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Electronic imaging — Media error monitoring and reporting techniques for verification of stored data on optical digital data disks

Imagerie électronique — Méthodes de surveillance et d'établissement de compte rendu d'erreurs pour la vérification des données stockées sur des disques optiques numériques

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Contents

Page

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this International Standard may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

International Standard ISO 12142 was prepared by Technical Committee ISO/TC 171, *Document imaging applications*, Subcommittee SC 1, *Quality*.

Annexes A to D of this International Standard are for information only.

Introduction

Data and records managers in many organizations are already using optical disk-based information systems for storing and retrieving large data sets and for storing valuable information. The optical disk drives that are part of these systems are designed with powerful, but not unlimited, error correction capabilities. If the level of errors in an optical digital data disk sector exceeds the error detection and correction mechanisms implemented in the optical disk drive controller, the sector cannot be corrected (data loss might occur). System managers would like to be able to use media error monitoring and reporting techniques to verify the information stored on optical digital data disks, both initially when the data is transferred to that media and periodically to monitor the status of their data. The Media Error Levels of correction taking place in the optical disk drive controller give an indication of the status of data saved on these optical digital data disks.

This International Standard documents two approaches of media error monitoring and reporting techniques to verify stored data on optical digital data disks:

— a high-level approach with functional commands;

— an implementation of a set of Small Computer System Interface-2 (SCSI-2) commands.

The high-level interface approach is independent of the host operating system (e.g. DOS, UNIX, OS/2, etc.) and the interface that communicates between the optical disk device and the host (e.g. SCSI-2, IPI, LAN, etc.). In addition, this high-level interface is media type and size independent. That is, it can be used with systems that use Write-Once-Read-Many (WORM), rewritable, or partially read-only media; and with optical disk drives for different media sizes from 90 mm to 356 mm media. Standard information about media errors allows end users and system integrators to retrieve the same information even if their configurations consist of drives of different types, sizes, and manufacturers. This information can be retrieved using the same software, which can be integrated into the media error information utilities or device drivers.

The SCSI interface can be used instead of the high-level interface by using the selected set of SCSI-2 commands. This selected set of SCSI-2 commands allows system manufacturers to develop drive type and size independent data verification tools at the SCSI level through the use of media error monitoring and reporting techniques. The use of a selected standard set of commands and approaches for media error monitoring and reporting allows any implementor to use a common set of software tools that do not change from drive to drive.

The media error information that can be obtained using the high-level or SCSI-2 tools includes:

— a list of reallocated sectors;

— corrections above some Media Error Levels;

— warning above some Verify Media Error Levels;

— the total number of bytes in error, the number of bytes in error per sector, and the maximum number of bytes in error in any sector codeword;

— the uncorrected or corrected sector content;

— errors encountered when reading header information, such as the sector address, sector marks, and synchronization signals;

— the maximum length of contiguous defective bytes.

By acquiring optical disk-based information systems that comply with this International Standard, system managers will be able to access media error information at both a functional (higher) level and an interface level for optical disk drives that implement ISO/IEC 9316. These tools facilitate a better understanding of the status of information stored on optical digital data disks. The tools provide for design of more efficient media error monitoring and reporting techniques, and data verification and recopying policies for transferring recorded data to similar or different media in a timely and economic manner.

These media error monitoring and reporting techniques also allow system managers to obtain media error information either in quasi-real time or during off-line operations. These techniques provide data recovery and media error monitoring tools with different levels of sophistication. Information on media errors can be obtained, which will enable the highlighting of trends on particular selected disks or in their entire data sets. Decisions on frequency of use of these tools and the level of sophistication selected are not part of this International Standard.

Electronic imaging — Media error monitoring and reporting techniques for verification of stored data on optical digital data disks

1 Scope

This International Standard specifies two techniques for media error monitoring and reporting for the verification of data stored on optical digital data disks:

— high-level, which uses a set of functional commands;

— SCSI-2 level, which uses a set of SCSI-2 commands.

It specifies two media error monitoring and reporting levels:

— system level, which uses a set of functional commands that can be used by the operating system, application software, and remote users;

— optical disk device level, which uses a set of SCSI-2 commands that can be used by the device driver or a device application programme.

Compliance to the requirements of this International Standard is specified in clause 4.

This International Standard applies to both rewritable and read only optical disk media.

Part of the information in this International Standard may be useful for CD-ROM subsystems, but implementations for that technology are beyond the scope of this International Standard.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO/IEC 9316:1995, *Information technology — Small Computer System Interface-2*

ISO 12651:1999, *Electronic imaging — Vocabulary*

3 Terms and definitions

For the purposes of this International Standard, the terms and definitions given in ISO/IEC 9316, ISO 12651 and the following apply.

3.1
band
specified number of contiguous tracks

NOTE It is a useful notation for referencing disk regions and plotting physically descriptive media error results.

3.2
byte error rate
BER
total number of bytes in error in a given sample divided by the sample size

3.3
constant angular velocity
recording method in which the number of clock periods per revolution is constant, independent of radius

NOTE This method implies that the amount of data per track is independent of radial position.

3.4
continuous–servo media
media on which the servo information for tracking is continuously available on adjacent grooves

3.5
data field
user data, defect management pointers (DMP), cyclic redundancy check (CRC), and error correction code (ECC) bytes of a recorded sector

3.6
format
arrangement or layout of the data on the disk

3.7
initiator
SCSI device that requests an I/O process to be performed by another SCSI device (a target)

3.8
interleaving
process of allocating the physical sequence of units of data in order to render the data more immune to burst errors

3.9
native format
error correction code (ECC) data and control bytes, and stripping sync bytes

3.10
Reed–Solomon codes
error correction code particularly suited to the correction of errors that occur in bursts or are strongly correlated

3.11
sampled–servo media
media on which the servo information for focusing and tracking, along with clock information, is obtained by means of periodic sampling of information on the optical disk

3.12
target
SCSI device that performs an operation requested by the initiator

3.13
verification of data
verification of the integrity and status of data

4 Requirements

This International Standard specifies the following two levels of compliance:

— the BASIC level which uses a minimal set of functions and commands;

— the EXTENDED level which uses all of the functions and commands in the BASIC level plus a MEDIA ERROR LOG and user-set optical disk device programmable Media Error Levels and Verify Media Error Levels. The EXTENDED level also allows users to interrogate the optical disk system (using the functional commands) or the optical disk device (using a set of SCSI-2 commands) about the current setting of the optical disk device set Media Error Levels and set Verify Media Error Levels.

Statements of compliance to the requirements of this International Standard shall state the level of compliance used, BASIC or EXTENDED, at the system level interface and device level.

An optical disk-based information system is in accordance with this International Standard when it meets all the requirements specified in clause 7 (for BASIC or EXTENDED compliance).

An optical disk device that conforms to ISO/IEC 9316 is in accordance with this International Standard when it meets all the requirements specified in clause 8 (for BASIC or EXTENDED compliance).

Table 1 summarizes the BASIC and EXTENDED levels of compliance at the optical disk-based system level (system level). Table 2 summarizes the BASIC and EXTENDED levels of compliance at the optical disk device level (application of SCSI-2 commands for optical disk devices).

Table 1 — System level compliance

Functional level for optical disk-based subsystems: Function description	Level of compliance	
	BASIC	EXTENDED
Define media error recovery procedures (DMERP)	Yes	Yes
Read defect data list (RDDL)	Yes	Yes
Read media error data (RDMED)	Yes	Yes
Read log data (RLD) – Media error log and current Media Error Levels	No	Yes
Set Media Error Levels (SMEL)	No	Yes
Set Verify Media Error Levels (SVMEL)	No	Yes

Table 2 — Conformance at the optical disk device level

Application of SCSI-2 commands for optical disk devices	Level of compliance	
	BASIC	EXTENDED
The FORMAT UNIT command	Yes	Yes
The LOG SELECT command and the following pages:	No	Yes
— The media error log (MEL) page	No	Yes
— The clear MEL page	No	Yes
The LOG SENSE command and the following pages:	No	Yes
— The MEL page	No	Yes
— The clear MEL page	No	Yes
The MODE SELECT command and the following pages:	No	Yes
— The read-write error recovery page for optical disk devices	No	Yes
— The verify recovery page for optical disk devices	No	Yes
The MODE SENSE command and the following pages:	No	Yes
— The read-write error recovery page for optical disk devices	No	Yes
— The verify recovery page for optical disk devices	No	Yes
The READ DEFECT DATA command and the PDL, SDL, and WDL	Yes	Yes
The READ LONG command	Yes	Yes
The REQUEST SENSE command, the sense keys 01h or 03h, and the related ASC or ASCQs	Yes	Yes
The VERIFY command	Yes	Yes
The WRITE AND VERIFY command	Yes	Yes

5 Conventions

This International Standard follows the conventions given in 4.2 of ISO/IEC 9316:1995. For the purpose of identification, the parameters “Media Error Levels” and “Verify Media Error Levels” used in this International Standard are shown with first upper case letters. The following conventions from ISO/IEC 9316 are reproduced:

Numbers that are not immediately followed by lower-case b or h are decimal values.

Numbers immediately followed by lower-case b (xxb) are binary values.

Numbers immediately followed by lower case h (xxh) are hexadecimal values.

6 Capabilities of media error monitoring techniques

The high-level interface functions specified in clause 7 and the application of SCSI-2 commands specified in clause 8 provide two approaches for retrieving the following information about a disk:

— consumption of spare sectors (physical address of each sector reallocated and of spare sectors still available in the reallocation table, when a reallocation table exists, or a list of sector addresses of the replaced sector and its replacement);

— corrections that exceeded Media Error Levels;

— warning on Verify Media Error Levels;

— the total number of bytes in error, the number of bytes in error per sector, and the maximum number of bytes in error in any codeword;

— the uncorrected or corrected sector content;

— errors encountered when reading header information (bad IDs, sector missing marks, data syncs, and resync marks);

— maximum length of contiguous defective bytes.

Media Error Levels and Verify Media Error Levels can be set.

7 High-level techniques

7.1 Introduction

The purpose of this clause is to provide high-level (a set of functional commands) media error monitoring and reporting techniques for verifying stored data on optical digital data disks. By implementing this International Standard, the following are enabled:

— set Media Error Levels to reallocate sectors whenever one of the Media Error Levels is exceeded;

— obtain the value of the Media Error Levels;

— set Verify Media Error Levels to obtain early warning information on the status of the data when one of the Verify Media Error Levels is exceeded;

— obtain the values of the Verify Media Error Levels;

— obtain information about all the reallocated sectors and a defect list of initial media defects;

— retrieve a media error log with information about the media error activity detected by the drive;

— obtain the corrected sector content or the uncorrected sector content including user data bytes and error correction code (ECC) bytes.

The high-level interface approach is independent of the host operating system (e.g. DOS, UNIX, OS/2, etc.) and the interface between the optical disk device and the host (e.g. SCSI-2, IPI, LAN, etc.). In addition, this high-level interface is media type and size independent. That is, it can be used with systems that use WORM, rewritable or partially read-only media, and optical disk devices for different media sizes (e.g. 90 mm to 356 mm).

Standard formats for disk errors will allow the retrieval of the same information from configurations consisting of drives of different types, sizes, and manufacturers by using the same routines integrated into the media error information utilities or device drivers.

7.2 Functional commands

The following functional, or high-level (host), commands shall be used for verifying the data.

7.2.1 Generic command description

The following command syntax is used in this International Standard:

Command name [parameter 1] [parameter 2] [parameter 3] ……… [parameter *n*]

At least one parameter shall be included with the command name. A parameter that can be set ON or OFF is indicated as:

⌈Parameter ON⌉

⌊ OFF⌋

7.2.2 Define Media Error Recovery Procedures (DMERP)

The DMERP command shall be used to define to the optical disk device the following error recovery procedures:

— media error reporting;

— media error data transfer that shall be executed.

The default for an unspecified parameter shall be OFF.

DMERP ⌈WR ON⌉ ⌈RE ON⌉ ⌈RRE ON⌉

⌊ OFF⌋ ⌊ OFF⌋ ⌊ OFF⌋

WR: Sector Reallocation on Write Error

— ON: Enables the device error recovery procedures to automatically reallocate a sector(s) to a spare sector area on the disk whenever the optical disk device encounters an error level that exceeds the set Media Error Levels during writing operations;

— OFF: Disables the optical disk device error recovery procedures from automatically reallocating a sector(s) whenever the optical disk drive encounters an error level that exceeds the set Media Error Levels during writing operations.

RE: Sector Reallocation on Read Error

— ON: Enables the optical disk device error recovery procedures to automatically reallocate a sector(s) to a spare sector area on the disk, whenever the optical disk device encounters an error level that exceeds the set Media Error Levels when reading a sector(s);

— OFF: Disables the device error recovery procedures from automatically reallocating a sector(s) whenever the optical disk device encounters an error level that exceeds the set Media Error Levels when reading a sector(s).

RRE: Report Recovered Errors

— ON: The optical disk device shall report recovered errors to the host computer;

— OFF: The optical disk device shall not report recovered errors to the host computer.

7.2.3 Read Defect Data List (RDDL)

The RDDL command shall be used to read the defect data list from the optical disk device. The defect data list is shown in Table 3.

Table 3 — Defect data list

Byte	Description
1	Number of entries in the list (MSB)
2	Number of entries in the list (LSB)
3	Defective sector track number (MSB)
4	Defective sector track number
5	Defective sector track number (LSB)
6	Defective sector number
$n-3$	Defective sector track number (MSB)
$n-2$	Defective sector track number
$n-1$	Defective sector track number (LSB)
n	Defective sector number

RDDL [List Size]

List Size specifies, in hexadecimal, the number of bytes to be transferred. The defect list data shall be returned to the host in the format shown in Table 3. If List Size is set to zero, no data shall be transferred. Bytes shall be transferred in hexadecimal values.

7.2.4 Read Media Error Data (RDMED)

The RDMED command shall be used to request the optical disk device to transfer the content of a sector to the host computer. The data transferred to the host shall include the following:

— the user data bytes;

— the ECC bytes;

— the defect management pointers (DMP) bytes;

— any other bytes that are part of the sector data field and can be corrected by the ECC.

These bytes shall be sent to the host in the same order as they occur on the medium, according to any existing related medium International Standard (e.g. for ISO/IEC 10089, format A media, the type of bytes shall be Data, DMP, CRC, and ECC. See ISO/IEC 10089:1991, annex G). The bytes shall be expressed in hexadecimal values. The most recent data written to the addressed sector shall be read from the medium and returned.

RDMED ⌈ADDR BXFER ⌈CORR ON⌉⌉
⌊ ⌊ OFF⌋⌋

where

ADDR is the logical or physical address of the sector that shall be transferred expressed as track and sector number (expressed in hexadecimal values);

BXFER is the number of bytes that shall be read by the optical disk device and transferred to the host computer (expressed in hexadecimal values);

CORR is the data corrected by the ECC. The default shall be to turn ECC correction ON.

- ON: Causes data to be corrected by the ECC before being transferred to the host computer.
- OFF: Causes uncorrected data to be transferred to the host computer.

7.2.5 Read Log Data (RLD)

The RLD command shall be used to request that the optical disk device report log data to the host. Each parameter included with the command identifies a different log.

The logs shall be returned to the host in the order that the log parameters are passed to the optical disk device.

RLD ⌈MEL ⌈CLRMEL ON⌉⌉ [CMELL] [VCMELL]

⌊ ⌊ OFF⌋⌋

MEL is the Media Error Log; it provides detailed information about different media error indicators. The data in the MEL shall be sent to the host in the sequence defined in clause 8 and Table 22. That is, number of read retries shall be sent first, followed by number or write retries, etc. Each parameter shall have a length of 6 bytes. This is the same parameter length specified for the same parameters in 8.12.3.2 and Table 21. The parameters shall be transferred as hexadecimal values.

CLRMEL specifies that the MEL shall be cleared when read. The default shall be OFF.

- ON: The MEL shall be cleared when it is read.
- OFF: The MEL shall not be cleared when it is read.

CMELL is the Current Media Error Levels Log; it reports the current set media error level values. These values shall be used by the optical disk device to reallocate a sector(s). Table 4 shows the four specified media error level parameters.

The media error level values shall be sent to the host in the sequence shown in Table 4. Each parameter shall have a length of 6 bytes. This is the same parameter length specified for the same parameters in 8.12.2.1 and Table 18. The parameters shall be transferred as hexadecimal values.

Table 4 — Media Error Levels

Maximum number of bytes in error per codeword per sector
Number of bytes in error per sector
Number of bad IDs
Number missing resync [a]
[a] If the medium does not use resyncs, this level is N/A and the parameter shall be FFh.

If either the WR or the RE parameters from the DMERP command is ON, the optical disk device shall reallocate sector(s) that have an error recovery level exceeding one or more of the set Media Error Levels as specified in Table 4.

VCMELL is the Verify Current Media Error Levels Log; it reports the current set verify level values. These levels shall be used by the optical disk device to provide an early warning to the host computer that the correction level exceeded the value for the related set level as defined in Table 5.

The sector(s) that provoke the early warning can be found through the MEL. Table 5 shows the four specified verify media error level parameters. The data in the VCMELL shall be sent to the host in the sequence shown in Table 3. Each parameter shall have a length of 6 bytes. This is the same parameter length specified for the same parameters in 8.12.2.2 and Table 19. The parameters shall be transferred as hexadecimal values.

Table 5 — Verify Media Error Levels

Verify maximum number of bytes in error per codeword per sector
Verify number of bytes in error per sector
Verify number of bad IDs
Verify number missing resync [a]
[a] If the medium does not use resyncs, this level is N/A and the parameter shall be FFh.

7.2.6 Set Media Error Levels (SMEL)

The SMEL command shall be used to set Media Error Levels that the optical disk device shall use for error recovery. The four Media Error Levels that can be set with this command are specified in Table 4. The Media Error Levels are the same as those that are reported by CMELL using the RLD command.

The Media Error Levels shall be used for reallocating sectors. If the ECC level of correction exceeds one or more of the set levels and the parameters WR or RE in the DMERP command are ON, the sector shall be reallocated to a spare sector. If the parameters WR or RE in the DMERP command are OFF, the optical disk device shall not reallocate the sector. In either case, the optical disk device shall report that a set level was exceeded, identify the level, and indicate whether the data were recovered or unrecovered.

SMEL [LBECW = n1] [LBES = n2] [LID = n3] [LMRS = n4]

where n1 to n4 are the level values (expressed in hexadecimal) specified below:

— LBECW: level for maximum number of bytes in error per codeword per sector;

— LBES: level for number of bytes in error per sector;

— LID: level for number of bad IDs;

— LMRS: level for missing resync.

7.2.7 Set Verify Media Error Levels (SVMEL)

The SVMEL command shall be used to set Verify Media Error Levels that the optical disk device shall use for error recovery. The four Verify Media Error Levels that can be set with this command are specified in Table 5. The Verify Media Error Levels are the same as those that are reported by VCMELL using the RLD command.

These levels shall be used for obtaining an early warning of media errors that exceeded any level set by this command. The optical disk device shall report that a set level was exceeded, identify the level, and indicate whether the data were recovered or unrecovered.

SVMEL [VLBECW = n1] [VLBES = n2] [VLID = n3] [VLMRS = n4] where n1 to n4 are the level values (expressed in hexadecimal) specified below:

- VLBECW: verify level for maximum number of bytes in error per codeword per sector;
- VLBES: verify level for number of bytes in error per sector;
- VLID: verify level for number of bad IDs;
- VLMRS: verify level for missing resync.

8 SCSI-2 level techniques

8.1 Introduction

The purpose of this clause is to provide an application of a selected set of SCSI-2 commands.

Selected commands from the SCSI-2 command set can be used to tailor the retrieval of media error information according to system requirements. The application of a selected set of SCSI-2 commands from the SCSI-2 command set in this International Standard is related to media error information only and is to be used in conjunction with ISO/IEC 9316. Some of the SCSI-2 commands that are specified in ISO/IEC 9316 are included here. However, to use the SCSI-2 commands for applications other than media error monitoring and reporting refer to ISO/IEC 9316.

In 8.2 to 8.11, requirements for media error monitoring and reporting are described. These requirements define information about methods for implementing better media error monitoring and reporting approaches, and provide users with more information on how to satisfy the system requirements through the use of this International Standard. Requirements for media error monitoring and reporting described in each command implementation supersede the implementation requirements given in ISO/IEC 9316. Any command, option, or implementation not covered in this International Standard will remain as specified in ISO/IEC 9316. It is the responsibility of the user to request from the target any information provided by the commands as specified in this clause.

The FORMAT UNIT command shall be used to format the media. This command allows users, as an option, to certify the media and create a certification list, which is retrievable as part of the information available through the READ DEFECT DATA command (see 8.2 and 8.7).

The LOG SELECT command shall be used to clear the MEL page specified in this International Standard, which provides information about different media error indicators (see 8.3 and 8.12.3.3).

The LOG SENSE command shall be used to retrieve the MEL (see 8.4 and 8.12.3.3).

The read-write error recovery page for optical disk devices and the verify error recovery page for optical disk devices, as specified in this International Standard, shall be implemented by a device/subsystem manufacturer or implementor claiming EXTENDED compliance to this International Standard (see 8.12.2).

The MODE SELECT command and the read-write error recovery page for optical disk devices shall be used to set Media Error Levels different from the drive default values (see 8.5 and 8.12.2). When automatic reallocation is set, the set media error level values shall be used by the optical disk device to reallocate sectors that have exceeded the reallocation criteria defined in Table 4.

The MODE SELECT command and the verify error recovery page for optical disk devices shall be used to set new verify media error level values (see 8.5 and 8.12.2). The set verify media error level values shall be used by the optical disk device to warn users that the disk has exceeded one or more of the Verify Media Error Levels defined in Table 5.

The MODE SENSE command shall be used to retrieve from the device the Media Error Levels in the read-write error recovery page for optical disk devices and the Verify Media Error Levels in the verify error recovery page for optical disk devices, both specified in this International Standard (see 8.6 and 8.12.2).

The READ DEFECT DATA command shall be used to retrieve information about bad sectors and sectors that have been reallocated (see 8.7).

The READ LONG command shall be used to retrieve the corrected content of a sector or the uncorrected content of a sector including user data, ECC, and other sector bytes (see 8.8). This command can also be used to determine the length of media defects (see 8.8.2.2).

The REQUEST SENSE command shall be used to transfer sense data to the initiator (see 8.9).

The list of the selected set of SCSI-2 commands included in this International Standard is shown in Table 6.

Table 6 — Selected set of SCSI-2 commands

SCSI-2 Command	Rewritable media	WORM/ read-only
FORMAT UNIT	✓	—
LOG SELECT	✓	✓
LOG SENSE	✓	✓
MODE SELECT	✓	✓
MODE SENSE	✓	✓
READ DEFECT DATA	✓	✓
READ LONG	✓	✓
REQUEST SENSE	✓	✓
VERIFY	✓	✓
WRITE AND VERIFY	✓	✓

8.2 The FORMAT UNIT command

8.2.1 Introduction

In 9.2.1 of ISO/IEC 9316:1995, the use of the FORMAT UNIT command is documented. That information shall be considered part of this International Standard.

8.2.2 Requirements for media error monitoring and reporting

Before using the FORMAT UNIT command, disks shall be inspected, and reasonable precautions taken to ensure that the disk is clean and free of contamination. If the disk is not clean or free of contamination, it shall be cleaned using procedures recommended by the media vendor. Formatting a disk with an unclean surface forces sectors that could be used to be reallocated. The original manufacturer of the device or media might not certify the media. If the media is not certified, the disk should be formatted with certification ON before implementing media error monitoring and reporting techniques. Formatting with certification ON will create a defect list and baseline information useful for media error monitoring.

Table 7 provides the results of executing the READ DEFECT DATA command. The acronym PDL stands for primary defect list; SDL is the acronym for secondary defect list. PDL and SDL, as well as the Plist and Glist bits are defined in ISO/IEC 9316 under the READ DEFECT DATA command (see 9.2.8 of ISO/IEC 9316:1995).

Table 7 — Result of using the READ DEFECT DATA command

Plist bit	Glist bit	Result transmitted	Qualifier
ON	OFF	PDL	If it exists
OFF	ON	SDL	
ON	ON	PDL first followed by SDL [a]	

[a] For WORM media and devices, a working defect list (WDL) might exist. See both 8.7 (which describes the READ DEFECT DATA Command) and Table 10, Defect descriptor 2 format (WDL).

It is recommended that the READ DEFECT DATA command should be executed with the Glist and the Plist bits ON, immediately after certifying the media. When the SDL and the PDL exist on the media, they are part of the disk definition structure (DDS). This structure is defined in the media standards listed in the Bibliography.

In the case of alternative structures (such as other defect management pointers or sector maps) when using the READ DEFECT DATA command with the Glist bit ON, the data transferred to the initiator shall be the list of reallocated sectors and replaced sectors sent to the host computer in the format of a SDL (see 8.7 and Table 9).

It is recommended that MODE SELECT parameters be set before executing the FORMAT UNIT command. Otherwise, the values recorded on the media will be used, if available. If these values are not on the media, the default values of the optical disk device will be used (to set the MODE SELECT parameters, see the manufacturer's SCSI-2 programming manual for the appropriate optical disk device).

Defect descriptors shall be returned in either the block format or the physical format. The parameter shall be expressed in hexadecimal values. The bytes from index format in Tables 112 and 114 of ISO/IEC 9316:1995 do not apply to this International Standard.

For implementations of this International Standard, bytes 0 to 2 in Table 115 of ISO/IEC 9316:1995 shall contain the parameter "Track number of defect" (the track where the defect occurred) instead of "Cylinder number of defect" parameter specified in ISO/IEC 9316.

Parameters shall be expressed in hexadecimal values.

8.3 The LOG SELECT command

8.3.1 Introduction

In 8.2.6 of ISO/IEC 9316:1995, the use of the LOG SELECT command is documented. That information shall be considered part of this International Standard.

8.3.2 Requirements for media error monitoring and reporting

The LOG SELECT command shall be used to clear the MEL page (see 8.12.3 and 8.12.3.2). The MEL page provides information about different media error indicators. Three approaches are defined to clear the MEL page.

a) The first alternative is to use the LOG SELECT command with the clear MEL page (see Table 23). When a target receives this page, it shall clear the MEL page. The page code for the clear MEL page shall be 3Ah for SCSI-2 compliant devices and 0Ah for SCSI-3 compliant devices as shown in Table 20.

b) The second alternative is to use the LOG SELECT command with the parameter code reset (PCR) bit set to one and the parameter list length set to zero (see 8.2.6 of ISO/IEC 9316:1995). No page shall be sent to the target. All implemented parameters of the target are set to their default values.

c) The third alternative is to use the LOG SELECT command with the page code (PC) set to 11b and the parameter list length set to zero (see 8.2.6 of ISO/IEC 9316:1995). No page shall be sent to the target. All the cumulative parameters are set to their default values.

8.4 The LOG SENSE command

8.4.1 Introduction

In 8.2.7 of ISO/IEC 9316:1995, the use of the LOG SENSE command is documented. That information shall be considered part of this International Standard.

8.4.2 Requirements for media error monitoring and reporting

The LOG SENSE command shall be used to retrieve the MEL page (see 8.12.3 and 8.12.3.2). The MEL page provides information about different media error indicators. The MEL page is retrieved through the use of a log page specified by the page code field.

The page code for the MEL page shall be 39h for SCSI-2 compliant devices and 09h for SCSI-3 compliant devices (see Table 20, 8.12.3.2 and Table 21).

8.5 The MODE SELECT command

8.5.1 Introduction

In 8.2.8 and 8.2.9 of ISO/IEC 9316:1995, the use of the MODE SELECT command is documented. That information shall be considered part of this International Standard.

8.5.2 Requirements for media error monitoring and reporting

Some applications are more critical than others and systems implemented in more critical applications might want to adjust the sector retirement or early warning thresholds according to their applications. For instance, an application might want highly reliable media error reporting. Other applications need recoverable data but cannot afford to perform frequent recopy operations because of the large size of the data sets and consequent high cost. For these applications, obtaining the maximum useful lifetime from their media may be important.

The target shall provide user-modifiable Media Error Levels to decide when to reallocate defective sectors, and Verify Media Error Levels to warn that the disk has exceeded a certain level of errors. The following media error conditions are specified:

— number of bytes in error per sector;

— maximum number of bytes in error per codeword per sector;

— number of bad IDs;

— number of missing resyncs.

The levels shall be set for the optical disk device through the read-write error recovery page for optical disk devices and the verify error recovery page for optical disk devices specified in this International Standard (see 8.12). These specified pages are extensions of the original read-write and verify recovery pages specified in ISO/IEC 9316 (see 9.3.3.6 and 9.3.3.8 of ISO/IEC 9316:1995).

The MODE SELECT command shall be used to set the new Media Error Levels through the read-write error recovery page for optical disk devices, and to set the new Verify Media Error Levels through the verify error recovery page for optical disk devices.

If a media error level is exceeded during reading or writing operations, the optical disk device shall return a CHECK CONDITION status with a sense key of 01h (RECOVERED ERROR) if the PER bit was set to ONE, or 03h (MEDIUM ERROR). Additional sense codes (ASCs) and additional sense code qualifiers (ASCQs) can be retrieved with the REQUEST SENSE command (see Tables 11, 12 and 13).

If a verify media error level is exceeded during a VERIFY command or the verify operation of a WRITE AND VERIFY command, the optical disk device shall return a CHECK CONDITION status with a sense key of 03h (MEDIUM ERROR). Additional sense codes (ASCs) and additional sense code qualifiers (ASCQs) can be retrieved with the REQUEST SENSE command (see Table 14).

8.6 The MODE SENSE command

8.6.1 Introduction

In 8.2.10 and 8.2.11 of ISO/IEC 9316:1995, the use of the MODE SENSE command is documented. That information shall be considered part of this International Standard.

8.6.2 Requirements for media error monitoring and reporting

The requirements for media error monitoring and reporting are specified in 8.5.2. The MODE SENSE command shall be used to retrieve the values of the current Media Error Levels defined in the read-write error recovery page for optical disk devices, and the values of the current Verify Media Error Levels specified in the verify error recovery page for optical disk devices.

8.7 The READ DEFECT DATA command

8.7.1 Introduction

In 9.2.8 of ISO/IEC 9316:1995, the use of the READ DEFECT DATA command is documented. That information shall be considered part of this International Standard.

8.7.2 Requirements for media error monitoring and reporting

See Table 7 for the result of using the READ DEFECT DATA command. A primary defect list (PDL) might or might not exist on the media. If the PDL exists, it shall be sent through the READ DEFECT DATA command using defect descriptor 0 (see Table 8 for reading the PDL.) The bytes of the defect descriptor 0 format (PDL) shall be expressed in hexadecimal values.

If a secondary defect list (SDL) exists on the media (empty or not), it shall be sent through the READ DEFECT DATA command using defect descriptor 1 for reading the Glist (see Table 9.) The bytes of the defect descriptor 1 format (SDL) shall be expressed in hexadecimal form.

Table 8 — Defect descriptor 0 format (PDL)

Byte	Description
0	(00h)
1	(01h) (Defect list identifier)
2	Number of entries MSB (each entry is 4 bytes long)
3	Number of entries LSB
4	Address of the first defective sector (track number MSB)
5	Address of the first defective sector (track number)
6	Address of the first defective sector (track number LSB)
7	Address of the first defective sector (sector number)
4*n*-3	Address of the *n*th defective sector (track number MSB)
4*n*-2	Address of the *n*th defective sector (track number)
4*n*-1	Address of the *n*th defective sector (track number LSB)
4*n*	Address of the *n*th defective sector (sector number)

Table 9 — Defect descriptor 1 format (SDL)

Byte	Description
0	(00h)
1	(02h) (Defect list identifier)
2	(00h)
3	(01h)
4	MSB of the list length specified in number of bytes from byte 6 to byte x-1
5	LSB of the list length
6	(02h) (SDL)
7	(01h)
8	MSB of the list length specified in number of bytes from byte 10 to byte x-1
9	LSB of the list length
10	Address of the first defective sector (track number MSB)
11	Address of the first defective sector (track number)
12	Address of the first defective sector (track number LSB)
13	Address of the first defective sector (sector number)
14	Address of the first replacement sector (track number MSB)
15	Address of the first replacement sector (track number)
16	Address of the first replacement sector (track number LSB)
17	Address of the first replacement sector (sector number)
x-8	Address of the last defective sector (track number MSB)
x-7	Address of the last defective sector (track number)
x-6	Address of the last defective sector (track number LSB)
x-5	Address of the last defective sector (sector number)
x-4	Address of the last replacement sector (track number MSB)
x-3	Address of the last replacement sector (track number)
x-2	Address of the last replacement sector (track number LSB)
x-1	Address of the last replacement sector (sector number)

For WORM media, a third list might exist — the working defect list (WDL). The WDL shall be sent through the READ DEFECT DATA command using defect descriptor 2 with the Glist bit ON (see Table 10.) The bytes of the defect descriptor 2 format (WDL) shall be expressed in hexadecimal values (See the WORM media interchange standards for the definition of the WDL.) Note that the WDL might not exist on the media, or if it exists, it might be empty. The format of defect descriptors 0 (PDL), 1 (SDL), and 2 (WDL) shall be as shown in Tables 8, 9, and 10.

For optical digital data disks that do not specify defect lists (such as PDL, SDL and WDL) but use spare areas and defect management pointers (DMP) only or other types of defect management, such as sector maps, the information on defective sectors shall be provided to the host computer as defined in Table 5.

Table 10 — Defect descriptor 2 format (WDL)

Byte	Description
0	(00h)
1	(03h) (Defect List Identifier)
2	(00h)
3	(00h), indicating that the WDL has no sublist
4	The list length specified in number of bytes from byte 6 to byte x(*)(MSB)
5	The list length specified in number of bytes from byte 6 to byte x(*)(LSB)
6	(00h)
7	The page number of the WDL
8	(FFh)
9	(FFh)
10	Address of the first defective sector (track number MSB)
11	Address of the first defective sector (track number)
12	Address of the first defective sector (track number LSB)
13	Address of the first defective sector (sector number)
14	Address of the first replacement sector (track number MSB)
15	Address of the first replacement sector (track number)
16	Address of the first replacement sector (track number LSB)
17	Address of the first replacement sector (sector number)
.	(each unit shall correspond to byte 10 to 17)
y+1	This byte shall be set to (FFh)
z [a]	This byte shall be set to (FFh)

[a] x is the last byte that has the newest link information of the replacement; z is usually equal to 1023 for a 1024 byte sector and equal to 511 for a 512 byte sector.

8.8 The READ LONG command

8.8.1 Introduction

In 9.2.9 of ISO/IEC 9316:1995, the use of the READ LONG command is documented. That information shall be considered part of this International Standard.

8.8.2 Requirements for media error monitoring and reporting

8.8.2.1 Format of the data passed during the READ LONG command

The data passed during the READ LONG command shall include the user data bytes, the ECC bytes, and any other bytes that can be corrected by the ECC (e.g. data synchronization mark within the area covered by ECC). It is not important for the ECC bytes to be at the end of the data bytes; however, they shall be in the same order as they occur on the media, according to any existing media interchange International Standard for the type of media used. For example, for ISO/IEC 10089 Format A media, the type of bytes shall be Data, DMP, CRC, and ECC; see ISO/IEC 10089 listed in Bibliography. The most recent data written to the addressed logical block shall be read from the media and returned. The bytes shall be expressed in hexadecimal values.

8.8.2.2 How to determine the defect length using the READ LONG command

Use the following procedure to determine the length of a defect in a sector:

a) Compare the data obtained using the READ LONG command with error correction ON followed by the READ LONG command with error correction OFF.

b) Analyse the contiguous bytes which are in error to tabulate the defect length for any defect found in that sector.

8.9 The REQUEST SENSE command

8.9.1 Introduction

In 8.2.14 of ISO/IEC 9316:1995, the use of the REQUEST SENSE command is documented. That information shall be considered part of this International Standard. An additional requirement for the REQUEST SENSE command specified in this International Standard is that a CHECK CONDITION status returned because a media error level or a verify media error level was exceeded shall set the ASCs and ASCQs (see 8.5.2 and 8.9.2).

8.9.2 Requirements for media error monitoring and reporting

8.9.2.1 Media Error Levels and Verify Media Error Levels

If a media error level is exceeded during reading or writing operations, the optical disk device shall return a CHECK CONDITION status with a sense key of 01h (RECOVERED ERROR) if the PER bit was set to ONE, or 03h (MEDIUM ERROR). The REQUEST SENSE command shall be used to retrieve the ASCs and the ASCQs. (See Tables 11, 12 and 13).

If a verify media error level is exceeded during a VERIFY command or during the verify operation of a WRITE AND VERIFY, the optical disk device shall return a CHECK CONDITION status with a sense key of 03h (MEDIUM ERROR). The REQUEST SENSE command shall be used to retrieve the ASCs and the ASCQs (see Table 14).

Table 11 — Sense codes when reallocation is ON and the drive is able to reassign defective sectors

Condition	Sense key	ASC	ASCQ	Description
Maximum bytes in error per codeword per sector				
— when writing	1	03h	00h	Peripheral device write fault
— when reading	1	18h	00h	Recovered data with error correction applied
ID	1	10h	00h	ID CRC or ECC error
Resync	1	11h	07h	Data resynchronization error

Table 12 — Sense codes when reallocation is ON and the drive is unable to reassign defective sectors

Condition	Sense key	ASC	ASCQ	Description
Maximum bytes in error per codeword per sector				
— when writing	3	0Ch	02h	Write error — auto reallocation failed
— when reading	3	11h	04h	Unrecovered read error — auto reallocate failed
ID	3	11h	00h	ID CRC or ECC error
Resync	3	11h	07h	Data resynchronization error

Table 13 — Sense codes when reallocation is OFF

Condition	Sense key	ASC	ASCQ	Description
Maximum bytes in error per codeword per sector				
— when writing	3	03h	00h	Peripheral device write fault
— when reading	3	11h	00h	Unrecovered read error
ID	3	10h	00h	ID CRC or ECC Error
Resync	3	11h	07h	Data resynchronization error

Table 14 — Sense codes used when a verify media error level is exceeded

Condition	Sense key	ASC	ASCQ	Description
Maximum bytes in error per codeword per sector	3	11h		Unrecovered read error
ID	3	10h		ID CRC or ECC error
Resync	3	11h		Data resynchronization error

8.9.2.2 ID, sector mark, and sync mark error monitoring

In addition to monitoring the user data portion of a sector, users should monitor the sector header information, specifically the IDs, the sector mark, and the sync mark.

8.9.2.2.1 Recovered errors

The optical disk device shall report recovered errors in the sense data with a sense key of 01h (Recovered Error). The optical disk device, as part of its error recovery, shall also report when detecting sector mark, ID CRC, and sync mark errors using the ASCs and ASCQs, as shown in Table 15. As part of its error recovery, the optical disk device might reassign the sector to a spare sector area of the disk.

Table 15 — ASC and ASCQ for sector marks, IDs, and sync mark errors

Error	ASC	ASCQ
No index sector signal	01h	00h
ID CRC error	10h	00h
Data sync mark error	16h	00h

Users might want to either clean the media or copy the data to another optical disk if there are excessive recovered errors or if there is excessive reallocation of sectors.

8.9.2.2.2 Unrecoverable errors

The optical disk device shall report the error in the sense data with a sense key of 03h for errors that are not recovered. The ASC and ASCQ shall be as shown in Table 15.

8.10 The VERIFY command

8.10.1 Introduction

In 9.2.19 of ISO/IEC 9316:1995, the use of the VERIFY command is documented. That information shall be considered part of this International Standard.

8.10.2 Requirements for media error monitoring and reporting

The MODE SELECT command, the MODE SENSE command, and verify error recovery page for optical disk devices shall be implemented.

The VERIFY command shall use media error monitoring criteria that are more demanding than the criteria used by the drive during normal reading and writing. The more demanding criteria shall ensure that the data can be verified under this condition and shall set the levels shown in Table 16. The Verify Media Error Levels shall be expressed in hexadecimal values.

Table 16 — Verify Media Error Levels

Verify maximum number of bytes in error per codeword per sector
Verify number of bytes in error per sector
Verify number of bad IDs
Verify number of missing resync [a]
[a] If the medium does not use resync, this level shall not be implemented in the device.

When a verify media error level is exceeded during a VERIFY command, the optical disk device shall return a CHECK CONDITION status with the appropriate ASC and ASCQ sense key (see 8.5.2 and 8.9.2).

8.11 The WRITE AND VERIFY command

8.11.1 Introduction

In 9.2.22 of ISO/IEC 9316:1995, the use of the WRITE AND VERIFY command is documented. That information shall be considered part of this International Standard.

8.11.2 Requirements for media error monitoring and reporting

The MODE SELECT command, the MODE SENSE command, the Read/Write error recovery page for optical disk devices, and the verify error recovery page for optical disk devices shall be implemented.

The verify operation of the WRITE AND VERIFY command shall use media error monitoring criteria that are more demanding than the criteria used by the drive during normal reading and writing. The more demanding criteria shall ensure that the data can be verified under this condition and shall set the levels shown in Table 16.

When a verify media error level is exceeded during the verify operation of a WRITE AND VERIFY command, the optical disk device shall return a CHECK CONDITION status with the appropriate ASC and ASCQ sense key.

The Media Error Levels are shown in Table 17. When one of these levels is exceeded during the write operation, the optical disk device shall return a CHECK CONDITION status with the appropriate ASC and ASCQ sense key (see 8.5.2 and 8.9.2). The Media Error Levels shall be expressed in hexadecimal values.

Table 17 — Media Error Levels

Maximum number of bytes in error per codeword per sector
Number of bytes in error per sector
Number of bad IDs
Number of missing resync [a]
[a] If the medium does not use resync, this level shall not be implemented in the device.

8.12 Parameters for optical disk devices

8.12.1 Media error monitoring and reporting associated parameters

In 8.3, 9.3, and 16.3 of ISO/IEC 9316:1995, parameters, descriptors, and page structures used by different SCSI commands are specified. The following specify only the parameters, descriptors, and page structures associated with media error monitoring and reporting in optical disk devices. When appropriate, information extracted from 8.3, 9.3 and 16.3 of ISO/IEC 9316:1995 has been combined to apply to optical disk devices only.

8.12.2 Mode parameters

In 8.3.3 and 16.3.3 of ISO/IEC 9316:1995, the mode parameters are described. That information shall be considered part of this International Standard. These subclauses of ISO/IEC 9316 shall be used with the MODE SELECT and MODE SENSE commands.

Two mode pages shall be implemented:

— the read-write error recovery page for optical disk devices;

— the verify error recovery page for optical disk devices.

These two pages are based on the Read-Write and verify error recovery pages specified in ISO/IEC 9316, but are extended to specify additional error level parameters and vendor-specific parameters.

8.12.2.1 The Read-Write error recovery page for optical disk devices

This subclause describes a Read-Write error recovery page for optical disk devices (see Table 18), which specifies four new parameters:

— the maximum number of bytes in error per codeword per sector;

— the number of bytes in error per sector;

— the number of bad IDs;

— the number of missing resyncs;

These parameters are expressed in hexadecimal values.

Sixteen byte length vendor-specific registers are provided for the vendor to add other Media Error Levels not specified in this International Standard. With the exception of the parameters specified in this new page (bytes 12 through 83), the implementation of the parameters and bits specified in this new page shall follow the implementation of the Read-Write recovery page specified in ISO/IEC 9316 (see 9.3.3.6 of ISO/IEC 9316:1995). That information shall be considered part of this International Standard.

When one of the Media Error Levels (bytes 12 through 35) is exceeded during reading or writing operations, the optical disk device shall return a CHECK CONDITION status with the appropriate sense key. If the AWRE bit or the ARRE bit is set to one, the defective sectors shall be reallocated.

The optical disk device shall return the sense key RECOVERED ERROR (01h) (if the PER bit was set to ONE) if reallocation was ON (AWRE or ARRE bit ON), and the drive was able to reassign the sector. If the drive was unable to reassign the sector or reallocation was OFF, the drive shall return the MEDIUM ERROR (03h) sense key. Users can retrieve ASC and ASCQ with the REQUEST SENSE command (see 8.9).

Table 18 — Read-Write error recovery page for optical disk devices

Byte	Bit							
	7	6	5	4	3	2	1	0
0	PS	Reserved	Page code (01h)					
1	Page length							
2	AWRE	ARRE	TB	RC	EER	PER	DTE	DCR
3	Read retry count							
4	Correction span							
5	Head offset count							
6	Data strobe offset count							
7	Reserved							
8	Write retry count							
9	Reserved							
10 11	(MSB) Recovery time limit (LSB)							
12 – 17	Maximum number of bytes in error per codeword per sector							
18 – 23	Number of bytes in error per sector							
24 – 29	Number of bad IDs							
30 – 35	Number of missing resync [a]							
36 – 51	Vendor specific							
52 – 67	Vendor specific							
68 – 83	Vendor specific							

[a] If the medium does not use resync, this level is N/A and the parameter shall be Ffh.

8.12.2.2 The verify error recovery page for optical disk devices

This subclause describes a verify error recovery page for optical disk devices (see Table 19) that specifies four new parameters:

— the verify maximum number of bytes in error per codeword per sector;

— the verify number of bytes in error per sector;

— the verify number of bad IDs;

— the verify number of missing resync;

— These parameters shall be expressed in hexadecimal values.

Table 19 — Verify error recovery page for optical disk devices

Byte	Bit							
	7	6	5	4	3	2	1	0
0	PS	Reserved	Page code (07h)					
1	Parameter length							
2	Reserved				EER	PER	DTE	DCR
3	Verify retry count							
4	Verify correction span							
5	Reserved							
6	Reserved							
7	Reserved							
8	Reserved							
9	Reserved							
10 11	(MSB) Verify recovery time limit (LSB)							
12 – 17	Verify maximum number of bytes in error per codeword per sector							
18 – 23	Verify number of bytes in error per sector							
24 – 29	Verify number of bad IDs							
30 – 35	Verify number of missing resync [a]							
36 – 51	Vendor specific							
52 – 67	Vendor specific							
68 – 83	Vendor specific							

[a] If the medium does not use resync, this level is N/A and the parameter shall be Ffh.

Sixteen byte length vendor-specific registers are provided for the vendor to add other Verify Media Error Levels not specified in this International Standard. With the exception of the parameters specified in this new page (bytes 12 through 83), the implementation of the parameters and bits specified in this new page shall follow the implementation of the Verify Recovery Page specified in ISO/IEC 9316 (see 9.3.3.8 of ISO/IEC 9316:1995). That information shall be considered part of this International Standard.

When one of the Verify Media Error Levels (bytes 12 through 35) is exceeded, the optical disk device shall return a CHECK CONDITION status with the MEDIUM ERROR (03h) sense key. Users can retrieve ASC and ASCQ with the REQUEST SENSE command (see 8.9).

8.12.3 Log parameters

In 8.3.2 and 16.3.2 of ISO/IEC 9316:1995, the log parameters are described. That information shall be considered part of this International Standard. These subclauses of ISO/IEC 9316 shall be used with the LOG SELECT (see 8.3) and the LOG SENSE commands (see 8.4).

8.12.3.1 Log page codes for optical disk devices

Two log pages shall be implemented:

- The MEL page: the log page code for the MEL page shall be 39h for SCSI-2 compliant devices and 09h for SCSI-3 compliant devices.
- The clear MEL page: the log page code for the Clear MEL page shall be 3Ah for SCSI-2 compliant devices, and 0Ah for SCSI-3 compliant devices.

Table 18 specifies these new log page codes for optical disk devices: the MEL page and the clear MEL page. Except for the addition of these new codes used in this International Standard for both SCSI-2 and SCSI-3 implementations, Table 20 is the same table as that shown in 16.3.2 of ISO/IEC 9316:1995.

8.12.3.2 The MEL page

The MEL page provides cumulative media error information. This page includes 32 data counters (see Table 21) that can be retrieved with the LOG SENSE command (see 8.4.) The page length, parameter code, parameter length and the 32 data counter shall be expressed in hexadecimal values.

Table 22 shows the parameter codes (from 0000h to 001Fh) associated with the log parameters. The List Parameter (LP) bit in the parameter control byte shall be set to zero (defining data counters). The other bits of the parameter control bytes are not qualified by this International Standard.

Table 20 — Log page code usage for optical memory devices

Page code	Description	Comments
01h	Buffer overrun/underrun page	
03h	Error counter page (read) page	
05h	Error counter page (verify) page	
02h	Error counter page (write) page	
07h	Last *n* error events page	
00h	List of supported parameters page	
06h	Non-media error page	
04h	Reserved	
08h	Reserved	
09h	Reserved for SCSI-2 devices The Media Error Log (MEL) page for SCSI-3 optical memory devices	Reserved for this International Standard
0Ah	Reserved for SCSI-2 devices The Clear Media Error Log page for SCSI-3 optical memory devices	Reserved for this International Standard
0Bh – 2Fh	Reserved	
30h – 38h	Vendor Specific pages	
39h	Media Error Log (MEL) page for SCSI-2 optical memory devices	ISO/IEC 9316 defines this code as a vendor specific page
3Ah	Clear Media Error Log page for SCSI-2 optical memory devices	ISO/IEC 9316 defines this code as a vendor specific page
3Bh – 3Eh	Vendor specific pages	
3Fh	Reserved	

Table 21 — Media error log page

Byte	Bit 7	6	5	4	3	2	1	0
0	Reserved		Page Code – 39h for SCSI-2 devices or 09h for SCSI-3 devices					
1	Reserved							
2	(MSB)							
				Page length				
3							(LSB)	
4	(MSB)							
				Parameter code				
5							(LSB)	
6	DU	DS	TSD	ETC	TMC		Reserved	LP
7	Parameter length							
8 – 13	Number of read retries							
14	(MSB)							
				Parameter code				
15							(LSB)	
16	DU	DS	TSD	ETC	TMC		Reserved	LP
17	Parameter length							
18 – 23	Number of write retries							
24	(MSB)							
				Parameter code				
25							(LSB)	
26	DU	DS	TSD	ETC	TMC		Reserved	LP
27	Parameter length							
28 – 33	Number of total bytes corrected							
34	(MSB)							
				Parameter code				
35							(LSB)	
36	DU	DS	TSD	ETC	TMC		Reserved	LP
37	Parameter length							
38 – 43	Number of sectors read							
44	(MSB)							
				Parameter code				
45							(LSB)	
46	DU	DS	TSD	ETC	TMC		Reserved	LP

Table 21 *(continued)*

Byte	Bit						
	7	6	5	4	3	2	1	0
47	Parameter length							
48 – 53	Number of sectors uncorrectable by the ECC							
54	(MSB)							
				Parameter code				
55							(LSB)	
56	DU	DS	TSD	ETC	TMC		Reserved	LP
57	Parameter length							
58 – 63	Number of sectors having codewords with more than 8 bytes in error							
64	(MSB)							
				Parameter code				
65							(LSB)	
66	DU	DS	TSD	ETC	TMC		Reserved	LP
67	Parameter length							
68 – 73	Number of sectors with a maximum of 8 bytes in error per codeword							
74	(MSB)							
				Parameter code				
75							(LSB)	
76	DU	DS	TSD	ETC	TMC		Reserved	LP
77	Parameter length							
78 – 83	Number of sectors with a maximum of 7 bytes in error per codeword							
84	(MSB)							
				Parameter code				
85							(LSB)	
86	DU	DS	TSD	ETC	TMC		Reserved	LP
87	Parameter length							
88 – 93	Number of sectors with a maximum of 6 bytes in error per codeword							
94	(MSB)							
				Parameter code				
95							(LSB)	
96	DU	DS	TSD	ETC	TMC		Reserved	LP
97	Parameter length							
98 –103	Number of sectors with a maximum of 5 bytes in error per codeword							
104	(MSB)							
				Parameter code				
105							(LSB)	

Table 21 *(continued)*

Byte	Bit 7	6	5	4	3	2	1	0
106	DU	DS	TSD	ETC	TMC		Reserved	LP
107	Parameter length							
108 –113	Number of sectors with a maximum of 4 bytes in error per codeword							
114	(MSB)							
				Parameter code				
115							(LSB)	
116	DU	DS	TSD	ETC	TMC		Reserved	LP
117	Parameter length							
118 –123	Number of sectors with a maximum of 3 bytes in error per codeword							
124	(MSB)							
				Parameter code				
125							LSB)	
126	DU	DS	TSD	ETC	TMC		Reserved	LP
127	Parameter length							
128 –133	Number of sectors with a maximum of 2 bytes in error per codeword							
134	(MSB)							
				Parameter code				
135							(LSB)	
136	DU	DS	TSD	ETC	TMC		Reserved	LP
137	Parameter length							
138 –143	Number of sectors with a maximum of 1 bytes in error per codeword							
144	(MSB)							
				Parameter code				
145							(LSB)	
146	DU	DS	TSD	ETC	TMC		Reserved	LP
147	Parameter length							
148– 153	Total number of bytes in error							
154	(MSB)							
				Parameter code				
155							(LSB)	
156	DU	DS	TSD	ETC	TMC		Reserved	LP
157	Parameter length							
158–163	Number of sectors with over Maximum number of bytes in error [a]							

Table 21 *(continued)*

Byte	Bit							
	7	6	5	4	3	2	1	0
164	(MSB)							
	Parameter code							
165							(LSB)	
166	DU	DS	TSD	ETC	TMC		Reserved	LP
167	Parameter length							
168–173	Number of sectors with [7*Maximum/8] to Maximum bytes in error[a, b]							
174	(MSB)							
	Parameter code							
175							(LSB)	
176	DU	DS	TSD	ETC	TMC		Reserved	LP
177	Parameter length							
178–183	Number of sectors with [6*Maximum/8] to [7*Maximum/8]-1 bytes in error[a, b]							
184	(MSB)							
	Parameter code							
185							(LSB)	
186	DU	DS	TSD	ETC	TMC		Reserved	LP
187	Parameter length							
188–193	Number of sectors with [5*Maximum/8] to [6*Maximum/8]-1 bytes in error[a, b]							
194	(MSB)							
	Parameter code							
195							(LSB)	
196	DU	DS	TSD	ETC	TMC		Reserved	LP
197	Parameter length							
198–203	Number of sectors with [4*Maximum/8] to [5*Maximum/8]-1 bytes in error[a, b]							
204	(MSB)							
	Parameter code							
205							(LSB)	
206	DU	DS	TSD	ETC	TMC		Reserved	LP
207	Parameter length							
208–213	Number of sectors with [3*Maximum /8] to [4*Maximum/8]-1 bytes in error[a, b]							
214	(MSB)							
	Parameter code							
215							(LSB)	
216	DU	DS	TSD	ETC	TMC		Reserved	LP

Table 21 *(continued)*

Byte	Bit							
	7	6	5	4	3	2	1	0
217	Parameter length							
218–223	Number of sectors with [2*Maximum/8] to [3*Maximum/8]-1 bytes in error[a, b]							
224	(MSB)							
	Parameter code							
225							(LSB)	
226	DU	DS	TSD	ETC	TMC		Reserved	LP
227	Parameter length							
228–233	Number of sectors with [Maximum/8] to [2*Maximum/8]-1 bytes in error[a, b]							
234	(MSB)							
	Parameter code							
235							(LSB)	
236	DU	DS	TSD	ETC	TMC		Reserved	LP
237	Parameter length							
238–243	Number of sectors with 0 to [Maximum/8]-1 bytes in error[a, b]							
244	(MSB)							
	Parameter code							
245							(LSB)	
246	DU	DS	TSD	ETC	TMC		Reserved	LP
247	Parameter length							
248–253	Number of sectors with 3 sector IDs in error							
254	(MSB)							
	Parameter code							
255							(LSB)	
256	DU	DS	TSD	ETC	TMC		Reserved	LP
257	Parameter length							
258–263	Number of sectors with 2 sector IDs in error							
264	(MSB)							
	Parameter code							
265							(LSB)	
266	DU	DS	TSD	ETC	TMC		Reserved	LP
267	Parameter length							
268–273	Number of sectors with 1 sector ID in error							

Table 21 *(continued)*

Byte	Bit							
	7	**6**	**5**	**4**	**3**	**2**	**1**	**0**
274 275	(MSB) Parameter code (LSB)							
276	DU	DS	TSD	ETC	TMC		Reserved	LP
277	Parameter Length							
278–283	Number of Sectors with 0 Sector ID in Error							
284 285	(MSB) Parameter code (LSB)							
286	DU	DS	TSD	ETC	TMC		Reserved	LP
287	Parameter length							
288–293	Number of sectors with errors in the Sector Mark – sectors readable							
294 295	(MSB) Parameter code (LSB)							
296	DU	DS	TSD	ETC	TMC		Reserved	LP
297	Parameter length							
298–303	Number of sectors with errors in the Data Sync – sectors readable							
304 305	(MSB) Parameter code (LSB)							
306	DU	DS	TSD	ETC	TMC		Reserved	LP
307	Parameter length							
308–313	Number of sectors with missing ReSync Marks – sectors readable							
314 315	(MSB) Parameter code (LSB)							

[a] “Maximum” refers to a value that the device might use as a criterion for reallocating sectors. See the device manufacturer for information about this value.

[b] Brackets indicate the greatest integer less than or equal to the number. For example, [3,15] is 3.

Table 22 — Parameter codes for the media error log page

Parameter code	Description
0000h	Number of read retries
0001h	Number of write retries
0002h	Number of total bytes corrected
0003h	Number of sectors read
0004h	Number of sectors uncorrectable by the ECC
0005h	Number of sectors having codewords with more than 8 bytes in error
0006h	Number of sectors with a maximum of 8 bytes in error per codeword
0007h	Number of sectors with a maximum of 7 bytes in error per codeword
0008h	Number of sectors with a maximum of 6 bytes in error per codeword
0009h	Number of sectors with a maximum of 5 bytes in error per codeword
000Ah	Number of sectors with a maximum of 4 bytes in error per codeword
000Bh	Number of sectors with a maximum of 3 bytes in error per codeword
000Ch	Number of sectors with a maximum of 2 bytes in error per codeword
000Dh	Number of sectors with a maximum of 1 bytes in error per codeword
000Eh	Total number of bytes in error
000Fh	Number of sectors with over maximum number of bytes in error[a]
0010h	Number of sectors with [7 × maximum /8] to maximum bytes in error[a, b]
0011h	Number of sectors with [6 × maximum /8] to [7 × maximum/8] – 1 bytes in error[a, b]
0012h	Number of sectors with [5 × maximum /8] to [6 × maximum/8] – 1 bytes in error[a, b]
0013h	Number of sectors with [4 × maximum /8] to [5 × maximum/8] – 1 bytes in error[a, b]
0014h	Number of sectors with [3 × maximum /8] to [4 × maximum/8] – 1 bytes in error[a, b]
0015h	Number of sectors with [2 × maximum /8] to [3 × maximum/8] – 1 bytes in error[a, b]
0016h	Number of sectors with [maximum /8] to [2 × maximum)/8] – 1 bytes in error[a, b]
0017h	Number of sectors with 0 to [maximum /8] – 1 bytes in error[a, b]
0018h	Number of sectors requiring no correction with ECC
0019h	Number of sectors with 3 sector IDs in error
001Ah	Number of sectors with 2 sector IDs in error
001Bh	Number of sectors with 1 sector IDs in error
001Ch	Number of sectors with 0 sector IDs in error
001Dh	Number of sectors with errors in the Sector Mark – sectors readable
001Eh	Number of sectors with errors in the Data Sync – sectors readable
001Fh	Number of sectors with missing ReSync Marks – sectors readable

a “Maximum” refers to a value that the device might use as a criterion for reallocating sectors. See the device manufacturer for information about this value.

b Brackets indicate the greatest integer less than or equal to the number. For example, [3,15] is 3.

8.12.3.3 The clear MEL page

Three approaches to clear the MEL page are defined in this International Standard.

1) The first alternative is to use the LOG SELECT command with the clear MEL page (see Table 23), which does not have any log parameters. When a target receives this page, it shall clear the MEL page.

2) The second alternative is to use the LOG SELECT command with a parameter code reset (PCR) bit set to 01h and the parameter list length of 00h (see 8.2.6 of ISO/IEC 9316:1995). No page shall be sent to the target. All implemented parameters of the target are set to their default values.

3) The third alternative is to use the LOG SELECT command with the page code (PC) set to 11b and a parameter list length of 00h (see 8.2.6 of ISO/IEC 9316:1995). No page shall be sent to the target. All the cumulative parameters are set to their default values.

Table 23 — Clear MEL page

Byte	Bit							
	7	6	5	4	3	2	1	0
0	Reserved		Page Code – 3Ah for SCSI-2 devices or 0Ah for SCSI-3 devices					
1	Reserved							
2	(MSB)							
				Page length = 0				
3						(LSB)		

Annex A
(informative)

Recommendations on Verify Media Error Levels for early warning and Media Error Levels for sector retirement

A.1 Introduction

This annex provides two examples of sector retirement guidelines, as follows:

a) recommendations on Verify Media Error Levels for early warning;

b) more demanding criteria definitions for different media types.

The information has been extracted from two media interchange standards. It is not uncommon that some errors might occur in the media. Therefore, it is not recommended to set overly conservative Media Error Levels for sector reallocation. Refer to the documentation associated with a particular drive.

A.2 Sector retirement guidelines according to ISO/IEC 10089

Annex H (informative) of ISO/IEC 10089:1991 recommends the following set of sector retirement guidelines.

ISO/IEC 10089 assumes that up to 2,048 sectors can be replaced in any of the following cases:

— a sector has fewer than two reliable headers;

— the Sector Mark is not readable;

— a single defect of more than 30 bytes in a 1024-byte sector is detected (15 bytes in a 512-byte sector);

— the total number of defective bytes exceeds 40 in a 1024-byte sector (15 in a 512-byte sector), or 5 in one ECC codeword of a 1024-byte sector (3 bytes in a 512-byte sector).

A.3 Sector retirement guidelines according to ISO/IEC 13403

Annex H (informative) of ISO/IEC 13403:1995 recommends that a sector is assumed to be defective and will be replaced by the defect management when any of the following conditions exist:

— a sector has two or three address fields with an error detected by the CRC check;

— a column in the Data field (see Figure E.1 of ISO/IEC 13403:1995) contains more than three defective bytes A_n.

For other examples of sector retirement guidelines, refer to the International Standards listed in the bibliography.

Annex B
(informative)

Guidelines for use of media error monitoring and reporting techniques for the verification of stored data on optical digital data disks

B.1 Introduction

Data and records managers in many organizations are already using optical disk-based information systems for storing and retrieving large sets of valuable information. The optical disk drives that are used by these systems incorporate powerful, but not unlimited, error correction capabilities. If the level of errors in an optical digital data disk sector exceeds the error detection and correction mechanisms implemented in the optical disk drive controller, the sector becomes uncorrectable and data loss occurs.

This International Standard provides a comprehensive set of media error monitoring and reporting tools. These tools will enable managers and users of optical disk libraries to verify the integrity of stored data both initially – when data are transferred to the media and periodically – when monitoring the status of data. The media error information that can be obtained using drives that are fully compliant with this International Standard includes:

- a list of reallocated sectors;
- warnings about exceeded Verify Media Error Levels;
- corrections above media levels;
- the total number of bytes in error, the number of bytes in error per sector, and the maximum number of bytes in error in any sector codeword;
- the corrected or uncorrected sector content;
- errors encountered when header information such as the sector address, sector marks, and synchronization signals is read;
- the maximum length of contiguous defective bytes.

In addition, this International Standard provides information about Media Error Levels that are set in the drive and the ability to modify these Media Error Levels. The media error monitoring and reporting techniques allow users to obtain media error information whenever required and at different levels of sophistication.

Depending upon the importance of stored data, the organization's data storage requirements, and the required data retention period, users might want to implement some or all of the tools provided by drives complying to this International Standard. The use of statistical techniques and the maintenance of reported media error data should also be considered. Users whose population of optical digital data disks is very large might require the application of sampling techniques to test disks from their population. In addition, consideration should also be given to defining appropriate early warning indicators of data degradation and to the development of backup and data transferring policies.

This annex provides an introduction to the command set specified in this International Standard. It also provides useful information on:

- sampling data;
- displaying measured values;

— using modelled distributions as baselines for comparing media error results.

Data retirement and transfer policies should balance user requirements of data integrity and storage costs. This annex outlines the optical digital data disk media error monitoring and reporting tools defined in this International Standard and provides guidelines for their implementation. The procedures addressed include:

— the maintenance of information on media errors and data degradation;

— the use of statistical models and sampling plans (data that would allow users to make more informed decisions when they develop policies and procedures for data backup and data transfer).

This annex cannot recommend specific intervals for media testing or data transfer because these activities are application-dependent.

Users of media error monitoring tools, similar to those provided by optical disk subsystems or devices that comply with this International Standard, might also find the methods documented in this report useful.

As data-intensive sources such as image, audio, and video make further demands on storage capacities, optical disk media are increasingly employed. As this trend continues and optical disk storage archives evolve and expand, a system of robust media error monitoring becomes increasingly important.

Errors occur in all storage systems and are corrected by integral error control codes, so the user is undisturbed by (but also unaware of) these events. The optical data disks referenced by the media error monitoring and reporting techniques specified in this International Standard employ Reed-Solomon error-correcting codes to protect stored data. Reed-Solomon codes are powerful burst error correcting codes. The method by which they correct errors involves complex mathematical Galois Field computations, which are both beyond the scope of this document and the requirements of media error monitoring.

It is important to note, however, that all error control codes have a finite correction capacity, which, if exceeded, results in uncorrectable errors. Media error occurrences can increase in size and frequency with age, usage, or handling. As a result, the error correction code can become increasingly burdened. In the absence of media error monitoring, the user is not made aware of error events until data becomes irretrievable. In the event that corrupted data forms an integral part of a linked structure — particularly a compressed entity — a substantial data loss, considerably beyond the original number of bytes in error, could occur.

The appropriate implementation of the media error monitoring tools specified in this International Standard, or similar tools, will enable users to manage optical disk storage facilities. Users will be able to monitor media errors by time or usage, which helps them to determine appropriate media retirement criteria and reduce the risk of uncorrectable error events.

This annex has been prepared to demonstrate to the end user implementation options of the media error monitoring and reporting tools specified in. They do not specify media retirement policies or sampling plans. Such policies and plans must be designed for each application and must correctly balance user requirements for data integrity and storage costs.

B.2 Media error monitoring tools provided by this International Standard

B.2.1 Introduction

This International Standard provides a comprehensive set of commands for reporting media error information to users. To interpret this information properly, users require some understanding of the sector and codeword format of their recorded data. This clause:

— provides information about the sector and codeword structure of data that will help users judge the significance of any reported media errors;

— summarizes the different levels and conformances of media error reporting provided;

— briefly summarizes each of the available commands.

For precise information on each set of commands, users are referred to the relevant clauses of this International Standard.

B.2.2 Interpreting media error reports

The user data recorded on optical disks is partitioned into blocks called “sectors.” Each sector contains a specified number of bytes, e.g. 512 or 1024 bytes, depending upon the format. The format of these bytes depends upon the media recording method. For example, significant differences exist between sampled-servo and continuous-servo media. Users are strongly advised to study the media interchange standards relevant to their media type. In B.2.2.1 to B.2.2.3, an example of a continuous composite-servo media format is described. This type of media uses interleaved error correction codes. Each sector contains 512 bytes that are five-way interleaved (1024-byte sectors use a similar format to generate a 10-way interleave). Figure B.1 shows how bytes are positioned within a sector of this format.

B.2.2.1 Data field format

The data field of a sector contains all the user and error management bytes, but it does not contain the header or resynchronizing bytes. The data field is contained within the rectangle shown in Figure B.1. (Follow the outer rectangular border drawn with a double line.) It contains two portions: the portion above the double, bolded, horizontal line contains mostly user data bytes, and the portion below this line contains only error correction code (ECC) bytes.

The user data portion of the data field contains the following:

— user-data bytes represented by D_1 to D_{512};

— data management pointers (DMP) bytes, $P_{1,1}$, $P_{1,2}$, ..., $P_{3,4}$, contain information on sector reallocation by linking defective sectors and replacement sectors;

— bytes containing a value of FFh;

— check bytes for the cyclic redundancy check (CRC), C_1 to C_4.

The ECC data portion of the data field contains correction bytes for the ECC, $E_{1,1}$, $E_{2,1}$, ..., $E_{5,16}$.

In addition to the user data and ECC data portions, the sector also contains:

— synchronization bytes (SB), SB_1 to SB_3, which synchronize the data signal and the drive clock;

— resynchronization bytes (RS), RS_1 to RS_{40}, which preserve synchronization within the sector.

B.2.2.2 The recorded format

Sector bytes are recorded onto the disk as they appear in Figure B.1, from left to right and from top to bottom (according to the sequential order SB_1, SB_2, SB_3, D_1, D_2, ..., $E_{4,16}$, $E_{5,16}$).

B.2.2.3 The coded format

The column with the bold outline (D_3 down to $E_{3,16}$) represents one of the five codewords. CRC bytes are computed from the user, DMP, and (FFh) bytes. All of these bytes are then five-way interleaved into a two-dimensional matrix with 106 rows and 5 columns. Each of these five columns represents an error control codeword. Once the user data portion is complete, the ECC data portion is generated for each codeword. In this example, a Reed-Solomon code is used. Consider, for example, the codeword emboldened in Figure B.1. The 106 bytes, D_3, D_8, ..., D_{508}, $P_{1,1}$, $P_{2,2}$, $P_{3,3}$, C_2, are used to compute the 16 ECC bytes $E_{3,1}$, $E_{3,2}$, ..., $E_{3,16}$, which complete the 122–byte codeword.

Notice that if, for example, a 10-byte error burst occurs in this sector, it would affect 10 consecutive bytes, D_1, to D_{10}. However, each codeword would contain at most 2 bytes in error (D_3 and D_8 for codeword 3). Interleaving disperses error bursts, thus reducing the number of bytes in error per codeword.

Codeword No. ⇒			**1**	**2**	**3**	**4**	**5**	**Row No.⇓**
SB_1	SB_2	SB_3	D_1	D_2	D_3	D_4	D_5	105
			D_6	D_7	D_8	D_9	D_{10}	104
			D_{11}	D_{12}	D_{13}	D_{14}	D_{15}	103
		RS_1	D_{16}	D_{17}	D_{18}	D_{19}	D_{20}	102
			D_{21}	D_{22}	D_{23}	D_{24}	D_{25}	101
			D_{26}	D_{27}	D_{28}	D_{29}	D_{30}	100
		RS_2	D_{31}	D_{32}	D_{33}	D_{34}	D_{35}	99
			...	...	...	...	...	...
		RS_{33}	D_{496}	D_{497}	D_{498}	D_{499}	D_{500}	6
			D_{501}	D_{502}	D_{503}	D_{504}	D_{505}	5
			D_{506}	D_{507}	D_{508}	D_{509}	D_{510}	4
		RS_{34}	D_{511}	D_{512}	$P_{1,1}$	$P_{1,2}$	$P_{1,3}$	3
			$P_{1,4}$	$P_{2,1}$	$P_{2,2}$	$P_{2,3}$	$P_{2,4}$	2
			$P_{3,1}$	$P_{3,2}$	$P_{3,3}$	$P_{3,4}$	(FF)	1
		RS_{35}	(FF)	C_1	C_2	C_3	C_4	0
			$E_{1,1}$	$E_{2,1}$	$E_{3,1}$	$E_{4,1}$	$E_{5,1}$	-1
			$E_{1,2}$	$E_{2,2}$	$E_{3,2}$	$E_{4,2}$	$E_{5,2}$	-2
		RS_{36}	$E_{1,3}$	$E_{2,3}$	$E_{3,3}$	$E_{4,3}$	$E_{5,3}$	-3
			$E_{1,4}$	$E_{2,4}$	$E_{3,4}$	$E_{4,4}$	$E_{5,4}$	-4
			...	...	...	...	...	...
			$E_{1,14}$	$E_{2,14}$	$E_{3,14}$	$E_{4,14}$	$E_{5,14}$	-14
		RS_{40}	$E_{1,15}$	$E_{2,15}$	$E_{3,15}$	$E_{4,15}$	$E_{5,15}$	-15
			$E_{1,16}$	$E_{2,16}$	$E_{3,16}$	$E_{4,16}$	$E_{5,16}$	-16

Figure B.1 — Example of a five-way interleaved data field format

B.3 Deciding what to test

B.3.1 Introduction

Some users of this International Standard might administer large libraries of optical disks that require frequent media testing to verify data integrity. However, frequent tests of an entire population of disks could be unacceptably time-consuming. Administrators might, therefore, require statistical sampling methods to estimate the data integrity of individual disks or batches of disks.

A sampling procedure is an algorithm for selecting a statistically equivalent subpopulation; one that is representative of the entire population from which the sample items are drawn. The desired measurements are performed only on the sample, and conclusions are drawn for the entire population. Samples might be sectors, tracks, or bands of tracks from a specific disk or disks taken from a population. Practically, however, the time required to obtain media error information for each sample item should be considered. Where sampling is used to reduce test time, sampling individual sectors or even individual tracks could defeat this objective.

Inherent in any sampling operation is the risk of estimation errors that could lead to the acceptance of defective items or the rejection of non-defective items. Users of this International Standard might find that rejecting non-defective items is acceptable; it could result only in unnecessary data transfer. However, the risk of accepting defective items might be unacceptable because it could lead to data loss.

If the limitations of sampling are appropriately considered, sampling methods can be used to provide useful estimations of population data integrity. This information might not otherwise be available. In addition, sampling can also be used as a screening technique to determine the need for additional tests.

B.3.2 Sampling methods

B.3.2.1 Random sampling

Items can be sampled from a population in a number of ways; some involve "random" number generators, which might or might not be confirmed to be fully random. For example, random (N), the C-language random number generator, chooses an integer from 0 to N-1. The items comprising the population should be numbered by their physical location. The generated values could then be used to select a random sample of items from the population.

An alternative to random population sampling is to partition the population into M physically contiguous locations, each containing m items. Forcing the selection of x samples from each of the M locations would then generate a sample of size $m \times x = n$. This sampling decreases the likelihood of neglecting any physical area of the population, especially if the "random" number generator deviates from randomness. In fact, it might be acceptable in some circumstances to dispense with the random number generator altogether. The sample could be distributed evenly throughout the population by sampling items at regular physical intervals.

New disks that have been stored and handled according to the manufacturer's recommendations might have very sparse and seemingly random error profiles. However, disk defect distributions can become less random with age and handling. In addition, storage or usage/handling conditions within populations of disks might be significantly different. The samples could then violate the assumption of statistical equivalence, that is, the samples are not representative of the population.

Disk defects can result from improper user handling, storage conditions, or usage. Once created, the resultant damage and effects can spread preferentially to adjacent areas. Sectors in a particular area might have a BER while the average BER over the entire disk might be too low to result in general degradation of data integrity within the media.

In the case of data errors localized in particular defective sectors, three situations can occur.

— The number of defective sectors is relatively low and the level of bytes in error within these sectors is low enough to be handled by the ECC. Only the defective sectors are reallocated, and hence no data loss occurs.

— The number of defective sectors is relatively low but the level of errors within at least one sector exceeds the ECC capacity. Data might be lost.

— The number of defective sectors is excessive, whatever the byte error rate. The reallocation capability of the disk drive might be exceeded, and data could be lost.

These kinds of defects might not be detected by random sampling methods. Scanning the entire disk could be necessary. Restricting the investigation to particular areas where one suspects the data are affected might also be useful.

One criterion for determining whether defects are localized or randomly distributed over the entire disk could be the clustering of bytes in error or error bursts over the disk (the variation in the distribution of errors over different areas of the media). Variations can be evaluated by representing the distribution of the mean BER per sector over the entire disk or by using lag plots to identify correlations in sector or track error events.

B.3.2.2 Adaptive error–driven sampling

The sampling procedures discussed within B.3.2.1 are not varied, no matter how many defective items are detected. By contrast, an adaptive error-driven method forces the retrieval of items adjacent to defective items. For example, if an item randomly selected to be a part of a sample is in error, then neighbouring items along or across tracks might be included in the sample. This adaptive error-driven sampling is more complex than random sampling procedures, but, where errors are localized, this method would tend to detect more errors. It would produce a sample that might be of more interest to users of this International Standard, whose priority is the integrity of stored data.

B.3.3 Estimation from sampling methods

B.3.3.1 Estimating confidence intervals

By applying sampling methods to data storage media, an inherent risk exists. Incorrect estimations of the state of data within the submitted disk or population of disks could occur because all data are not tested. The loss of stored data could result, which would certainly be unacceptable.

Statistics associated with a sampling method should provide a confidence interval, Δ. For example, if this parameter is the BER, a specified probability exists that the true BER exceeds the measured BER by more than Δ. The user is responsible for choosing an appropriate sampling procedure, including the size of the sample and the way it is drawn from the total population. The user must ensure that the uncertainty of the measured parameter is acceptable for data integrity requirements.

B.3.3.2 Control charts

Control charts are frequently used to monitor of manufactured products over time. They are also used to monitor the ability of measurement systems to yield reproducible results over time by periodically measuring and comparing an unchanging artefact. Historical data are needed to set the target level and the acceptable error bounds (two or three standard deviations are often used). Statistical theory predicts the proportion of measurements that should normally be expected to occur outside these bounds. However, a tendency to drift away from the target value can often be observed even before measurements appear outside the bounds.

Control charts can be a useful way of detecting gradual deterioration of a disk or collection of disks. The BER[1)] distribution of a fixed sample of sectors or disks, for example, can be monitored over time. An increase in their level could signal the need for more frequent monitoring, or even for transfer of data to new media. Taking this action could prevent the loss of valuable data if the initial error rate is well below dangerous levels. A limitation of this approach is that the continuously monitored sample might become unrepresentative of the entire population (disks or sectors). The sample can be checked by comparing it to a different sample. Another limitation is that the bytes in error, or other measured quantity, might increase catastrophically rather than gradually. In this case, control charts would be of limited use.

B.3.3.3 Example of a control chart

Figure B.2 uses simulated data to demonstrate a media error control chart for a magneto-optic disk. In this case the BER is monitored.[1)] Upper acceptance limits for measured BER are shown. Lower acceptance limits are not usually appropriate in media error monitoring charts because data are not adversely affected by low error values. Upper limits depend:

1) A limitation of using only BER to monitor data integrity is discussed in B.3.2.1.

— on the uncertainty due to the sampling process;

— on the maximum acceptable BER for sampled population;

— on assumptions about the distribution of errors.

In the example shown in Figure B.2, initial BER readings are used to calculate an average, μ, and a standard deviation, σ. The upper limit of variation of the BER was then determined by upper limit is $\mu + k \times \sigma$, where: the value of k was set according to the degree of confidence desired. (k = 2 in the example of Figure B.2.)

Degradation in a medium can then be detected if values exceed these limits. It is important to note, however, that the BER is an average measure of media errors, which is a limited indicator of data integrity.[1)] Clause B.4 provides examples of other media error measures that can be monitored. Users should refer to the normative clauses of this International Standard for a full list of all the media error measures available.

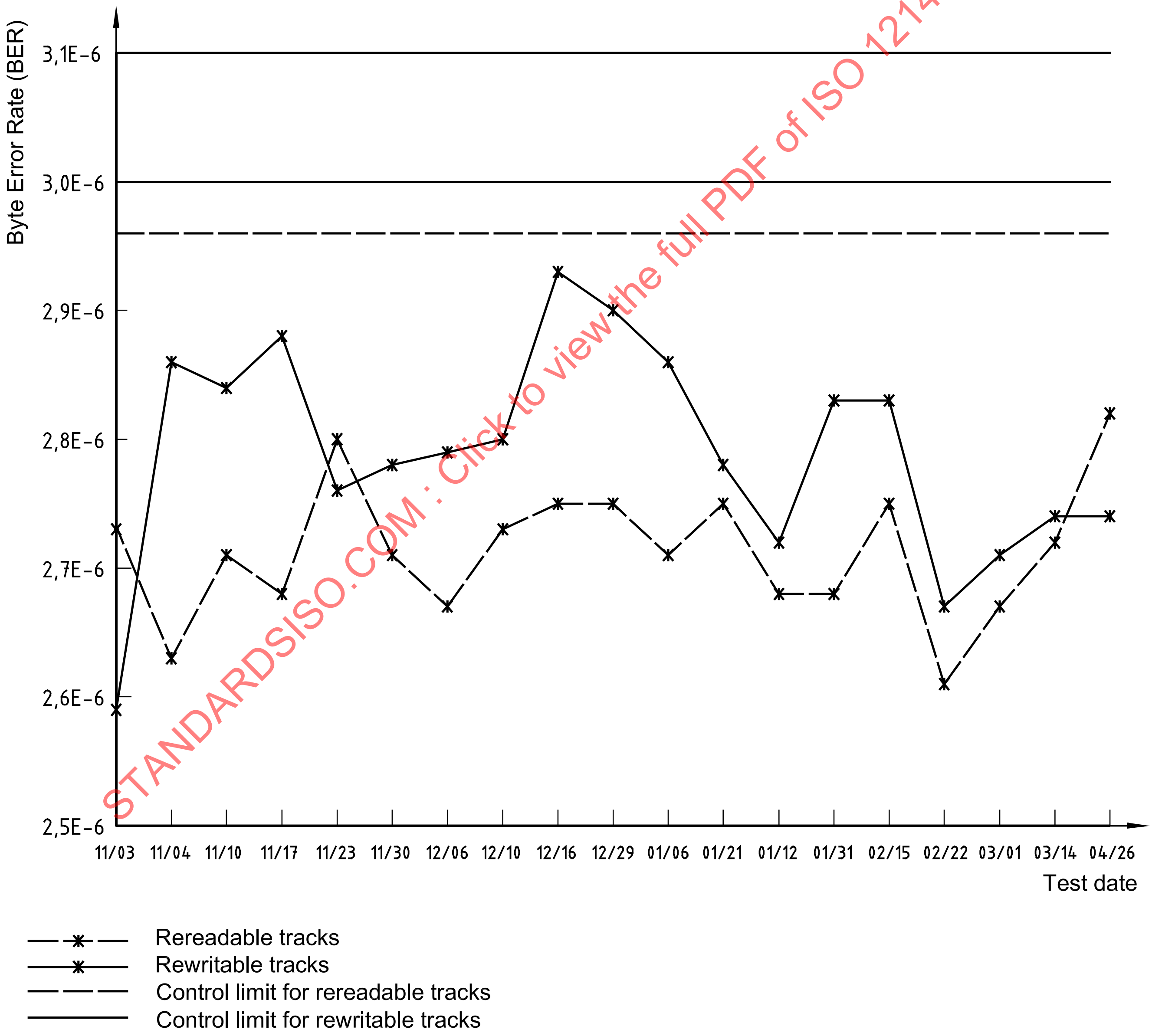

Figure B.2 — Example of a BER control chart

B.3.4 Using baseline media error parameters

Error data collected from tests performed on disks can be used to obtain values of characteristic media error parameters describing the status of data stored. For example, these values might be BERs, mean burst lengths, or burst length distributions. To estimate error levels, compare these measured values to equivalent baseline values or benchmark values that can be obtained by:

— retrieving baseline values or distributions from published literature;

— retrieving baseline values or distributions from the disk or drive manufacturer's guides;

— averaging error data gathered from an appropriate population of disks (i.e. the same type and brand of disks with a comparable level of data integrity and a correct data status).

Such sources could provide end users with expected ranges of error levels, so data status can be monitored.

B.4 Analysing media error reports provided by optical disk subsystems or devices complying to this International Standard, or similar media error reports

B.4.1 Introduction

This International Standard provides a tool kit of media error monitoring and reporting techniques. No single media error quantity fully describes the integrity of stored data. For example, monitoring the maximum number bytes in error per codeword per sector is very useful because it measures errors in terms of the ECC correction limit. However, it does not provide information on bad sector IDs or sector reallocations. Several media error measurements might be required, each of which should be retained in a media test log.

B.4.2 Automating media testing

Graphical display of information on media errors provided by media error reports specified in this International Standard (or other similar media error reports) can identify abnormalities or undesirable trends in media error statistics, estimate the integrity of stored data, and determine appropriate remedial action. Once the media error measures are understood, however, they need not be visualized using graphics. Instead, automated systems can be designed to warn of dangerous trends and suggest remedial action.

This clause presents suggestions on maintaining media logs and graphical design that can assist the users of this International Standard in producing useful representations of byte error statistics. Sample graphs are presented in a top-down form, starting first with high-level media error measures (for example, the proportion of sectors reallocated). They then work down to a more detailed description of byte error location (for example, the maximum number of bytes in error per codeword per band sector). The examples shown in this clause demonstrate the different levels at which users of this International Standard can monitor media errors.

When an appropriate set of media error reports have been selected for media error testing, users can automate the testing of samples from their disk population. By automating the sampling procedure and the detection of exceeded media error limits (e.g. user-defined acceptance limits, Verify Media Error Levels, or Media Error Levels), users can improve the performance of media error testing. For example, media error testing could be incorporated as a continuous function in large data sets and organized such that the testing procedure is transparent to normal operation.

B.4.3 Media error testing and log maintenance

B.4.3.1 Logging media error reports

In order to monitor media errors and hence data integrity properly, a log of media error reports specified in this International Standard should be maintained for each disk tested. Each media error test should be allocated a test number. The results of each test should be appended to the relevant media test log, so reports can be monitored over time. The test log should also include both:

— the test date and the time elapsed since the previous test;

— a measure of disk usage since the previous test.

In this way, logged error statistics can be reported correctly in terms of disk age or usage. In addition, in those cases in which sampling methods are employed, a record indicating the sampling parameters should also be included.

Appropriate visualization of media error reports specified in this International Standard (or other similar media error reports) can provide simple and clear representations from which trends can be identified and extrapolated. In B.4.4, a number of visualization options are explored. Specialized graphics packages should not be required for media error visualization. All of the graphs displayed in B.4.4 were created by a commercial spreadsheet package.

Many visualization formats could be used to represent logged media error reports. The following examples do not purport to be exhaustive but could be useful as suggested options. The specimen graphs are presented in the top-down form referred to in B.4.2.

The following notes are general suggestions for the design of media error graphs and refer to the example graphs, Figures B.3 to B.15.

B.4.3.2 Monitoring over time error measures specified in this International Standard

In Figures B.3 through B.6, various error measures are plotted against test number. Test number can correspond to disk usage or age, depending on the preference of the user.

B.4.3.3 Acceptable limits, Media Error Levels, and Verify Media Error Levels

All limits, Media Error Levels or Verify Media Error Levels shown on the example graphs are example values provided for the purpose of illustration. Users of media error reports specified in this International Standard should determine their own values based both on their media and their application requirements. Where possible, graphs should indicate any relevant limits, Media Error Levels, or Verify Media Error Levels, so they can be used to clearly indicate whether a media has passed or failed the specified test.

B.4.3.4 Axis scaling and labelling

The axis scaling used in the graphs in B.4.4 were selected to appropriately display the selected examples of user and device limits. Users of this International Standard should define axis scaling — upper and lower values, linear or logarithm scales — appropriate to their own data requirements. For a given application, however, standardizing the scaling is useful for directly comparing the different graphs that represent the same media error reports. For example, graphs indicating byte error rate variations for two different disks could be more easily compared if they share the same axes. Media error graphs should also be clearly labelled with a disk reference code (a user-assigned reference, unique to each disk tested) and the relevant test numbers used in their generation.

B.4.4 Sample graphs of media error reports specified in this International Standard

B.4.4.1 Monitoring sector reallocations and bad sector IDs

An increase in sector reallocation could indicate a degradation in data integrity and therefore be used to monitor media errors. A cumulative or interim measure of sector reallocations could form part of each media test log. Line graphs could then be used to identify any undesirable behaviour. Figure B.3 gives an example of a line graph visualization indicating an increase in sector reallocation, an increase which lies within user-specified acceptance limits. Similarly, Figure B.4 shows a line graph that monitors an increase in bad sector IDs.

B.4.4.2 Monitoring BERs and codeword maxima

The BER is often used as a measure of data integrity. However, it should be used with care because it is only an average measure of data integrity (see B.3.2.1). Figure B.5 shows a line graph that enables test results to be compared to a user-specified limit. Monitoring averaged test statistics presents a problem: worst-case values are not explicitly represented. Because error control coding has a finite correction capacity beyond which errors can persist, the monitoring of worst-case byte errors is important to data integrity.

Users of this International Standard tool kit should check the ECC correction capacity of their system. (For some optical data disks, the correction limit of the ECC is a maximum of 8 bytes in error per codeword.) The verification tools provided by the tool kit specified in this International Standard enable users to specify a lower value for bytes in error per codeword. Setting a lower value can be used as a warning — in advance of ECC overload — of excessive bytes in error. The number of bytes in error per codeword can, therefore, be a desirable measure of media errors.

Figure B.6 shows a line graph that monitors the maximum number of bytes in error per codeword per sector across the tested disk. In this simple format, increases are clearly visible. Because maximum values are used, the existence of any one corrupted codeword can be easily identified. Users of this International Standard might find the monitoring of these maxima, or worst-case, statistics useful in determining subsequent analyses. For example, users of this International Standard could decide that a disk’s data integrity was satisfactory if the maximum number of bytes in error per codeword per sector is less than two. They could, however, decide to study the frequency or location responsible for higher values before investigating data integrity.

Figures B.7 and B.8 show examples of the error distribution information provided by the media error log (MEL) specified in this International Standard. The media error values in the MEL page are cumulative totals of media errors from all the sectors accessed since the log was last cleared. With on-line testing, these media errors total the media error values for all of the sectors accessed by the user. If the same sectors are accessed several times, their media error values are added to the total each time they are accessed. As a result, the values in the MEL page would be biased toward these accessed disk areas and would not be representative of the whole disk.

Alternatively, with off-line testing, users can test specified areas of the disk or the whole disk and retrieve a less biased account of media errors. Figure B.7 shows an example of the relative frequency. (The relative frequency, or calculated probability, is obtained by dividing MEL counts by the total number of observations.) This form of output enables the user to determine the significance, or relative contribution, of the reported maximum number of bytes in error per codeword per sector. Figure B.8 shows an example of the relative frequency of sectors with different numbers of errors. The number of sector bytes in error are quantified in the MEL page in terms of a “maximum” value. “Maximum” refers to a value that the device might use as a criterion of reallocating sectors. See the device manufacturer for information about this value.

In addition to evaluating the frequency and magnitude of codeword corruptions, the user might require location information for given test numbers. Figure B.9 and Figure B.10 show examples of a breakdown of the maximum number of bytes in error per codeword per sector, for given test numbers, across radial areas and bands, respectively. These representations can give useful indications of radial area or band dependencies. Users of this International Standard should note, however, that this data is not directly reported by the commands specified in this International Standard. It would require a series of tests and reports to collate the appropriate data.

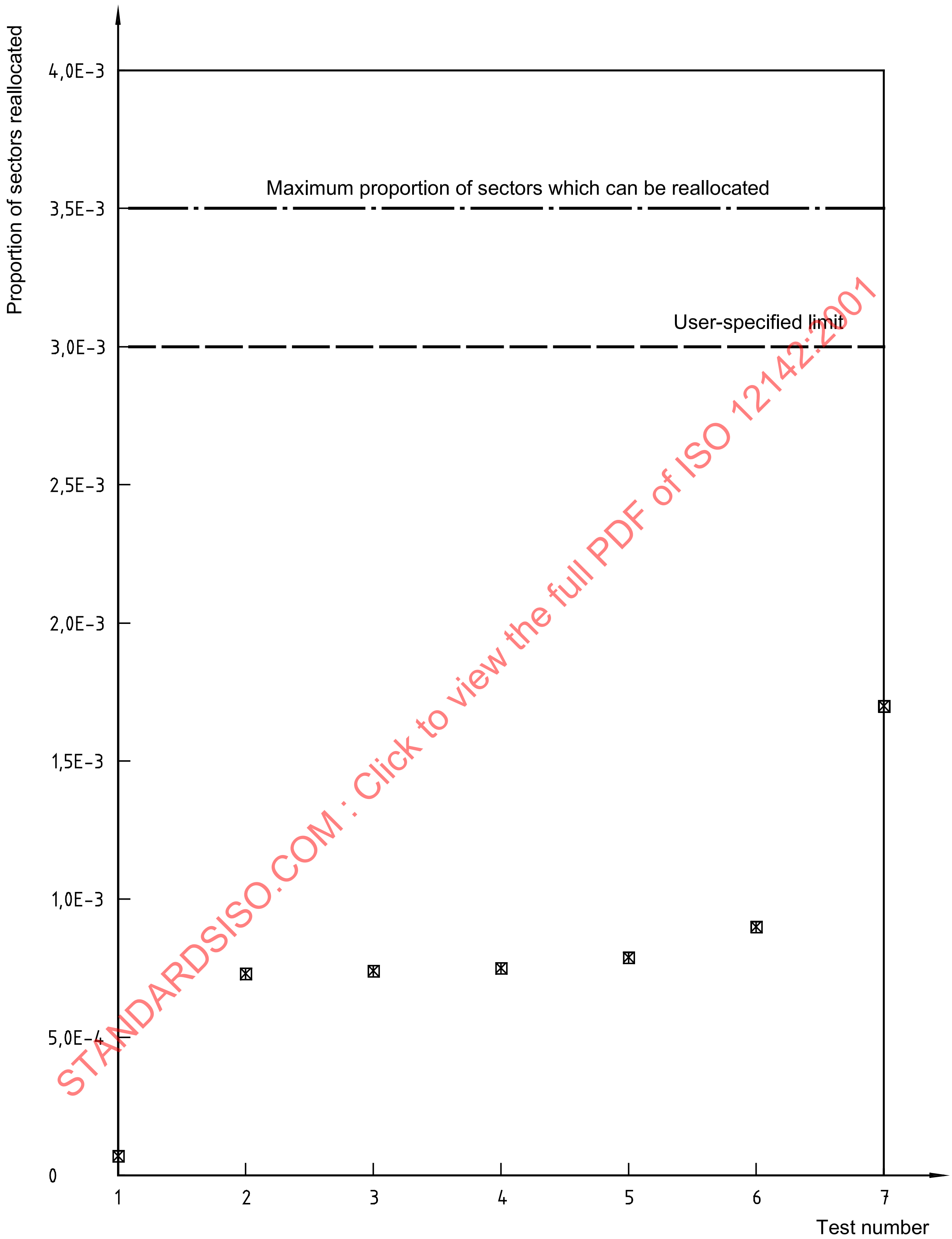

Figure B.3 — Sector reallocations

The scatter graph shown in Figure B.3 uses simulated data to show changes in the proportion of sectors reallocated for a given disk. The graph could be used to compare the results of several disks. Test numbers can be replaced by test dates, so sector reallocations can be monitored over time. The upper limit is determined by the number of spare sectors available for sector reallocation. A lower user-specified acceptance limit, selected by users of this International Standard, can also be represented. Any undesirably high values can then be easily identified.

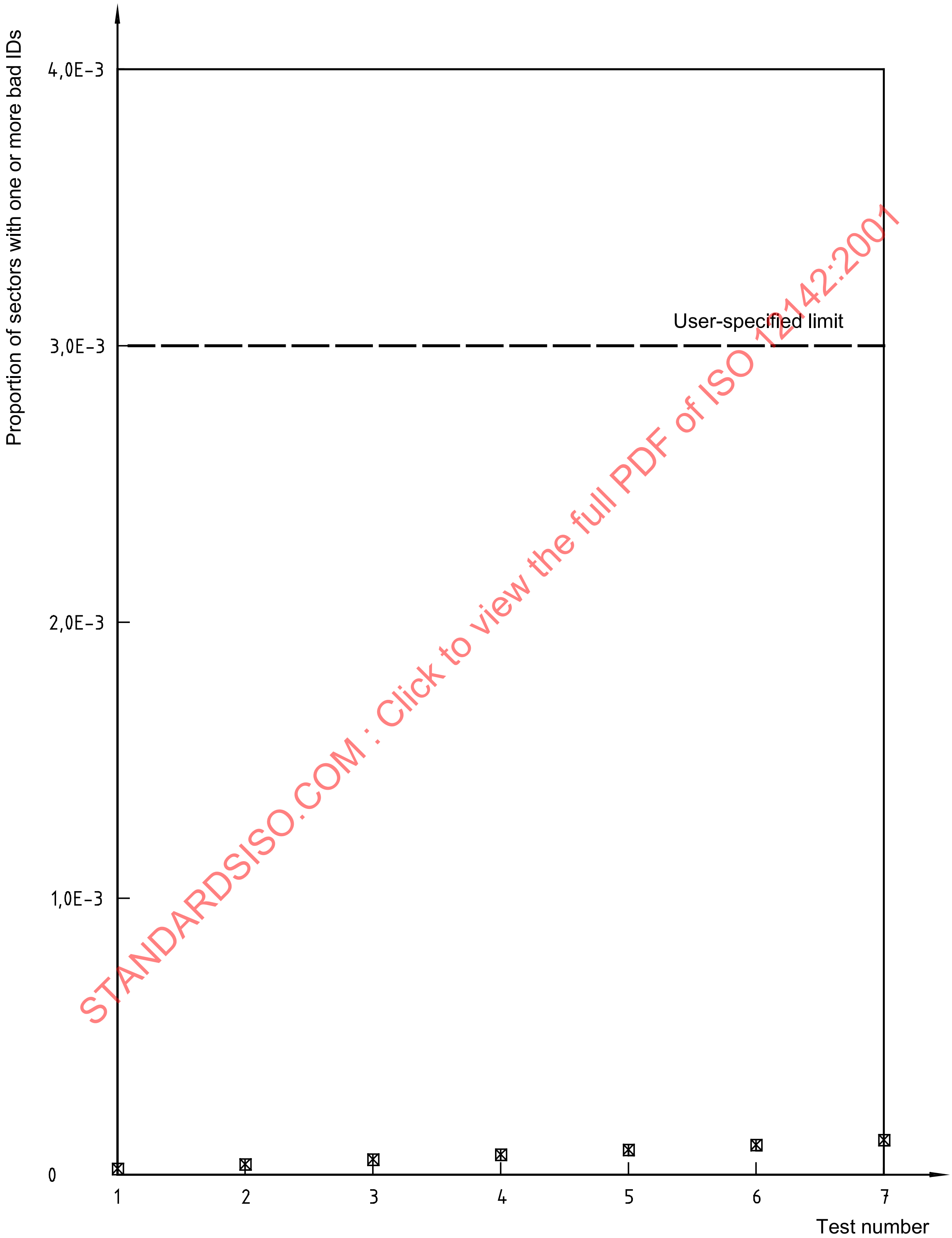

Figure B.4 — Monitoring bad sector IDs

The scatter graph shown in Figure B.4 uses simulated data to show changes in the proportion of sectors that have bad IDs. The graph could be used to compare the results of several disks. Test numbers can be replaced by test dates, so sector IDs can be monitored over time. Reductions in the proportion of sectors with bad IDs can occur as a result of sector reallocation. ID formats and default reallocation procedures vary between different systems. Users of this International Standard should check the relevant media interchange standards and system specifications to determine an appropriate user-specified acceptance limit that indicates undesirably high values.

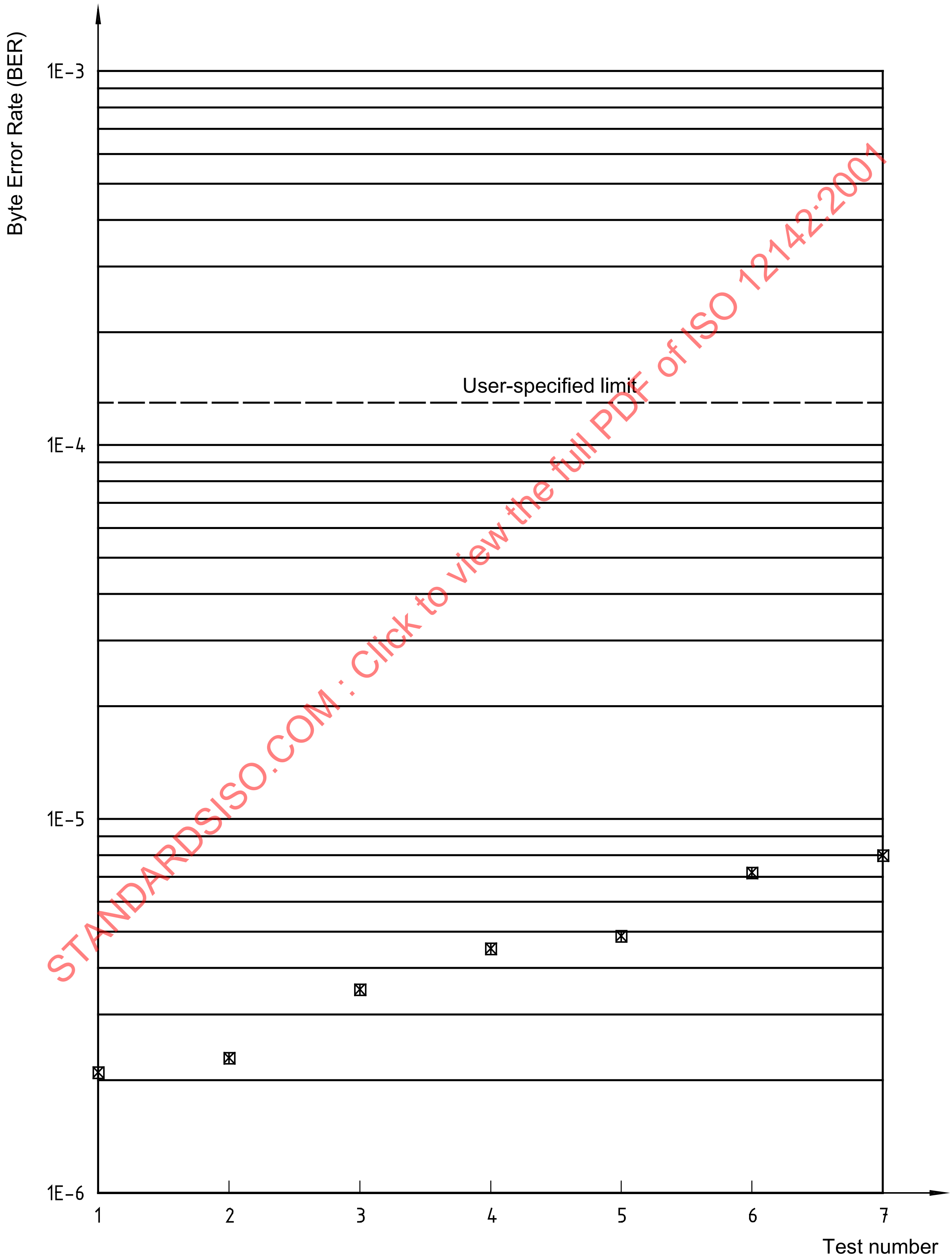

Figure B.5 — Monitoring BERs

The scatter graph shown in Figure B.4 uses simulated data to show changes in the BER. The graph could be used to compare the results of several disks. Test numbers can be replaced by test dates so that BERs can be monitored over time. The BERs shown in this graph were calculated by dividing the number of user bytes in error by the total number of user bytes. Users of this International Standard should determine a BER acceptance limit appropriate to their requirements, one that can be used to indicate undesirably high values.

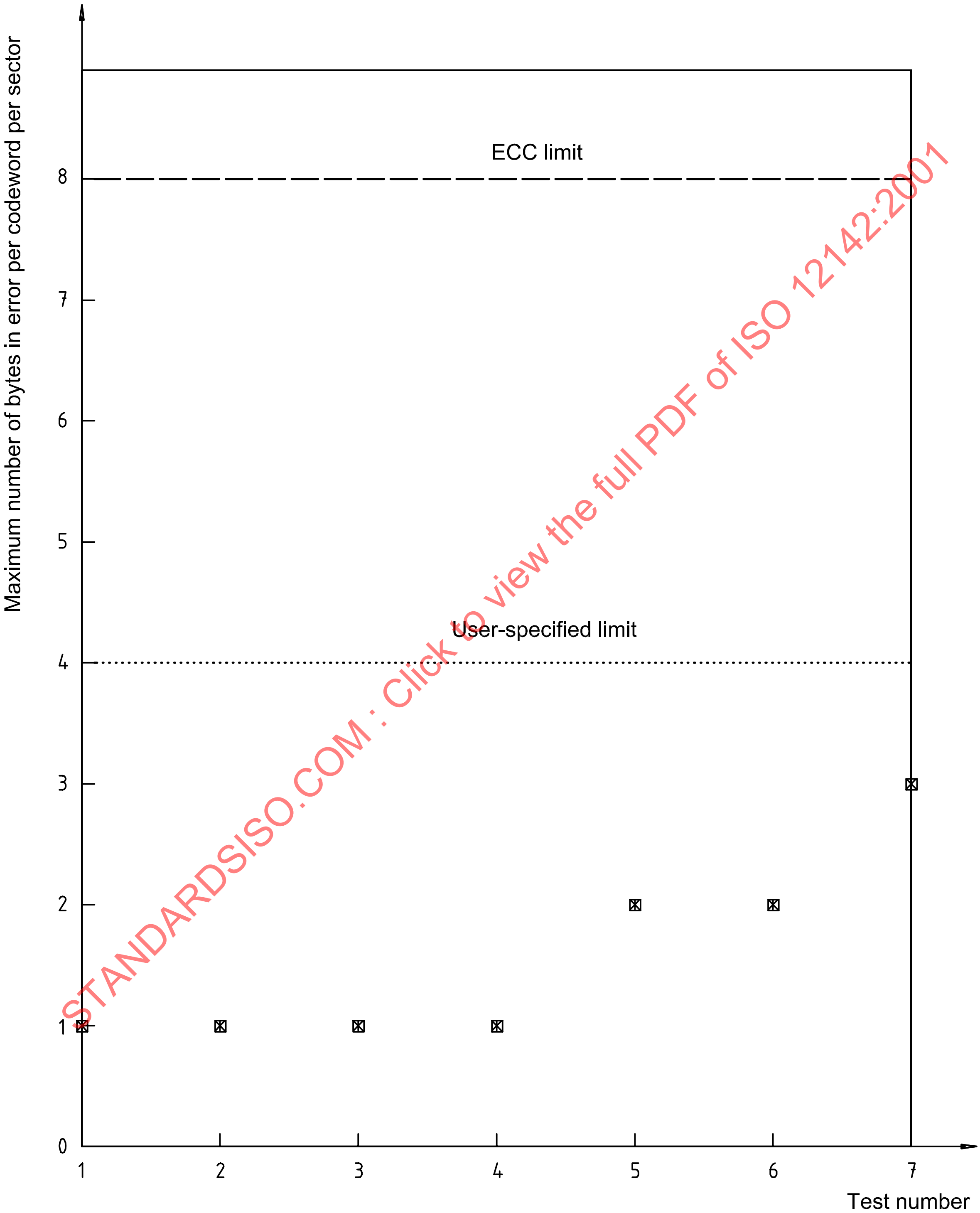

Figure B.6 — Monitoring the maximum number of bytes in error per codeword per sector

The scatter graph shown in Figure B.6 uses simulated data to show changes in the maximum, or worst-case, number of bytes in error per codeword for a given disk. The graph could be used to compare the results of several disks. Test numbers can be replaced by test dates, so the maximum number of bytes in error per codeword per sector can be monitored over time. Error correction code capabilities, error level warnings, and reallocation procedures vary according to the device. Users of the tools specified in this International Standard (or similar tools) should check the relevant media interchange standards and obtain the appropriate information from the drive manufacturer. Set Media Error Levels and Verify Media Error Levels can be usefully represented on this graph by replacing the user-specified limit.

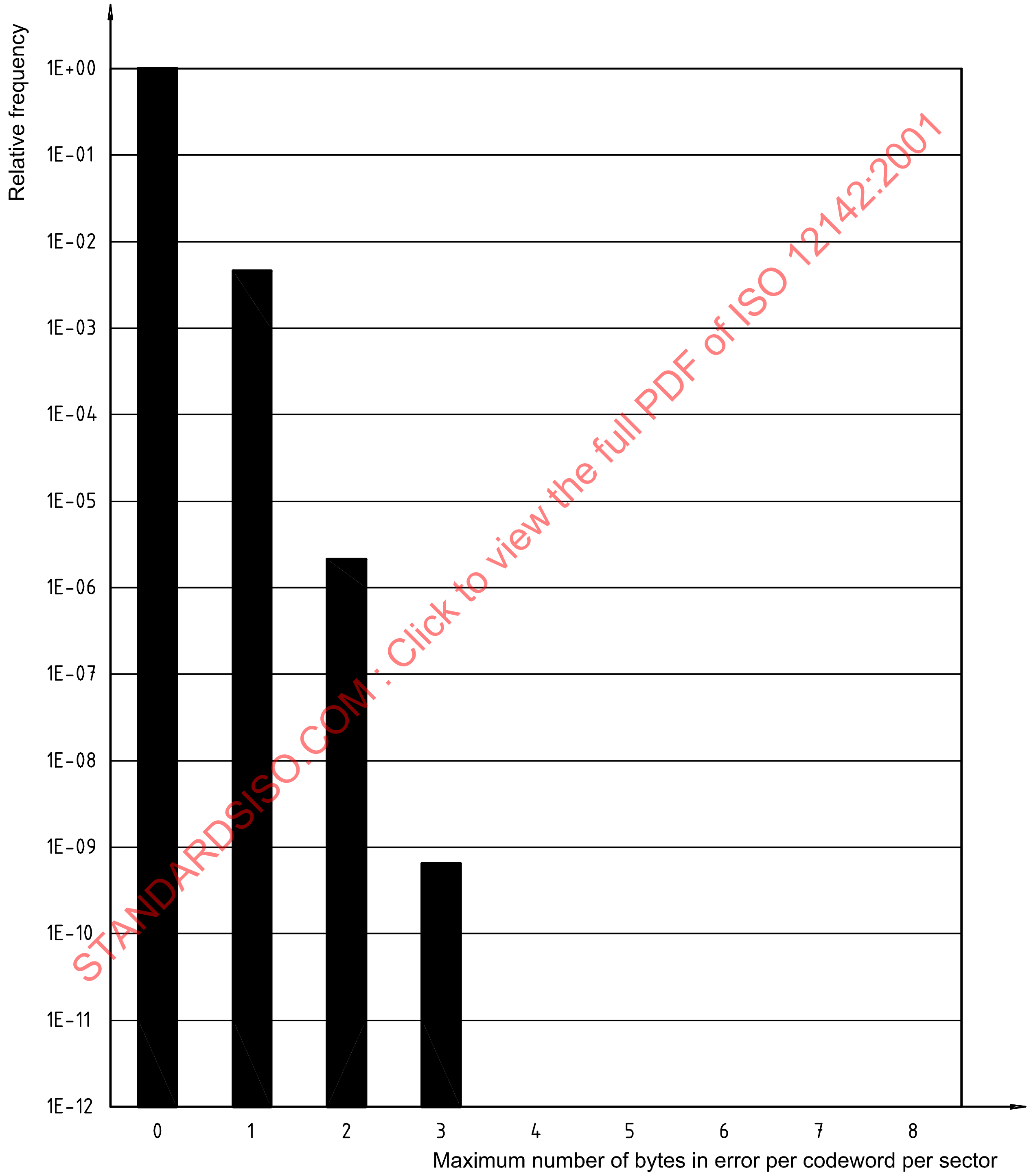

Figure B.7 — Relative frequency distribution of the maximum number of bytes in error per codeword per sector

The bar chart shown in Figure B.7 used simulated data to show the relative frequency distribution of the maximum number of bytes in error per codeword per sector for a given disk. The relative frequency for a maximum of m bytes in error per codeword per track sector is calculated by dividing the number of sectors with this maximum by the total number of sectors tested. These data are provided by the MEL.

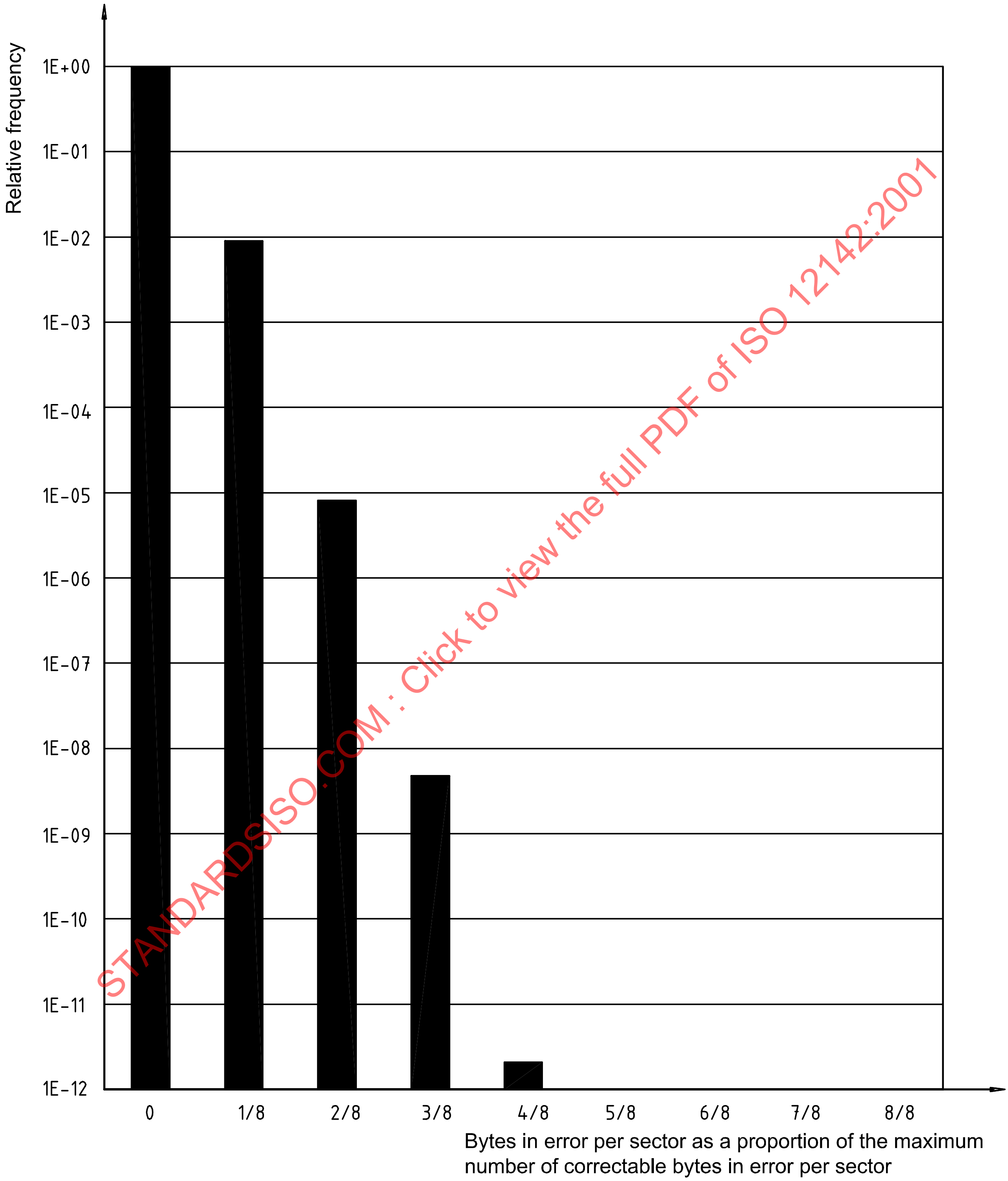

Figure B.8 — Relative frequency distribution of the number of bytes in error per sector

The bar chart shown in Figure B.8 uses simulated data to show the relative frequency distribution of sectors with between $[M \times (n-1)/8]$ and $[M \times (n/8)] - 1$ bytes in error[2], where M refers to a maximum value that the device might use as a criterion for reallocating sectors. See the device manufacturer for information about this value. These data are provided by the MEL.

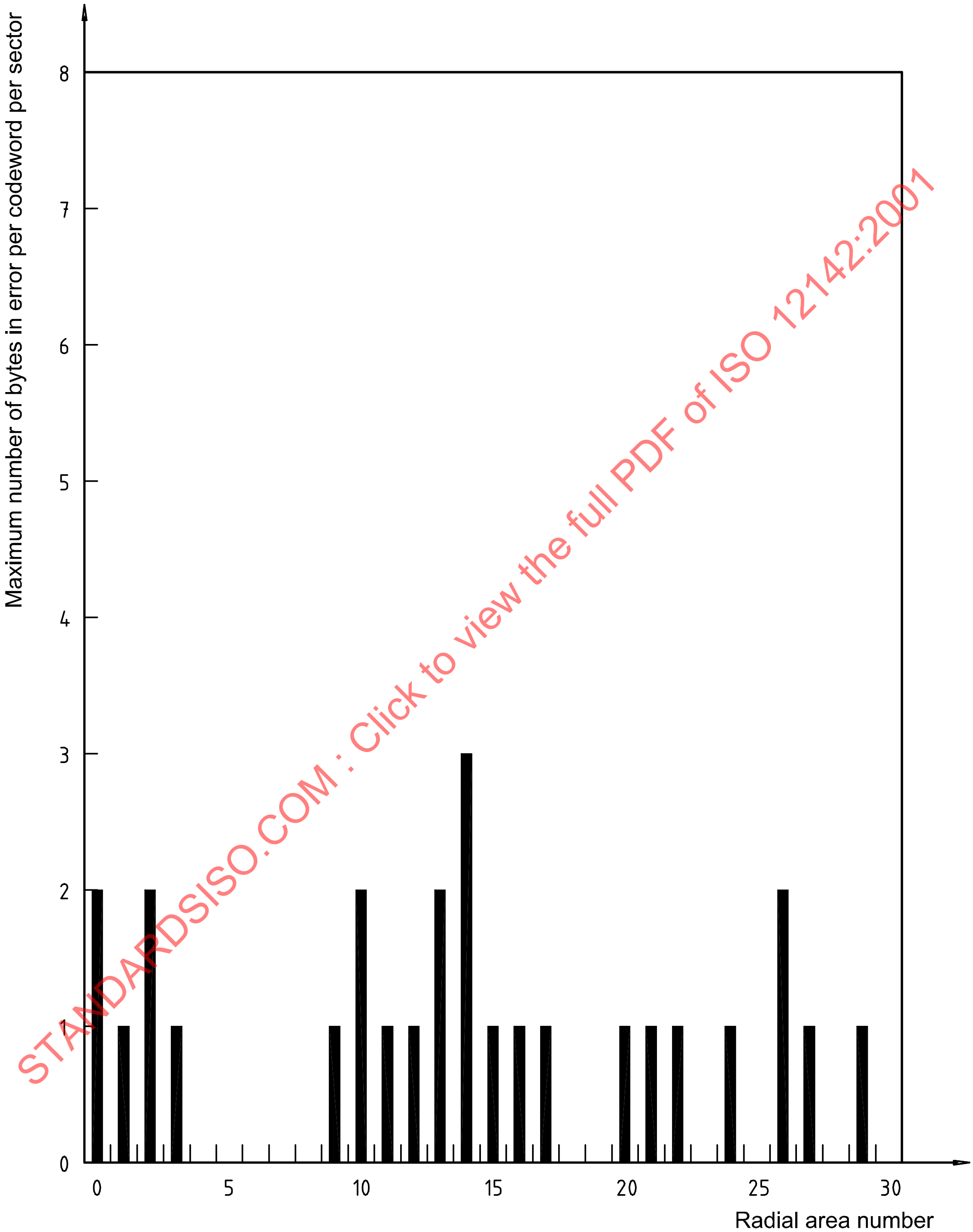

Figure B.9 — Maximum number of bytes in error per codeword per sector per radial area

2) $[x]$ is the greatest integer $\leqslant x$. For example, [3,15] = 3.

The bar chart shown in Figure B.9 uses simulated data to show the maximum number of bytes in error per codeword per sector for each radial area of a given disk. This data is not directly provided by the MEL.

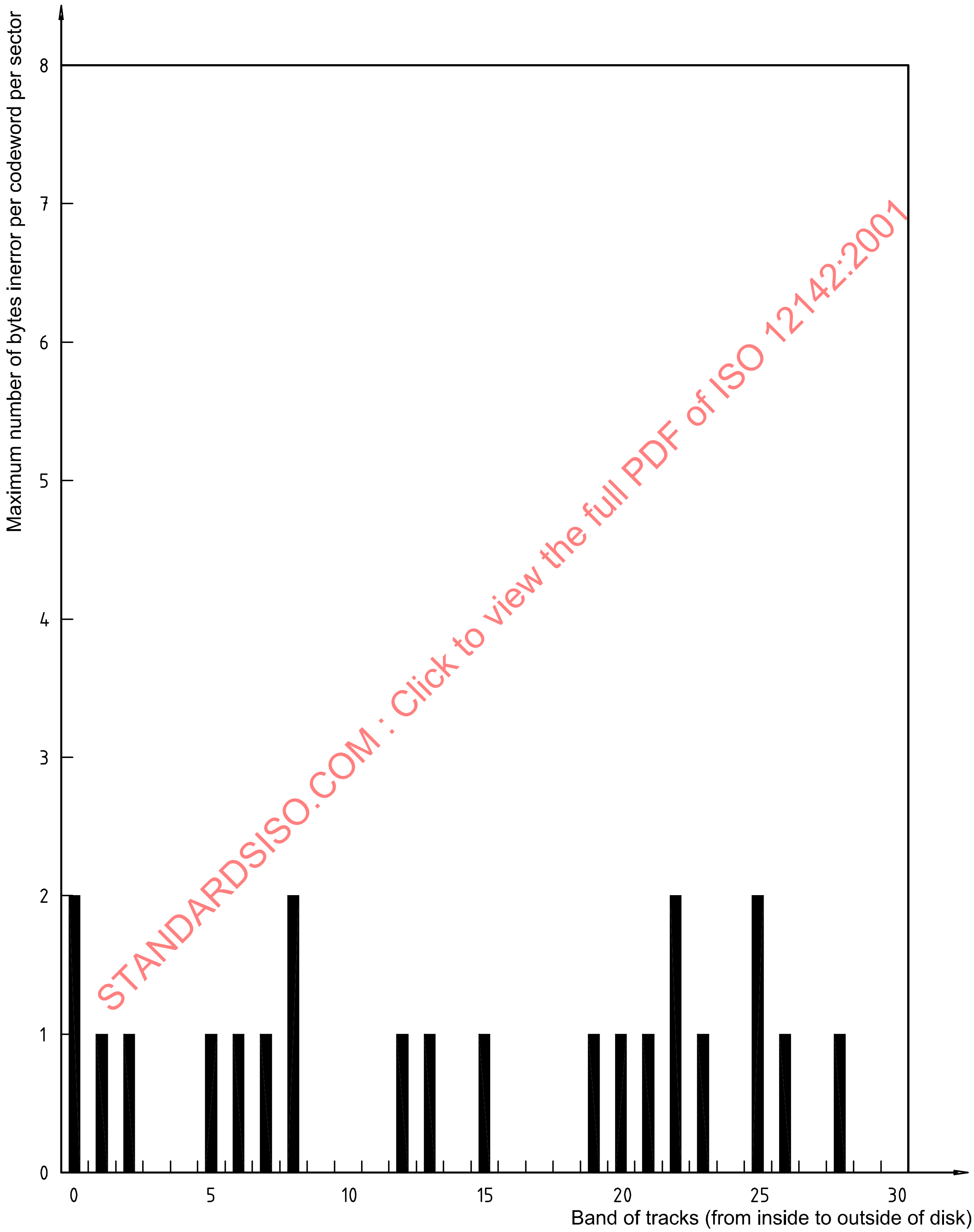

Figure B.10 — Maximum number of bytes in error per codeword per sector per band of tracks

The bar chart shown in Figure B.10 uses simulated data to show the maximum number of bytes in error per codeword per sector per band of tracks across a given disk. This data is not directly provided by the MEL.

B.4.4.3 Monitoring media error topography

A topographical description of media errors can be provided by three-dimensional (3-D) graphs. For example, reports from monitoring the maximum number of bytes in error per codeword can be used to formulate 3-D visualizations that represent their locations across the disk. Figure B.11 shows an example of a 3-D bar chart depicting the maximum number of bytes in error per codeword per band of tracks. The tracks are banded (collated into contiguous groups) in order to reduce the number of values plotted. For example, 130 mm magneto-optic disks that conform to the ISO/IEC 10089 contain over 18,000 tracks.

For users of this International Standard who are interested in an overall description of byte error locations, the graphs in Figures B.11 through B.15 could prove useful. Implementors of the tools specified in this International Standard not using constant angular velocity (CAV) media might find the band sector format of limited use because sector numbers will not refer to the same radial disk area. However, if approximate radial references are satisfactory, users might be able to use absolute sector addresses and track numbers to determine radial positions.

Figure B.12 shows a 3-D bar chart of the maximum number of bytes in error per sector per band of tracks. The MEL page provides this distribution in a grouped format, where data are grouped according to a maximum value of bytes per sector (M). The value M refers to a value that the device might use as a criterion for reallocating sectors. See the device manufacturer for information about this value. MEL reports the total number of inspected sectors that have $[\{(n-1)/8\} \times M]$ to $[(n/8) \times M] - 1$ for $n = 1$ to 7; $[(7/8) \times M]$ to M and > M bytes in error.[3)]

The values plotted in Figure B.12 use the maximum value of n for each band of tracks. Three-dimensional visualizations can also be used to represent BER variations over the disk, i.e. to represent local average media errors as opposed to maxima.

Figure B.13 depicts the BER per band of sectors using a 3-D surface plot. This figure provides a clear representation of media error frequencies and approximate locations, which can give an overall impression of current data integrity. If users of this International Standard require more detailed geographic descriptions, the number of tracks per band could be reduced, or individual tracks could be monitored. Sector references could be replaced by individual codewords. A more localized, but more detailed, description of media error locations would then be provided.

In addition to 3-D bar and surface plots, users of this International Standard might find contour maps useful to display 3-D information. These plots give a bird's eye view of the 3–D surface using colours or shading to indicate vertical axis values. Figure B.14 shows an example of a contour graph used to display frequency information. In this case, the graph shows the number of sectors containing one or more bytes in error.

Users of this International Standard might also find combinations of 3-D graphics more useful in the study of frequency distributions. The four graphs shown in Figure B.15 are examples of combined graphic visualizations. The viewer can see the frequency of different error events, determine their significance in terms of correctability, and determine their approximate physical location.

3) $[x]$ is the greatest integer $\leqslant x$. For example, [3,15] = 3.

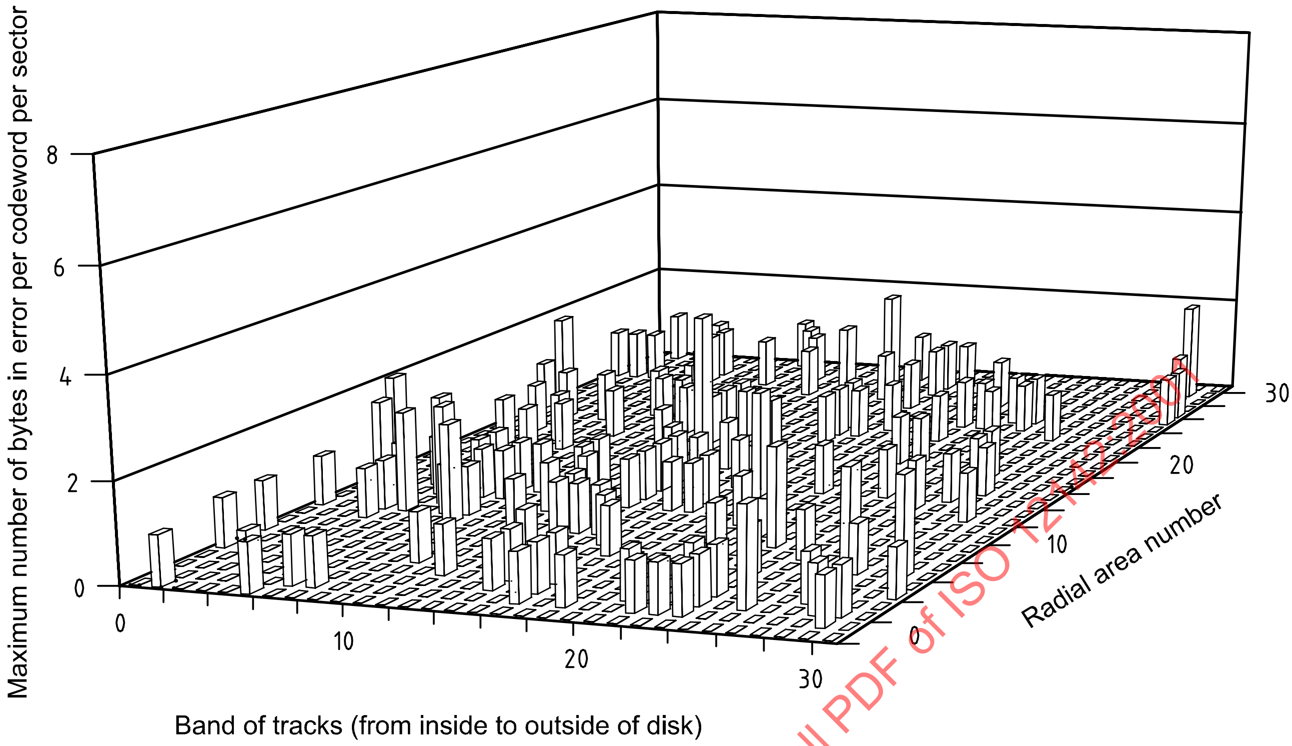

Figure B.11 — Maximum number of bytes in error per codeword per sector

The 3-D bar chart shown in Figure B.11 uses simulated data to show the maximum number of bytes in error per codeword per sector across a given disk.

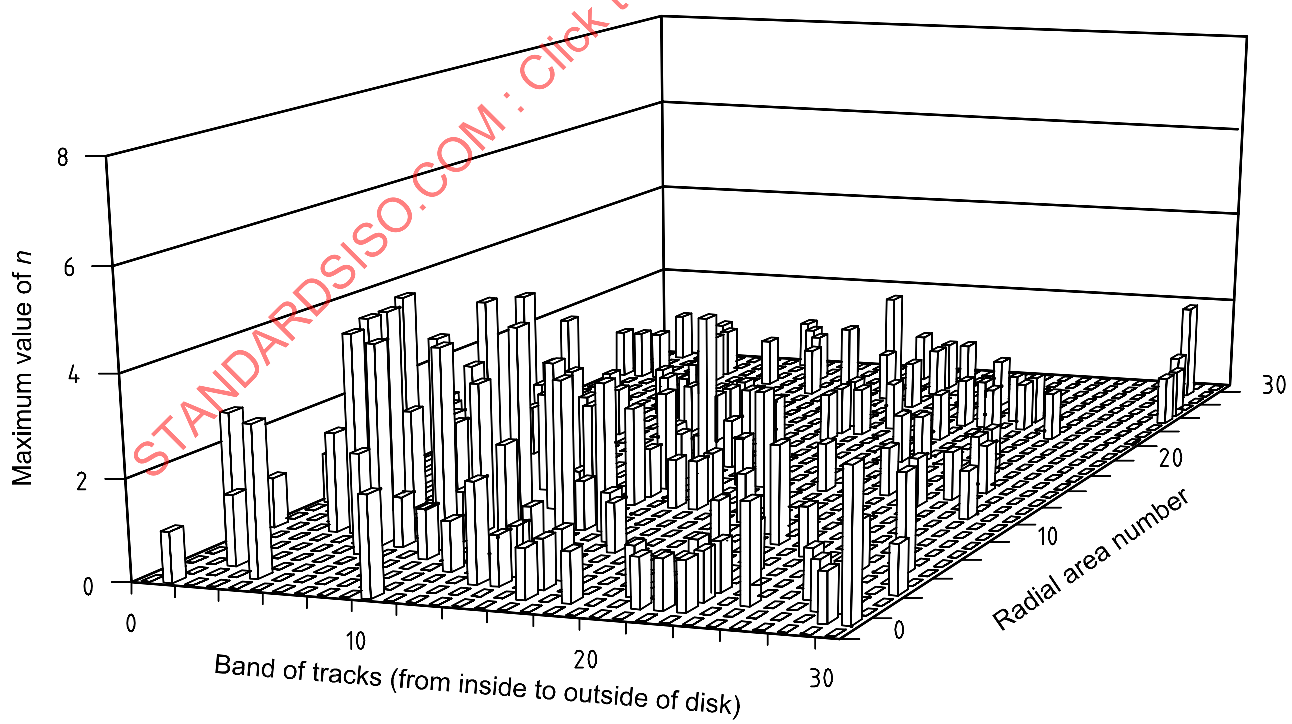

Figure B.12 — Maximum number of bytes in error per sector (n)

The 3-D bar chart shown in Figure B.12 uses simulated data to show variations in the maximum number of bytes in error per sector (n) for each disk area (defined by a band of tracks in a given radial area).