloadable via the SAS SSP port using the WRITE BUFFER command. All devices shall at least support the WRITE BUFFER command modes 07h, 0Eh, and 0Fh.
SAS-CMD-8	The device supplier shall validate in their design lab that if power is removed from the device precisely at the time the device is programming its firmware code, i.e., “flashing its code” to its non-volatile component, it shall not become inoperable, but rather, recover from that power loss. When power is re-applied it shall become ready for subsequent applicable protocol that normally follows the re-application of power (e.g., COMRESET, DWS, and commands). Recovery may be dependent upon the download mode used as follows. For example: • If mode 7h: Typically, revert to the prior firmware code only if unable to re-flash this new firmware code upon power restoration since it was “saved” prior to the flashing operation which was interrupted by the power loss. • If mode 0Eh: Recommends that the device revert to the prior firmware code since the firmware code was “saved” but not activated (i.e., “considered deferred”). The deferred microcode shall be activated and no longer considered deferred if any one of the following occurs: a power on, a hard reset, a START STOP UNIT command is processed, a FORMAT UNIT command is processed, or a WRITE BUFFER command with the activate deferred microcode mode (0Fh) is processed. This guarantees compliance with the T10 (SPC-5) Specification. • If mode 0Fh: Typically, revert to the prior firmware code only if the WRITE BUFFER mode 0Fh command did not complete with GOOD Status. If the command did complete

Requirement ID	Description
	with GOOD Status, then the device shall re-flash this new firmware code upon power restoration since it was “saved” (via Mode 0Eh) prior to the flashing /activation operation. (NOTE: It is assumed that the power loss did not affect the previously completed mode 0Eh firmware code save operation and GOOD Status has been returned for this WRITE BUFFER mode 0Fh command.) Devices shall be able to reflash and activate the new firmware code under these circumstances.
SAS-CMD-9	The device shall support the WR_UNCOR (1) bit fields of the WRITE LONG command as defined in the ANSI T10 SBC-4 r21 specification document. The device shall indicate this by returning a non-zero value in the LOGICAL BLOCKS PER PHYSICAL BLOCK EXPONENT field in the parameter data returned in response to a READ CAPACITY (16) command.
SAS-CMD-10	There shall be no limit imposed by the device relative to the number of uncorrectable errors created by the WRITE LONG command with all supported WR_UNCOR (1) bit field settings other than the limit imposed by the total device capacity limit.
SAS-CMD-11	When the Write Long command (with the WR Uncor bit = 1) is issued to a device formatted with a 512e sector size, the device shall only mark the LBA or LBAs identified in the command as uncorrectable (i.e., Not mark the entire physical (4k size) sector as Uncorrectable.)
SAS-CMD-12	SSD devices shall support the UNMAP bit and shall ignore the ANCHOR bit for the WRITE SAME command.

6.4.2 Sanitize Device Commands

Requirement ID	Description										
SAS-SDC-1	The device shall support the following Sanitize service action codes: <table> <tr> <th>Code</th><th>Name</th></tr> <tr> <td>01h</td><td>OVERWRITE</td></tr> <tr> <td>02h</td><td>BLOCK ERASE</td></tr> <tr> <td>03h</td><td>CRYPTOGRAPHIC ERASE</td></tr> <tr> <td>1Fh</td><td>EXIT FAILURE MODE</td></tr> </table>	Code	Name	01h	OVERWRITE	02h	BLOCK ERASE	03h	CRYPTOGRAPHIC ERASE	1Fh	EXIT FAILURE MODE
Code	Name										
01h	OVERWRITE										
02h	BLOCK ERASE										
03h	CRYPTOGRAPHIC ERASE										
1Fh	EXIT FAILURE MODE										
SAS-SDC-2	The device shall service LOG SENSE commands during Sanitize operations.										
SAS-SDC-3	The device shall be able to provide any requested log page while a Sanitize operation is under way.										
SAS-SDC-4	Specifically, if a Sanitize operation is in progress and a LOG SENSE command is received requesting the Temperature log, the device shall not return an error, but rather, shall service the command by returning all current content for the log page. All of the content of the page shall be available and be current, but most critical to the host application, is the current most recent temperature reading retrieved by the device’s temperature sensor at the time the command is received from the host.										
SAS-SDC-5	After a Sanitize command, the device shall enable reads to the sanitized LBAs without generating errors. After a CRYPTOGRAPHIC ERASE service action per SEC-52 or Block Erase,										

Requirement ID	Description
	the device shall return all zeros for host reads to LBAs that have not been written since the last Sanitize command.

6.4.3 VPD Pages

Requirement ID	Description			
SAS-VPD-1	The device shall support the following VPD pages:			
	Page	Description	Standard	Shall be accessible while NOT READY?
	00h	Supported VPD Pages	Primary	Yes
	80h	Unit Serial Number VPD Page	Primary	Yes
	83h	Device Identification VPD Page	Primary	Yes
	86h	Extended INQUIRY Data VPD Page	Primary	No
	87h	Mode Page Policy VPD Page	Primary	No
	88h	SCSI Ports VPD Page	Primary	No
	8Ah	Power Condition VPD Page	Primary	No
	8Dh	Power Consumption VPD Page	Primary	No
	90h	Protocol-Specific Logical Unit Information	Primary	No
	B0h	Block Limits	Block	No
	B1h	Block Device Characteristics	Block	Yes
	B2h	Logical Block Provisioning (SSD Only)	Block	No
SAS-VPD-2	The device shall support the Write Uncorrectable Supported (WU_SUP) bit in the Extended INQUIRY Data VPD page (86h). The device shall set the WU_SU bit to 1b.			
SAS-VPD-3	The Power Condition VPD page (8Ah) shall be supported and shall report which power conditions are supported and how they operate. Power condition timers shall be disabled by default and shall only be enable by the host.			

6.4.4 Mode Pages

Requirement ID	Description			
SAS-MOD-1	SAS devices shall support the following Mode pages and parameters:			
	• M = Mandatory. Mode Page shall be supported. • P = Prohibited. Mode Page shall not be supported (command rejected with ILLEGAL_FIELD_IN_CDB). • O = Optional. Mode Page support is optional.			
	Page Code	Page Description	Standard	Support
	00h	Vendor Specific (Does not require page format)	SPC-6	O

Requirement ID	Description			
	01h	Read-Write Error Recovery	SBC-5	M
	02h	Disconnect-Reconnect (SAS specific)	SPC-6 and SAS-5	M
	07h	Verify Error Recovery	SBC-5	M
	08h	Caching	SBC-5	M
	0Ah	Control	SPC-6	M
	0Ah/01h	Control Extensions	SPC-6	M
	0Ah/02h	Application Tag	SBC-5	O
	0Ah/FFh	Return all subpages of page 0Ah (MODE SENSE only)	SPC-6	M
	18h	Protocol-Specific Logical Unit	SAS-5	M
	19h	Protocol-Specific Port - short format	SAS-5	M
	19h/01h	Protocol-Specific Port - PHY Control and Discover	SAS-5	M
	19h/02h	Shared Port Control	SAS-5	M
	19h/03h	Enhanced PHY Control	SAS-5	M
	19h/FFh	Return all subpages of page 19h (MODE SENSE only)	SPC-6	M
	1Ah	Power Condition	SPC-6	M
	1Ah/01h	Power Consumption	SPC-6	M
	1Ch	Informational Exceptions Control	SPC-6	M
	1Ch/01h	Background Control	SBC-5	M
	1Ch/02h	Logical Block Provisioning	SBC-5	M
	3Fh	Return All Pages (MODE SENSE only)	SPC-6	M
SAS-MOD-2	If the host sends a MODE SENSE (6) command with SUBPAGE CODE field value of 00h, the device shall NOT terminate the command with CHECK CONDITION due to more information than allowed by the one-byte allocation length. The amount of data returned shall be equal to or less than allowed by the one-byte allocation length, and NO MODE PAGE SHALL BE TRUNCATED. The device shall return ALL supported subpage 00h mode pages in page_0 format.			
SAS-MOD-3	The device shall have the following default parameters from the factory for byte 02h of the Read-Write Error Recovery mode page (01h):			
	Bit	Description	Default	
	7	Automatic Write Reassignment Enabled (AWRE)	1b	
	6	Automatic Read Reassignment Enabled (ARRE)	1b	
	5	Transfer Block (TB)	0b	
	4	Read Continuous (RC)	0b	
	2	Post Error (PER)	1b	

Requirement ID	Description		
	1	Data Terminate on Error (DTE)	0b
SAS-MOD-4	The device shall have the following default parameters for the Verify Error Recovery mode page (07h) for byte 02h from the factory:		
	Bit	Description	Default
	2	Post Error (PER)	1b
	1	Data Terminate on Error (DTE)	0b
SAS-MOD-5	The device shall implement the Caching mode page with its full 20-byte length, not the 12-byte length defined in SCSI-2. A MODE SELECT with the SCSI-2 length shall be accepted by the device and shall not modify the bits not sent with the data. The device shall have the following default parameters for the Caching mode page (08h) for byte 2 from the factory:		
	Bit	Description	Default
	7	Initiator Control (IC)	0b
	6	Abort Pre-Fetch (ABPF)	0b
	5	Caching Analysis Permitted (CAP)	0b
	2	Writeback Cache Enable (WCE)	See COMM-2&3
	1	Multiplication Factor (MF)	0b
	0	Read Cache Disable (RCD)	0b
SAS-MOD-6	The device shall support minimum of two IDLE modes described below as defined in power condition mode page (1Ah): - Idle A (active idle) - Idle B (heads loaded to ramp)		
SAS-MOD-7	The device shall support MRIE (Method of Reporting Informational Exceptions) to control reporting methods or warnings and exceptions. The device shall have the following parameters set in the Informational Exceptions mode page (1Ch) by default: - MRIE = 00h or equivalent to disable all asynchronous warnings and exceptions - E_{WASC} = 01h, enable warnings reporting - D_{EXCPT} = 00h, enable exception reporting		
SAS-MOD-8	HDD devices shall allow user/host to control BGMS activity via background control mode page (page code 1Ch, subpage code 01h).		

6.4.5 Log Pages

Requirement ID	Description		
SAS-LOG-1	The device shall support the following log pages for reporting purposes. - M = Mandatory. Log Page shall be supported. - P = Prohibited. Log Page shall not be supported (command rejected with 05h/24h/00h CHECK CONDITION). - O = Optional. Log Page support is optional.		
	Log Address	Log Page Name	Support

Requirement ID	Description		
	00h	Supported log pages	M
	01h	Buffer over-run/under-run Log Page	P
	02h	Write Errors Log Page	M
	03h	Read Errors Log Page	M
	04h	Read reverse error counters Log Page	P
	05h	Verify Errors Log Page	M
	06h	Non-Medium Error Log Page	M
	07h	Last n Error Events Log page	P
	08h	Format status	P
	0Bh	Last n Deferred errors or async events Log Page	P
	0Dh	Temperature Log Page	M
	0Eh	Start/Stop Cycle Log Page	M
	0Fh	Application Client Log Page	P
	10h	Drive Self-Test Log Page	Yes
	11h	Solid State Media log page	M (SSD only)
	15h	Background Media Scan Log Page	M
	18h	Protocol-specific Log Page (SAS)	M
	19h	Cache Memory Statistics / General Statistics and Performance Log Page	P
	1Ah	Power Transition Log Page	M
	2Fh	Informational Exceptions Log Page	M

6.5 Dual port Requirements

If Dual port is supported the following requirements shall be supported.

Requirement ID	Description		
SAS-DP-1	A SAS device may have more than one port. The device shall report all port associated data structures accordingly. A single port device shall report the single port configuration information as described in # of Ports 1. A dual port device shall report the dual port configuration information as described in # of Ports 2.		
	Data Structure Description	# of Ports	
		1	2
	Standard INQUIRY "MULTIP" bit = 0b	x	
	Standard INQUIRY "MULTIP" bit = 1b		x

Requirement ID	Description		
	INQUIRY Device Identification VPD page (83h):	x	x
	- Logical Unit identifier	x	x
	- Target port identifier for the primary port (only)	x	
	- Target port identifier for <u>the port being used</u> by INQUIRY		x
	- Relative target port identifier for the primary target port (only)	x	
	- Relative target port identifier for <u>the target port being used</u> by INQUIRY		x
	- Target device name	x	x
	INQUIRY SCSI Ports VPD page (88h):	x	x
	- Primary port descriptor (only)	x	
	- Primary <u>and</u> secondary port descriptors available		x
	Log Pages:		
	Protocol-Specific log page (18h):	x	x
	- One log parameter (only); parameter code 0001h for primary port	x	
	- Two log parameters available; both parameter code 0001h and parameter code 0002h		x
	- One PHY IDENTIFIER (00h for primary port, only)	x	
	- Two PHY IDENTIFIERS available; (00h primary port and 01h secondary port)		x
	- SAS ADDRESS (for primary port, only)	x	
	- SAS ADDRESS (both available for primary port and secondary port)		x
	Mode Pages:		
	Protocol-Specific Port – PHY Control And Discover subpage (19h/01h):	x	x
	- NUMBER OF PHYS field (01h for one PHY)	x	
	- NUMBER OF PHYS field (02h for dual-port device)		x
	- One PHY mode descriptor (only)	x	
	- Two PHY mode descriptors available		x
	- PHY IDENTIFIER (00h for primary port, only)	x	
	- PHY IDENTIFIER (00h for primary port and 01h for secondary port)		x
	- SAS ADDRESS (for primary port, only)	x	
	- SAS ADDRESS (both available for primary port and secondary port)		x
SAS-DP-2	A dual port (two-PHY) physical connector is recommended with the primary PHY located in the “single port” location.		

Requirement ID	Description
SAS-DP-3	Each port shall support OOB, link resets, indiscriminately and asynchronously, totally without regard to the other port. Link resets shall be able to occur and complete simultaneously on both ports during the discovery process and any time thereafter.
SAS-DP-4	Each port shall have a separate, unique, SAS address (device port identifier).
SAS-DP-5	Each port shall have a different relative device port identifier.
SAS-DP-6	Each port has the same logical unit identifier and device name (for direct-access devices).
SAS-DP-7	Each port shall be able to support four separate, independent initiators.
SAS-DP-8	Each port shall support all the SCSI command set recommended.
SAS-DP-9	Each port shall support the total set of mode pages, log pages, VPD pages, and diagnostic pages as recommended. Values and data reporting content are different for dual port devices.
SAS-DP-10	Each port shall be able to support indiscriminately, independently, full duplex, concurrent command(s) reception while returning status.
SAS-DP-11	Each port shall support indiscriminately, independently, full duplex, concurrent data reception and data transmission.
SAS-DP-12	Each port shall support the BROADCAST (ASYNCHRONOUS EVENT) primitive.
SAS-DP-13	Each port should support and report INQUIRY data and VPD for that port.
SAS-DP-14	Each port shall support and report mode page settings for that port.
SAS-DP-15	Each port shall support and report log page settings for that port.
SAS-DP-16	Dual port implementations shall operate and perform exactly as how a single port device operates and performs with the benefit of providing an additional “connection point” (port) to the device. The additional identification and reporting data structures shall be implemented as well.

7 Power

Requirement ID	Description
PWR-1	The device shall consume < 5W at idle as defined by the COMMISSION REGULATION (EU) 2019/424.
PWR-2	The device max average power consumption shall be measured in a 500ms window with a sampling rate of 2ms or better. The measurement duration shall be at least 15 minutes.
PWR-3	The device peak power consumption shall be measured in a 100us window with a sampling rate of 4us or better. The measurement duration shall be at least 15 minutes.
PWR-4	The Max Power and Current Limits for PWR-5 through PWR-12 shall be measured at 35C° ± 5C°.
PWR-5	A 3.5” SAS/SATA LFF HDD device shall consume no more power than the limits in the table below:

Requirement ID	Description		
	Measurement Condition		Max Power
	Air-filled normal R/W operation, max average (Max. power access type, workload, queue depth)		14.5W
	Helium-filled normal R/W operation, max average (Max. power access type, workload, queue depth)		Single Actuator (SA): 11.0W Dual Actuator (DA): 14.0W
	Power Saving Mode A: Partial electronic power off		9.0W
	Power Saving Mode B: More electronic power off and park heads.		6.5W
	Power Saving Mode C: More electronic power off, park heads and partial RPM spin		3.5W
	Standby/Sleep: Major electronic power off, park heads and motor stop		Standby: 1.5W Sleep: 1.5W
PWR-6	A 3.5” SAS/SATA LFF HDD device shall consume no more current than the limits in the table below:		
	Measurement Condition		5V Current Limit12V Current Limit
	Spin Up Peak, I _{maxPeakSpin} < 0.1ms		1.5A2.9A
	Spin Up Average, I _{maxAvgSpin}		1.2A2.0A
	Normal R/W operation, peak (Max. power access type, workload, queue depth)		1.5A2.0A
	Air-filled normal R/W operation, max average (Max. power access type, workload, queue depth)		1.2A1.2A
	Helium-filled normal R/W operation, max average (Max. power access type, workload, queue depth)		1.2ASA: 0.9A DA: 1.1A
PWR-7	A 2.5” SAS3 (12G) SFF SDD device shall consume no more power than the limits in the table below:		
	Measurement Condition		Max Power
	Normal R/W operation, max average (Max. power access type, workload, queue depth)		11.0W
	Idle		4.0W
	Power consumed when Power Disable is asserted		0.25W
PWR-8	A 2.5” SAS3 (12G) SFF SDD device shall consume no more current than the limits in the table below:		
	Measurement Condition		5V Current Limit12V Current Limit
	Power Up Peak, I _{maxPeakPowerUp} < 0.1ms		1.8A3.0A
	Power Up Average, I _{maxAvgPowerUp}		1.3A2.0A

Requirement ID	Description		
	Normal R/W operation, peak (Max. power access type, workload, queue depth)	1.7A	1.8A
	Normal R/W operation, max average (Max. power access type, workload, queue depth)	1.2A	0.9A
PWR-9	A 2.5” SAS4 (24G) SFF SDD device shall consume no more power than the limits in the table below:		
	Measurement Condition	Max Power	
	Normal R/W operation, max average (Max. power access type, workload, queue depth)	18.0W	
	Idle	5.0W	
	Power consumed when Power Disable is asserted	0.25W	
PWR-10	A 2.5” SAS4 (24G) SFF SDD device shall consume no more current than the limits in the table below:		
	Measurement Condition	5V Current Limit	12V Current Limit
	Power Up Peak, I _{maxPeakPowerUp} < 0.1ms	1.8A	3.0A
	Power Up Average, I _{maxAvgPowerUp}	1.3A	2.0A
	Normal R/W operation, peak (Max. power access type, workload, queue depth)	2.0A	2.0A
	Normal R/W operation, max average (Max. power access type, workload, queue depth)	1.5A	1.0A
PWR-11	A 2.5” SATA SFF SSD device shall consume no more power than the limits in the table below:		
	Measurement Condition	Max Power	
	Normal R/W operation, peak (Max. power access type, workload, queue depth)	9.0W	
	Normal R/W operation, max average (Max. power access type, workload, queue depth)	9.0W	
	Idle	1.5W	
Power consumed when Power Disable is asserted	0.25W		
PWR-12	A 2.5” SATA SFF SSD device shall consume no more current than the limits in the table below:		
	Measurement Condition	5V Current Limit	12V Current Limit
	Power Up Peak, I _{maxPeakPowerUp} < 0.1ms	1.5A	0.7A
	Power Up Average, I _{maxAvgPowerUp}	1.5A	0.4A
	Normal R/W operation, peak (Max. power access type, workload, queue depth)	1.5A	0.4A

Requirement ID	Description		
	Normal R/W operation, max average (Max. power access type, workload, queue depth)	1.5A	0.4A
PWR-13	The device shall operate normally (e.g., no performance or reliability impact) with supply voltage variations up to +/- 5% for 5V and +/- 10% for 12V inputs.		
PWR-14	The vendor shall provide average and peak measurements for power and current during the conditions below: • Spin-up • Recovery from standby • Typical workloads (define) ○ random read, block size 4k, queue depth 16 ○ random write, block size 1m, queue depth 16 ○ sequential read, block size 1m, queue depth 16 ○ sequential write, block size 1m, queue depth 16 • Idle A, B and C • Firmware update		
PWR-15	The device shall report power on hours and power cycle counts during the life of operation. SATA devices shall report power on hours in SMART attribute 9 and power cycle counts in SMART attribute 12. SAS devices shall report power on hours in page code 10h byte 6:7 for last 20 self-test results and power cycle counts in page code 0Eh parameter code 04h.		
PWR-16	Data integrity shall be guaranteed during emergency or unplanned power off when write cache is disabled.		
PWR-17	The vendors shall provide command sequence guidance for graceful power off or reset operations in the product specification.		

8 Reliability

8.1 MTBF / AFR Requirements

Requirement ID	Description		
REL-1	The device shall meet an MTBF of 2.5 million hours (AFR of <= 0.35%) under the following operating environmental conditions:		
	Specification	Environment	Requirement
	Ambient Temperature	Operational	• 0°C to 50°C (32°F to 122°F) (< 20°C (68°F) per hour gradient)
		Non-Operational	• -40°C to 70°C (-40°F to 158°F) (< 30°C (86°F) per hour gradient)
	Humidity	Operational	• 10% to 90% non-condensing • Yearly weighted average: < 80% RH • 90% of year: < 80% • 10% of year: 80% to 90%

Requirement ID	Description		
			Maximum dewpoint: 29.4°C (85°F)
		Non-Operational	5% to 95% non-condensing 38°C (100.4°F) maximum wet bulb temperature
REL-2	The device shall meet an MTBF of 2.0 million hours (AFR of <= 0.44%) the following environmental conditions:		
	Specification	Environment	Requirement
	Ambient Temperature	Operational	0°C to 55°C (32°F to 131°F) (< 20°C (68°F) per hour gradient)
		Non-Operational	-40°C to 70°C (-40°F to 158°F) (< 30°C (86°F) per hour gradient)
	Humidity	Operational	10% to 90% non-condensing - Maximum dewpoint: 29.4°C (85°F)
		Non-Operational	5% to 95% non-condensing 38°C (100.4°F) maximum wet bulb temperature
REL-3	Supplier shall provide the acceleration factor, temperature and humidity conditions used to determine the MTBF based on REL-5 and REL-6.		
REL-4	Supplier shall provide AFR de-rating curves for the combined Temperature and Relative Humidity range shown in requirement REL-1/REL-2 for up to 70°C (158°F)		
REL-5	For HDD devices the reliability parameters shall be based on a minimum of 550 TB/ year per actuator for workloads of 100% read, 100% write and 50/50 read/write for a minimum of 5 years.		
REL-6	For HDD devices the reliability data shall be provided to the customer for 550 TB/ year per actuator for workloads of 100% read, 100% write and 50/50 read/write based on a 7-year service life.		

8.2 Load / Unload Cycles

Requirement ID	Description
LUL-1	The device shall be able to perform a minimum of 600,000 soft load/unload cycles during the life of the device.

8.3 EPO / Sudden Power Loss

Requirement ID	Description
EPO-1	The device shall be able to perform a minimum of 50,000 hard load/unload cycles during the life of the device based on REL-1 and REL-2.
EPO-2	The device shall support full power-loss protection for all acknowledged user data with write caching disabled.
EPO-3	The device shall support full power-loss protection for all telemetry and internal logging data with or without Write Caching.

8.4 Data Integrity / End to End Data Protection

Requirement ID	Description
E2E-1	All user data and metadata shall be protected using overlapping protection mechanisms throughout the entire read and write path in the device including all storage elements (registers, caches, SRAM, DRAM, NAND, etc.).
E2E-2	At least one bit of correction and 2 bits of detection is required for all memories. This shall be for all memories regardless of function.
E2E-4	Silent data corruption shall not be tolerated under any circumstances.
E2E-5	The device shall include a mechanism to protect against returning the data from the wrong logical block address (LBA), including previous copies from same LBA, to the host. It is acceptable if the device stores additional/modified information to provide protection against returning wrong data to the host. Device shall perform host LBA integrity checking on all transfers to and from the media.
E2E-6	All device metadata, firmware, firmware variables, and other device system data shall be protected by at least a single bit detection scheme.
E2E-7	Any memory buffers that are utilized to accelerate data transfer (read-ahead buffers for example) shall follow the protection scheme outlined in E2E-5.
E2E-8	Data path errors that are detected, but not corrected, are considered unrecoverable data errors, and shall be subject to unrecoverable data error rate limits. For SATA devices, detected data path errors shall factor into calculations for SMART attributes 180 (end-to-end error detection/correction rate) and 184 (end-to-end error detection/correction count), whether the errors are corrected or not.

8.5 UBER

Requirement ID	Description
UBER-1	The device shall support an Uncorrectable Bit Error Rate (UBER) of < 1 sector per 10^{15} bits read.
UBER-2	De-rating curves for the UBER shall be supplied for 5°C to 50°C (41°F to 122°F).

8.6 ORT Requirement

Requirement ID	Description
ORT-1	The vendor shall provide on-going reliability data for device in production and notify customer immediately if any quality escape or customer excursion scenario is likely.

8.7 Behavior on Assert / Firmware Crash

Requirement ID	Description
CRASH-1	If the device can guarantee data integrity, after a firmware crash, panic or assert in which the device can no longer accept write commands, the device shall allow read access.
CRASH-2	After a firmware crash, panic or assert, that is not a hardware failure, the device shall still support Read Log EXT / SMART Read (SATA) and Log Sense (SAS) commands including the ability to read any failure logs from the device to determine the nature of the failure.
CRASH-3	If after a firmware crash, panic or assert there is the possibility of user data corruption, the Device Recovery Action shall require a Format.

8.8 Head Wear-out / Degradation

Requirement ID	Description
HEADWEAR-1	HDD heads shall maintain the specified UBER for a minimum of 5 years.
HEADWEAR-2	The HDD heads due to wear shall not cause the average or P99 tail latency to degrade more than 5% over 5 years.

8.9 Shelf Life

Requirement ID	Description
SHELF-1	There shall be no permanent damage as result of storing the device within storage temperature and humidity boundaries within one year shelf-life period. Device shall maintain 5 years of service life.
SHELF-2	HDD shall have mitigation so that devices stored within the non-operating temperature range will not have issues with stiction among motor and head/disk interface.

9 Performance Requirements

9.1 Time to Ready

Requirement ID	Description
TTR-1	The device shall be ready to successfully process user IO commands within a maximum of 30 seconds to power being applied to the device.

9.2 Sequential Performance Requirements

Requirement ID	Description		
PERF-SEQ-1	The HDD device shall match or beat the following criteria for sequential operations for both reads and writes.		
	IO Size	QD	Performance (MB/s) per Actuator
	4K	1	62.5 MB/s or 25% of max SDR at OD
	4K	2	125 MB/s or 50% of max SDR at OD
	4K	4	187.5 MB/s or 75% of max SDR at OD
	4K	8 and up	250 MB/s or 100% of max SDR at OD
	8K	1	125 MB/s or 50% of max SDR at OD
	8K	2	187.5 MB/s or 75% of max SDR at OD
	8K	4 and up	250 MB/s or 100% of max SDR at OD
	16K	1	187.5 MB/s or 75% of max SDR at OD
	16K	2 and up	250 MB/s or 100% of max SDR at OD
PERF-SEQ-2	PERFSEQ-1 (OD) shall not degrade by more than 50% at ID. OD and ID are defined by 1% of physical space at the outer and inner portions of the device, respectively. If 1% and 99% LBA space does not align with physical OD/ID portion of the disk, the vendor shall provide this information for accurate measurement.		
PERF-SEQ-3	Newer model HDDs shall not degrade by more than 5% versus previous generations of the same product line.		

9.3 Random Read Performance Requirements

Requirement ID	Description		
PERF-RD-1	The HDD device shall match or beat the following criteria for random read operations:		
	IO Size	QD	Performance (IOPS) per Actuator
	4K	1	80
	4K	2	100
	4K	4	120
	4K	8	140
	4K	16	170
	4K	32	200
	4K	64	230 (SAS only)
	4K	128	260 (SAS only)

9.4 Random Write Performance Requirements

Requirement ID	Description
PERF-RW-1	The HDD device shall match or beat the following criteria for random writes.

	IO Size	QD	Cache Setting	Performance (IOPS) per Actuator
	4K / 8K	Any	WCD	300
	4K / 8K	Any	WCE	350

9.5 Latency Requirements

Requirement ID	Description												
LAT-1	The following latency criteria (per actuator) shall not be exceeded with 4K QD1 random reads. The latency measurement test shall take at least 10 minutes ramp time and 60 minutes run time. <table> <tr> <th>Percentile</th><th>Latency (ms)</th></tr> <tr> <td>P50</td><td>12</td></tr> <tr> <td>P75</td><td>15</td></tr> <tr> <td>P99</td><td>20</td></tr> <tr> <td>P99.9</td><td>25</td></tr> <tr> <td>P99.99</td><td>40</td></tr> </table>	Percentile	Latency (ms)	P50	12	P75	15	P99	20	P99.9	25	P99.99	40
Percentile	Latency (ms)												
P50	12												
P75	15												
P99	20												
P99.9	25												
P99.99	40												

9.6 Maximum Command Timeout

Requirement ID	Description
CCTO-1	No read/write IO operation shall take more than 6 seconds regardless of workload including error recovery running in the background.

9.7 Power Mode Transition Times

Requirement ID	Description
PMTT-1	Drive shall take no more than 30 seconds to recover from standby to ACTIVE mode
PMTT-2	Drive shall take no more than 10 ms to transition from IDLE_A to ACTIVE mode
PMTT-3	Drive shall take no more than 400 ms to transition from IDLE_B to ACTIVE mode
PMTT-4	Drive shall take no more than 8 seconds to transition from IDLE_C to ACTIVE mode

9.8 Write Cache Flushing Latency

Requirement ID	Description
SYNC-1	The write cache flushing commands shall take no more than 10 seconds at any conditions if write cache is enabled. The write cache flushing commands refer to FLUSH CACHE / FLUSH CACHE EXT for SATA device and SYNCHRONIZE CACHE for SAS device.

9.9 Multi-actuator Specific Considerations

Requirement ID	Description
MULTIA-1	The performance for devices with multi-actuators is expected to scale linearly. Each actuator in the multi-actuator device shall not lose more than 3% of performance vs baseline due to the adjacent actuators performing activities.

10 Environmental

10.1 Thermal

Requirement ID	Description
THRM-1	The device shall operate normally (e.g., performance, reliability, etc.) within the operating temperature range specified in REL-1 and REL-2.
THRM-2	The non-operating ambient temperature shall be between -40°C and 70°C.
THRM-3	A new device may be kept as a datacenter spare and therefore shall be fully functional even if it sits on the shelf for at least 1 year between a temperature range of 0°C (32°F) and 70°C (158°F) before being installed in a system. The device shall still be in Factory Out of Box (FOB) condition after 1 year.
THRM-4	The device shall operate normally with a max ambient temperature gradient of at least 20°C per hour. The minimal evaluation duration shall be one hour.
THRM-5	The non-operating max ambient temperature gradient shall be at least 20°C per hour. The minimal evaluation duration shall be one hour.
THRM-6	The device FW shall update the internal reported temperature with an interval of 5 second or less.
THRM-7	The device's device-to-device composite temperature variation shall be +/- 1 degrees C. Two different devices shall not report a composite temperature greater than 2 degrees apart under the same environmental conditions, slot location, and workload.
THRM-8	A single device's composite temperature shall not vary by more than +/-1 degrees C (1.8 degrees F) once it is in a steady state under the same environmental conditions, slot location, and workload.
THRM-9	The supplier shall provide the equation, settings, and thresholds used to calculate the composite temperature.

10.2 Altitude

Requirement ID	Description
ALTD-1	The device shall operate normally in data centers being located at an altitude between -1,000 feet and 10,000 feet.
ALTD-2	The storage non-operating altitude shall be between -1,000 ft and 40,000 feet

10.3 Humidity

Requirement ID	Description
HUMD-1	The device shall operate normally with relative humidity to be between 10% and 90% with maximum wet bulb temperature of 29°C.
HUMD-2	The device shall operate normally with relative humidity change rate at or under 20% per hour.
HUMD-3	The storage non-operating relative humidity shall be between 10% and 90% with maximum wet bulb temperature of 29°C.
HUMD-4	The storage non-operating relative humidity change rate shall be at or under 20% per hour.

10.4 Mechanical

10.4.1 Form Factor Requirements

10.4.1.1 Generic Form Factor Requirements

Requirement ID	Description
GFF-1	A compliance report and gap analysis for each supported form factor (e.g., M.2, 2.5", 3.5") shall be provided to the customer.
GFF-2	A CAD file and/or 2D/3D drawing of each supported form factor shall be provided
GFF-3	The device shall support the power disable feature. The feature allows the host to disable power to the device circuitry using pin 3.
GFF-4	The default setting for the Power Disable feature shall be enabled.
GFF-5	The device shall support hot installation and removal ("hot-pluggable"). The device shall not implement any form of a "latching" connector mechanism which might inhibit removal and installation of the device from a storage enclosure. Per SFF-8482 specification, connector mate / unmate minimal cycle life is 500 cycles.

10.4.1.2 3.5" Form Factor Requirements

Requirement ID	Description
FF35-1	The dimensions and connector locations shall conform to small form factor standard defined in SFF-8301 and SFF-8323. The A1 dimension (HDD height) shall meet 26.1 mm max.

10.4.1.3 2.5" Form Factor Requirements

Requirement ID	Description
FF25-1	The dimensions and connector locations shall conform to small form factor standard defined in SFF-8201 and SFF-8223.

10.4.1.4 M.2 Form Factor Requirements

Requirement ID	Description
----------------	-------------

FFM2-1	The device shall adhere to the latest revision of PCI-SIG PCI Express M.2 specification.
--------	--

10.4.2 Weight

Requirement ID	Description
WEIGHT-1	The device shall not weigh more than 750g.

10.4.3 Shock and Vibration

Requirement ID	Description									
VIBR-1	The device shall not experience any performance degradation (Including hard errors) during normal operating conditions as specified in VIBR-5.									
VIBR-2	Vendor shall provide acoustic sound pressure level and mask recommendations based on the OCP HDD acoustic white paper .									
VIBR-3	The operational and non-operational device shall support a minimum of 10 shocks per axis based on VIBR-6 without affecting device operation and performance.									
VIBR-4	The device operation and performance shall not be affected during or after the testing done in VIBR-5.									
VIBR-5	The device shall meet the following shock and vibration requirements at a minimum over a 15-minute test per axis.									
	Vibration	Operating				Non-Operating				Units
		2.5” SAS	2.5” SATA	3.5” SAS	3.5” SATA	2.5” SAS	2.5” SATA	3.5” SAS	3.5” SATA	
	HDD Linear, Random, 10-500 Hz, flat spectrum,	0.0046	0.0046	0.0046	0.0046	0.014	0.014	0.014	0.014	g^2/Hz
	SSD Linear, Random, 10-1000 Hz	0.004	0.004	n/a	n/a	0.0091	0.0091	n/a	n/a	g^2/Hz
		(2grms)	(2grms)			(3grms)	(3grms)			
	HDD Rotary, Random, 10-800Hz Minimum 100% pass level	21	21	21	21	n/a	n/a	n/a	n/a	rad/sec ²
	Shock	Operating				Non-Operating				Units

Requirement ID	Description									
		2.5 SAS	2.5 SATA	3.5 SAS	3.5 SATA	2.5 SAS	2.5 SATA	3.5 SAS	3.5 SATA	
	HDD, Linear, 2msec half sine, Midline	30	30	30	30	250	250	250	250	g's Peak
	SSD, Linear, 0.5msec half sine	1500	1500	n/a	n/a	n/a	n/a	n/a	n/a	rad/sec ²
	Shock (Tilt Drop) Minimum 100% pass level	n/a	n/a	n/a	n/a	90 Degrees (1.5")	90 Degrees (1.5")	90 Degrees (1.5")	90 Degrees (1.5")	

11 Sustainability Requirements

The following are the sustainability requirements for devices.

Requirement ID	Description
SUS-1	A Life Cycle Assessment (LCA) aligned with ISO 14040 for the device shall be provided to the customer.
SUS-2	Recycled content information per material type shall be provided to the customer.

12 Security

12.1 Basic Security Requirements

Requirement ID	Description
SEC-1	The device shall support signed firmware binary updates which are checked before firmware is activated. The device firmware shall be authenticated using cryptographic keys on every reboot and during firmware update.
SEC-2	The device shall support XTS-AES-256 (As specified in NIST SP 800-38E, which references IEEE STD 1619) or AES-256-GCM (As specified in NIST SP 800-38D) hardware-based data encryption. AES-256-GCM is the preferred mode.

Requirement ID	Description
SEC-3	The device shall support anti-rollback protection for firmware. The anti-rollback protection shall be implemented with a security version which is different than the firmware version. If the security version of the firmware being activated is greater or equal to the current security version the firmware may be activated. If the security version of the firmware being activated is not equal or greater than the firmware being activated the firmware update shall fail.
SEC-4	The device shall support Crypto Erase.
SEC-5	The device shall support Secure Boot.
SEC-6	The device shall have a method of identifying a secure boot failure which does not require physical access to the device.
SEC-7	The device's cryptographic module shall be FIPS 140-3 capable per CMVP (not required to get FIPS certificate) and shall follow the NIST 800-90 (A, B and C) specification.
SEC-8	The device shall implement only FIPS and NIST approved implementations and algorithms.
SEC-9	The device shall support Key revocation allowing a new key to be used for firmware verification on update. Preferred implementation is to allow at least 3 key revocations, and more is desired.
SEC-10	TCG devices shall support TCG Opal v2.01 with mandatory support for the Locking feature, the TCG Opal SSC feature, and the Datastore Table feature.
SEC-11	TCG devices shall support TCG Single User Mode feature set Version 1.00, revision 1.00.
SEC-12	Reserved for future use.
SEC-13	For models that support eDrive, the IEEE 1667 silo shall be supported.
SEC-14	Supplier shall follow the Security Development Lifecycle (SDL), and provide a report with the following for each qualification-ready or production-ready firmware version: • The Threat Model. • Fuzz & Pen Tests. • Static Analysis. • Build Logs and Compiler Security Settings. Additional information about the SDL is available here: https://www.microsoft.com/en-us/sdl/default.aspx
SEC-15	Security audits, including firmware source code review, shall be required. This will include telemetry and debug logs, etc.
SEC-16	All signing keys shall be stored in a Hardware Security Module (HSM) that is either FIPS 140-2 Level 3 (or greater) certified or FIPS 140-3 Level 3 (or greater) certified.
SEC-17	Access/use of signing keys shall be restricted to a small set of developers, following the principle of least privilege. Number of people with access and their corresponding roles shall be provided.
SEC-18	All debug ports shall be disabled before the device leaves the factory. Alternatively, the ports shall only be accessible in the field after a successful exchange of a challenge-response mechanism using an asymmetric crypto scheme (refer to NIST SP 800-63). The state shall be reset to inaccessible on any reset or power cycle.

Requirement ID	Description
SEC-19	All vendor unique commands, log pages or set features that are not explicitly defined in this specification or approved of in writing by the customer shall be disabled before the device leaves the factory. Alternatively, the commands/log pages/set features shall only be accessible in the field after a successful exchange of a challenge-response mechanism using an asymmetric crypto scheme (refer to NIST SP 800-63). The state shall be reset to inaccessible on any reset or power cycle.
SEC-20	Adversarial testing using red teams shall be conducted before qualification starts. A report of items attempted, and results shall be provided.
SEC-21	The vendor shall provide timely notification of security issues and delivery of fixes: • The vendor shall document all security fixes with each firmware update. • The vendor shall notify end customer within 7 days of discovering security issues in the device hardware or firmware. • Notification of issues shall include the process and timeline of the vendor's commitment to fix the issue: ○ For privately disclosed vulnerabilities, the duration shall be no longer than 90 days. ○ For publicly disclosed vulnerabilities, the duration shall be no longer than 7 days. Vendors shall notify the customers about the known CVEs and security issues and provide security-related updates before public announcement.
SEC-22	All Telemetry and debugging logs shall be human readable.
SEC-23	The device shall not include user data, passwords, keys or any secret or sensitive information in any Telemetry or debug logs.
SEC-24	All public keys shall be revocable.
SEC-25	Secure Boot Flow shall be based upon hardware root of trust. All mutable Key(s), Certificate(s) and/or firmware shall be cryptographically bound to the hardware root of trust.
SEC-26	Secure firmware update flow shall be immutable for exploitation and use immutable public keys.
SEC-27	For TCG Devices, if TCG Opal SP has been activated and the host has supplied a locking range password, the device shall use that password as an added source of randomness for its Deterministic Random Number Generator (DRNG). For example, the device may use KDF (PBKDF2) on the user provided locking range password to generate an output of equal length to the required locking range key length plus DRNG seed length. This output can then be utilized in parts, one part as Opal locking range key and the other part as an additional input to the DRNG. If the DRNG implementation does not allow taking additional input, then an alternate option would be to XOR this output (e.g., from PBKDF2 operation) with initial DRNG seed.
SEC-28	The device shall delete all keys from volatile memory as soon as they are no longer needed for operation during the current power on state.
SEC-29	The device shall only store host provided passwords, host provided keys, or any host provided secret information in non-volatile memory at any stage in an encrypted form. The

Requirement ID	Description
	encryption key for this protection shall not be stored in non-volatile memory. Device shall not store plaintext/cleartext secrets in any non-volatile memories.
SEC-30	The supplier must deliver key management and encryption flow diagram details (not source code) which includes: • Encryption algorithms and modes (e.g., RNG, wrapping function, key derivation function). • Key size and password length. • Any crypto information that is stored in nonvolatile memory. • Critical Security Parameters. Complete details about algorithm inputs (e.g., Initialization vector source and size, salt source and size, unique per device/product line/vendor)
SEC-31	The supplier must provide industry certification reports, if available, such as FIPS, NIST for device and device components such as TRNG, RNG, Crypto engine etc.
SEC-32	Log data shall be stored in a reserved area which is not part of the user data area.
SEC-33	The vendor shall provide a comprehensive list of what is and what is not in the logs.
SEC-34	The device shall support the Sanitize command and meet NIST SP800-88r1 Purge requirements. Crypto Erase shall be supported. If Overwrite is supported, it shall meet NIST SP800-88r1 Purge requirements.
SEC-35	All telemetry and debug logs shall only be writable by device firmware after a successful secure boot.
SEC-36	TCG devices shall set the default TryLimit to 5 for all TCG Opal authorities. The value of the Tries column shall only be cleared to 0 after a power cycle.
SEC-37	TCG devices shall support TCG Opal configuration (e.g., Level 0 discovery, ownership, etc.) through SCSI Security Protocol In/Security Protocol Out commands or through SATA Trusted Receive/Trusted Send commands.
SEC-38	TCG devices shall support TCG Feature Set: Block SID Authentication.
SEC-39	TCG devices shall enforce a minimum password length (C-PIN PinLength of 16) of 16-bytes for all TCG Opal authorities.
SEC-40	TCG devices shall allow a password length (C-PIN PinLength of 32) of at least 32-bytes for all TCG Opal authorities.
SEC-41	For TCG Devices, the current TCG feature set configuration settings, if any, shall persist through a download of firmware code. This is required regardless of the “default setting state” of the new code being downloaded.
SEC-42	TCG devices shall support TCG Storage Opal SSC Feature Set: PSID Version 1.00, revision 1.00.
SEC-43	The PSID shall not be deterministic, and shall comprise at least 128 bits of entropy, and shall comprise at least 160 bits of entropy. The entropy shall be unique for each drive.
SEC-44	The generation method for the PSID shall be documented and provided to the customer.
SEC-45	After the PSID is provisioned in manufacturing, the PSID shall not be persistently stored in a form that makes direct retrieval of the PSID by firmware possible, either on the drive or outside the drive (e.g., storing the PSID on the drive using a cryptographic hash such that it can only be used to verify a PSID input from the host).

Requirement ID	Description		
SEC-46	Once manufacturing is complete, the PSID shall not be stored anywhere other than on the physical drive label.		
SEC-47	In addition to supporting ALL mandatory features defined in the corresponding TCG specifications, TCG devices shall also support the features listed in the below table.		
	Feature/Parameters		Value
	SSC Feature Descriptor		Opal 2 (0x0203)
	Core Spec (TCG Storage Architecture)		2.01
	SID	# of SIDs	1
		Try Limit	5
		Persistence	FALSE
	Number of Locking SP	Admins	4 (min)
		User	8 (min)
	Number of Locking Ranges	Global	1
		Additional	8 (min)
	Number of Com IDs		1 (min)
	Data Store size		10 MB (min)
	MBR Table		128 MB (min)
	Configurable Access Control		Mandatory
	Life Cycle support		Mandatory
	Repurpose (Revert/ Revert SP)		Mandatory
	Shadow MBR		Shall not be supported
	Feature Set	Single User Mode	Shall be supported
		PSK Secure Messaging	Optional
PSID		Mandatory	
Block SID		Mandatory	
Additional Data Store Tables		Mandatory 5 min 128KB each	
SEC-48	The device shall not allow the host to read firmware or boot code from the device.		
SEC-49	All device firmware packages shall be encrypted based on a symmetric encryption and follow SEC-2 and SEC-29 for key storage.		
SEC-50	Device shall only support the activation of encrypted firmware images.		
SEC-51	The device shall only store firmware in encrypted format when stored in non-volatile memory.		
SEC-52	For any command that changes the media encryption key(s) (e.g., Sanitize command with Crypto Erase (100b), TCG Revert, TCG RevertSP, etc.), the device shall purge, as defined in IEEE 2883-2022, all copies of the previous key(s) before completing the command. If the device cannot guarantee that all copies of the previous media encryption key(s) have been purged, then the device shall fail the command.		

12.2 Secure Boot

The device shall support Secure Boot. There are two fundamental things to address for secure boot:

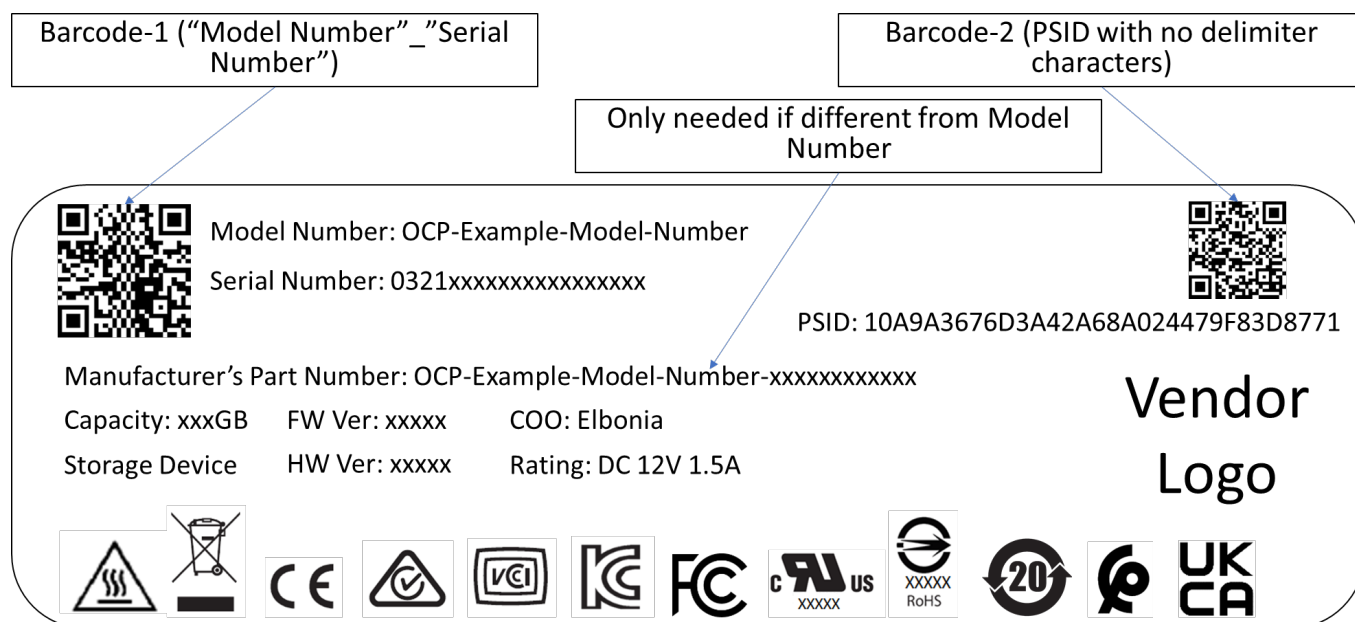
1. Secure boot rooted in hardware.
2. Core Root of Trust Measurement.

The vendor should follow the recommendations in the [TCG Publication for Hardware Requirements for a Device Identifier Composition Engine](#). DICE coupled with [RIOT Core](#) and Source for [RIOT](#) can help implement Cryptographic Identity with implicit attestation.

Requirement ID	Description
SBT-1	The device shall comply with the FIPS 186-4 Digital Signature Standard (DSS) and the Open Compute Security Project Publication for Secure Boot Requirements .
SBT-2	For Core Root of Trust measurement, each device shall have a Cryptographic Device Identity.
SBT-3	The TCG DICE standard , or hardware based cryptographic identity shall be implemented.
SBT-4	The device shall follow the guidance in the Commercial National Security Algorithm Suite 2.0 regarding quantum resistant algorithms, key sizes, and transition timelines.
SBT-5	Secure boot flow shall be immutable for exploitation and use immutable public keys.

13 Labeling

The following sample label is meant to be used to refer to the label requirements in Section 12.1 – Top Cover Label Requirements. It is not a model label and any markings on it are informative only. See the specifics in Section 13.1 – Label Requirements for actual requirements.



13.1 Top Cover Label Requirements

Requirement ID	Description
LABL-1	The following fields are required information that shall be placed on the label:

Requirement ID	Description				
	Item	Format	Text Required	Barcode Required	Barcode Type
	Barcode-1	‘Model Number’ ‘Underscore’ ‘Serial Number’ \n.	No	Yes	2d
	Model Number	See LABL-11 (Model Number must match).	Yes	No	N/A
	Serial Number	See LABL-12 (Serial Number must match), LABL-15 (certification logos), and LABL-17 (Serial Number format).	Yes	No	N/A
	Manufacturer’s Part Number	Number used for ordering.	Yes, if different from Model Number	No	N/A
	Capacity	Number of GB or TB.	Yes	No	N/A
	STORAGE DEVICE	Text shall be “STORAGE DEVICE”.	Yes	No	N/A
	PSID	TCG-OPAL Spec.	Yes	No	N/A
	Barcode-2	‘PSID’ \n	No	Yes	2d
	Firmware Name & Revision		Yes	No	N/A
	Regulatory Mark	See LABL-15 (certification logos).		No	N/A
	Country Certification Numbers	See LABL-15 (certification logos).		No	N/A
	Certification Logos	See LABL-15 (certification logos).		No	N/A
	RoHS/ Green	See LABL-15 (certification logos).		No	N/A
	LABL-2	The Model Name on the shipping label shall match the model name used during qualification.			
LABL-3	The minimum font size shall be 3 points and the typical size shall be 6 points.				
LABL-4	For the Capacity field, if there are space constraints, the manufacturer may remove “Capacity:” and just show “XXXGB” or “XXXTB”.				
LABL-5	To distinguish Model Number and Serial Number, Barcode-1 shall have an underscore “_” between the Model Number portion and the Serial Number portion. Example: Model Number: OCP-Example-Model-Number Serial Number: 0321xxxxxxxxxxxxxxxxxx				

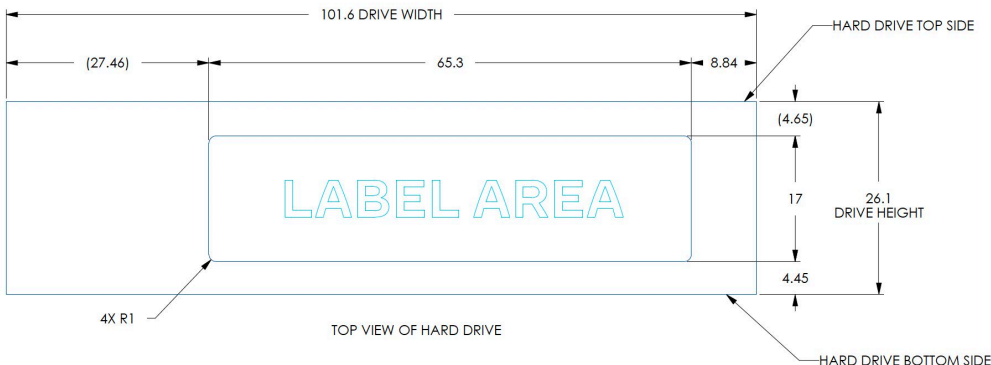
Requirement ID	Description				
	Barcod-1 Readout: OCP-Example-Model-Number_0321xxxxxxxxxxxxxxxxxx				
LABL-6	There shall be a line with the text “STORAGE DEVICE”.				
LABL-7	The following fields are optional information that can be placed on the label at the discretion of the device maker. Placement is also at the device maker’s discretion if such information does not interfere with the mandatory information above. No additional barcode shall be present.				
	Item	Format	Text Required	Barcode Required	Barcode Type
	Processor Code (BA)		Optional	No	N/A
	Maker Logo		Optional	No	N/A
	Rated Voltage & Current		Optional	No	N/A
	Production Date	DDMMYYYY: DD (Date), MM (Month), YYYY (Year)	Optional	No	N/A
	Weekly Code	YYWW: YY (Year), WW (Week)	Optional	No	N/A
	Warranty VOID IF REMOVED		Optional	No	N/A
	Makers Own Label Material Number		Optional	No	N/A
	Website, Company Address		Optional	No	N/A
	HDD		Optional	No	N/A
	Product Series Name		Optional	No	N/A
	SA: Stacking ID Value used within manufacturing		Optional	No	N/A
	PBA: Physical Board Address (identifies the physical configuration of the device)		Optional	No	N/A
	WWN: World Wide Number (unique for each device)		Yes	No	N/A

Requirement ID	Description	
LABL-8	To ensure that datacenter operations personnel can quickly and easily identify devices that have been ticketed for field replacement, it is mandatory to have the proper identifying fields on the label(s), in the format specified in LABL-17 to LABL-20.	
LABL-9	The label shall not degrade over the standard HDD lifetime under standard operating conditions.	
LABL-10	For each form factor, the label shall be placed as specified below: 3.5": the label shall be placed on the top side of the device.	
LABL-11	The Model Number in Barcode-1, the Model Number printed on the label and the Model Number returned in Identify Device (SATA) or Inquiry (SAS) shall all match and shall have no leading spaces.	
LABL-12	The Serial Number in Barcode-1, the Serial Number printed on the top and side labels and the Serial Number returned in Identify Device (SATA) or Inquiry (SAS) shall all match and shall have no leading spaces.	
LABL-13	All other electronically readable information shall also match their counterparts printed on the label.	
LABL-14	The following certification logos and their corresponding certifications are required:	
	Regulatory Mark/Text	Description
	Regulatory Model Number	Unique regulatory Identifier.
	Made in XXXX	Country of Origin.
	Manufacturer or Brand name	Identification of the party responsible for placing the device into the market.
	Address of the Manufacturer	Required for devices with the CE mark or UKCA mark.
	Date of Manufacture	Not needed if embedded in the Serial Number.
	Serial Number	Alpha-Numeric, 12-20 digits with first 4 digits indicating: Date of Manufacturing in Work Week and Year WWYY1234567890123456.
		[Europe] Compliance with EU WEEE directive 2010/19/EU.

Requirement ID	Description
	 [Europe] Compliance with EU EMC directive 2014/30/EU and RoHS directive 2011/65/EU.
	 [Australia, New Zealand] Compliance with requirements of the relevant Australian ACMA Standards, under the Radiocommunications Act 1992 and the Telecommunications Act 1997.
	 [Japan] Compliance with Japan VCCI requirements.
	 XXXX-XX-XX [Korea] Compliance with requirements of the Radio Research Laboratory Ministry of Information and Communication Republic of Korea.
	CAN ICES-3(*)/NMB-3(*) [Canada] Compliance with Canada standard ICES 003. Where * is either A or B.
	 [USA] Optional. Compliance with United States Federal Communications Commission requirement.
	 [USA] Compliance with UL standards and Canadian Safety Standards.
	 XXXXXX RoHS [Taiwan] Compliance with Taiwan EMC and RoHS.
	 [China] Compliance with Chinese environmental requirements. The number inside the circle is usually 10 or 20.
	 [Morocco] Compliance with Moroccan EMC standards.
	 [United Kingdom] Mandatory after 1/1/2022. Guidance to UKCA marking.
LABL-15	If the surface of any component or casing will reach a temperature of 70°C (158°F) or greater the following warning logo shall be either printed on the label or placed separately on the device: 
LABL-16	The format of the serial number shall be WWYYSerialNumber (e.g., WWYY1234567890123456).

Requirement ID	Description
LABL-17	Barcodes shall be printed using Datamatrix ECC200 or Model 2 QR code only.
LABL-18	QR codes shall use a minimum of ECC Level M (15%).
LABL-19	The density of the barcode shall be 10 mil or larger.
LABL-20	The label shall only be printed on Polyester or Plastic labels using a Wax/Resin ribbon.
LABL-21	The PSID shall be printed on the label in its direct 32-character alphanumeric representation without any ancillary delimiting characters (e.g., underscore, dash, backslash, forward slash, etc.) and shall exactly match the readout of Barcode-1.
LABL-22	For a SATA device the label shall be printed with the minimum supported ERC value if the full range timeout value cannot be supported under warranty (e.g., Min ERC 0.1s).

13.2 Edge Label Requirements

Requirement ID	Description
LBLE-1	The edge label shall contain the QR code for HDD serial number.
LBLE-2	The edge label shall be placed within and towards the center of the label area defined in the diagram below: 

14 Compliance

14.1 ROHS Compliance

Requirement ID	Description
ROHS-1	The Supplier shall provide component-level reporting on the use of listed materials by concentration (ppm) for all homogenous materials.

14.2 ESD Compliance

Requirement ID	Description
ESD-1	The device shall support an ESD Human Body Model (HBM) immunity level in accordance with IEC-61000-4-2.

15 Appendix A

Requirements	Details	Link to which Section in Spec
Contribution License Agreement	OPTION B: Open Web Foundation (OWF) CLA	License OWF Option
Are All Contributors listed in Sec 1: License?	Yes	License OWF Option
Did All the Contributors sign the appropriate license for this spec? Final Spec Agreement/HW License?	Yes	
Which OCP Tenets are supported by this Spec?	Efficiency Scalability Openness Impact Sustainability	▪ Efficiency Enables a common design that can be used across multiple end users which reduces the number of SKU's ▪ Scalability Simpler design allows for scale, manageability and reliability • Openness Provides an open specification for Datacenter HDD Requirements ▪ Impact This contribution provides the community a public SSD specification for HDD users and providers to focus on. Enables a more robust supply chain and increased quality. For HDDs this is the first component level specification we are aware of. Enabling the eco-system to have an open component specification thus enabling innovation. ▪ Sustainability This contribution contains sustainability requirements for a device of this type.
Is there a Supplier(s) that is building a product based on this		

Requirements	Details	Link to which Section in Spec
Spec?		
Will Supplier(s) have the product available for GENERAL AVAILABILITY within 120 days?		