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Information technology — Digitally recorded media for information interchange and storage — Test method for the estimation of lifetime of optical disks for long-term data storage

Technologies de l'information — Supports pour l'échange d'informations et le stockage enregistrés numériquement — Méthode d'essai pour l'estimation de la durée de vie de disques optiques pour le stockage à long terme

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Foreword

ISO (the International Organization for Standardization) and IEC (the International Electrotechnical Commission) form the specialized system for worldwide standardization. National bodies that are members of ISO or IEC participate in the development of International Standards through technical committees established by the respective organization to deal with particular fields of technical activity. ISO and IEC technical committees collaborate in fields of mutual interest. Other international organizations, governmental and non-governmental, in liaison with ISO and IEC, also take part in the work. In the field of information technology, ISO and IEC have established a joint technical committee, ISO/IEC JTC 1.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/IEC JTC 1, *Information technology*, SC 23, *Digitally recorded media for information interchange and storage*.

This third edition cancels and replaces the second edition (ISO/IEC 16963:2015), which has been technically revised.

The main changes compared to the previous edition are as follows:

— minor enhancement has been made so that the stress condition and the disk testing location are independent of each other and the cross-combinations of them are applicable; and

— minor editorial changes have been made to conform to the latest version of the ISO/IEC Directives Part 2.

This corrected version of ISO/IEC 16963:2017 incorporates the following corrections:

— correction of the formula in E.3 that uses function ln L = ln L(β,σ) to express the Fisher information matrix I in E.2.

Introduction

Markets and industry have developed a common understanding that the property referred to as the lifetime of data recorded to optical disks plays an increasingly important role in many applications. Disparate standardized test methodologies exist for Magneto-Optical disks versus recordable compact disks and DVD systems. The first edition of this document provided a common methodology applicable for various purposes that included lifetime testing of then available writable CD and DVD optical disks.

ISO/IEC JTC 1/SC 23/JWG 1, which is a joint working group comprising ISO/TC 42, ISO/TC 171/SC 1 and ISO/IEC JTC 1/SC 23, initiated work on this subject and developed initial drafts with assistance from Ecma International TC 31.

After the issuance of the first edition of this document, ISO/IEC standards for the physical formats of BD Recordable and Rewritable disks were published. Accordingly, ISO/IEC JTC 1/SC 23/JWG 1 started work again to include testing of writable BD optical disks in the second edition of this document. Additional details for lifetime estimation are also incorporated.

The third edition was issued as a minor enhancement of this document. It is clarified that the stress condition and the disk testing location are independent each other and the cross-combinations of them are applicable.

Information technology — Digitally recorded media for information interchange and storage — Test method for the estimation of lifetime of optical disks for long-term data storage

1 Scope

This document specifies an accelerated ageing test method for estimating the lifetime of the retrievability of information stored on recordable or rewritable optical disks.

The method is based on the theoretical assumption that the lifetime of data recorded on an optical disk has a lognormal distribution.

Detailed testing is specified for the following formats: DVD-R/RW/RAM disks, +R/+RW disks, CD-R/RW disks and BD recordable/rewritable disks. The testing can be applied to additional optical-disk formats with substitution of the appropriate specifications and can also be updated by the committee in the future as required.

This document includes:

— stress conditions:

  — Basic and Rigorous stress-conditions for testing and subsequent analysis using both the Eyring and Arrhenius methods;

— ambient storage conditions in which the lifetime of data stored on optical disk is estimated:

  — a Controlled storage-condition, *Temp* = 25 °C and *RH* = 50 %, representing full-time air conditioning. The Eyring method is used to estimate the lifetime under this storage condition;

  — a Harsh storage-condition, *Temp* = 30 °C and *RH* = 80 %, representing the most severe conditions in which users handle and store optical disks. The Arrhenius method is used to estimate the lifetime under this storage condition;

— a description of the evaluation system;

— procedures for specimen preparation and data acquisition;

— definitions and methods used in testing specific disk types;

— analysis of test results to determine the lifetime of stored data;

— a format for reporting the estimated lifetime of stored data.

The methodology includes only the effects of temperature and relative humidity. It does not attempt to model degradation due to complex failure mechanism kinetics, nor does it test for exposure to light, corrosive gases, contaminants, handling, or variations in playback subsystems. Disks exposed to these additional sources of stress or higher levels of temperature and relative humidity are expected to experience shorter usable lifetime.

2 Normative references

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

ISO/IEC 12862, *Information technology — 120 mm (8,54 Gbytes per side) and 80 mm (2,66 Gbytes per side) DVD recordable disk for dual layer (DVD-R for DL)*

ISO/IEC 13170, *Information technology — 120 mm (8,54 Gbytes per side) and 80 mm (2,66 Gbytes per side) DVD re-recordable disk for dual layer (DVD-RW for DL)*

ISO/IEC 17341, *Information technology — Data interchange on 120 mm and 80 mm optical disk using +RW format — Capacity: 4,7 Gbytes and 1,46 Gbytes per side (recording speed up to 4X)*

ISO/IEC 17342, *Information technology — 80 mm (1,46 Gbytes per side) and 120 mm (4,70 Gbytes per side) DVD re-recordable disk (DVD-RW)*

ISO/IEC 17344, *Information technology — Data interchange on 120 mm and 80 mm optical disk using +R format — Capacity: 4,7 Gbytes and 1,46 Gbytes per side (recording speed up to 16X)*

ISO/IEC 17592, *Information technology — 120 mm (4,7 Gbytes per side) and 80 mm (1,46 Gbytes per side) DVD rewritable disk (DVD-RAM)*

ISO/IEC 23912, *Information technology — 80 mm (1,46 Gbytes per side) and 120 mm (4,70 Gbytes per side) DVD Recordable Disk (DVD-R)*

ISO/IEC 25434, *Information technology — Data interchange on 120 mm and 80 mm optical disk using +R DL format — Capacity: 8,55 Gbytes and 2,66 Gbytes per side (recording speed up to 16X)*

ISO/IEC 26925, *Information technology — Data interchange on 120 mm and 80 mm optical disk using +RW HS format — Capacity: 4,7 Gbytes and 1,46 Gbytes per side (recording speed 8X)*

ISO/IEC 29642, *Information technology — Data interchange on 120 mm and 80 mm optical disk using +RW DL format — Capacity: 8,55 Gbytes and 2,66 Gbytes per side (recording speed 2,4X)*

ISO/IEC 30190, *Information technology — Digitally recorded media for information interchange and storage — 120 mm Single Layer (25,0 Gbytes per disk) and Dual Layer (50,0 Gbytes per disk) BD Recordable disk*

ISO/IEC 30191, *Information technology — Digitally recorded media for information interchange and storage — 120 mm Triple Layer (100,0 Gbytes single sided disk and 200,0 Gbytes double sided disk) and Quadruple Layer (128,0 Gbytes single sided disk) BD Recordable disk*

ISO/IEC 30192, *Information technology — Digitally recorded media for information interchange and storage — 120 mm Single Layer (25,0 Gbytes per disk) and Dual Layer (50,0 Gbytes per disk) BD Rewritable disk*

ISO/IEC 30193, *Information technology — Digitally recorded media for information interchange and storage — 120 mm Triple Layer (100,0 Gbytes per disk) BD Rewritable disk*

ECMA-394, *Recordable Compact Disc Systems CD-R Multi-Speed*

ECMA-395, *Recordable Compact Disc Systems CD-RW Ultra-Speed*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

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

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

— ISO Online browsing platform: available at http://www.iso.org/obp

3.1
Arrhenius method
accelerated ageing model based on the effects of temperature only

3.2
baseline
analysis of an initial test (e.g. initial data errors) after recording and before exposure to any stress condition, i.e. measurement at stress time t = 0 h

3.3
Basic stress-condition
accelerated-ageing condition for estimating the lifetime of data stored on optical disks with a reasonable amount of time and labour

3.4
B_5 Life
5 percentile of the lifetime distribution (i.e. 5 % failure time) or 95 % survival lifetime

3.5
$(B_5 \text{ Life})_L$
95 % lower confidence bound of B_5 Life

3.6
B_{50} Life
50 percentile of the lifetime distribution (i.e. 50 % failure time) or 50 % survival lifetime

3.7
Controlled storage-condition
well-controlled storage-condition with full-time air conditioning (*Temp* = 25 °C and *RH* = 50 %) which can extend the lifetime of data stored on optical disks

3.8
Eyring method
accelerated-ageing model based on the combined effects of temperature and relative humidity

3.9
data error
measured error on a sample disk before error correction is applied

3.10
Harsh storage-condition
most-severe condition in which users handle and store the optical disks (*Temp* = 30 °C and *RH* = 80 %) under which the lifetime of data stored on optical disks can be reduced

3.11
incubation
process of enclosing and maintaining controlled test-sample environments

3.12
LDC Block
ECC Block of BDs using Long-Distance Code

[SOURCE: ISO/IEC 30190:2016, 13.6]

3.13
Maximum Data Error
greatest level of data error measured anywhere in one of the relevant areas on the disk

Note 1 to entry: For BD Recordable SL/DL disks, BD Recordable TL/QL disks, BD Rewritable SL/DL disks, and BD Rewritable TL disks, this is the Maximum RSER; for DVD-R/RW disks and +R/+RW disks, this is the Maximum PI Sum 8; for DVD-RAM disks, this is the Maximum BER; and for CD-R/RW disks, this is the Maximum C1 Ave 10.

3.14
retrievability
ability to recover physically-recorded information as recorded

3.15
RH
variable for relative humidity used with %

3.16
Rigorous stress-condition
accelerated-ageing condition for estimating the lifetime of data stored on optical disks with higher confidence

3.17
shelf life
maximum time an unrecorded disk can be stored under specific conditions and still meet the performance requirements specified

3.18
shelf time
time of an unrecorded disk spent on the shelf

3.19
stress
temperature and relative humidity variables to which the sample is exposed during the *incubation* (3.11) sub-intervals

3.20
system
combination of hardware, software, storage medium, and documentation used to record, retrieve, and reproduce information

3.21
Temp
variable for Celsius temperature used with °C

4 Abbreviated terms

BER	Byte Error Rate
BLER	BLock Error Rate
DL	Dual Layer
ECC	Error-Correction Code
LDC	Long-Distance Code
PI	Parity (of the) Inner (code)
QL	Quadruple Layer
RSER	Random Symbol Error Rate
SER	Symbol Error Rate
SL	Single Layer
TL	Triple Layer

5 Conformance

A disk tested by this methodology shall conform to all normative references specific to that disk format.

6 Convention and notations

6.1 Representation numbers

A measured value is rounded off to the least significant digit of the corresponding specified value. For instance, it follows that a specified value of 1,26 with a positive tolerance of +0,01 and a negative tolerance of −0,02 allows a range of measured values from 1,235 to 1,275.

6.2 Variables

A variable with "^" above the character denotes that its value is obtained by estimation.

6.3 Names

The names of entities having explicitly-defined meanings for the purpose of this document are capitalized.

7 Measurements

7.1 Summary

7.1.1 Stress incubation and measuring

A group of disks shall be measured at four stress conditions for Basic stress-condition testing, or five stress conditions for Rigorous stress-condition testing, for analysis by the Eyring method. For analysis by the Arrhenius method, three stress conditions shall be used for Basic stress-condition testing and four stress conditions shall be used for the Rigorous stress-condition testing.

Each total incubation time is divided into several incubation sub-interval time periods. The purpose of the sub-intervals is to provide sufficient data points to enable proper fitting of the data to an exponential curve during analysis. Each disk in each group of disks has its initial data errors measured before exposure to a stress condition. After each incubation sub-interval, each disk shall be measured for its data errors again.

A control disk used for monitoring the measurement equipment may also be measured after each incubation sub-interval.

7.1.2 Assumptions

This document is based on the following assumptions for applicability to the optical disks to be tested:

— the life-distribution of the disks is appropriately modelled by a statistical distribution;

— the Eyring method can be used to model ageing with both stresses involved (temperature and relative humidity);

— the dominant failure mechanism acting when disks are in use under normal conditions will be the same as that acting under the stress conditions;

— compatibility of a disk and drive combination can assure the initial recording quality and will not otherwise affect the resulting lifetime estimation;

— a hardware and software system needed to read the disk will be available at the time retrieval of the information is attempted;

— the recorded format will be recognizable and interpretable by the reading software.

7.1.3 Data error

7.1.3.1 General

Data errors shall be measured at disk testing locations defined in 7.5. For each format, the Maximum Data Error used to estimate the time-to-failure shall be determined as follows:

BD Recordable SL/DL disks, BD Recordable TL/QL disks, BD Rewritable SL/DL disks and BD Rewritable TL disks defined in ISO/IEC 30190, ISO/IEC 30191, ISO/IEC 30192 and ISO/IEC 30193, respectively:

Maximum Random SER (Max RSER)

DVD-R disks defined in ISO/IEC 23912 and ISO/IEC 12862, DVD-RW disks defined in ISO/IEC 17342 and ISO/IEC 13170, +R disks defined in ISO/IEC 25434 and ISO/IEC 17344, and +RW disks defined in ISO/IEC 17341, ISO/IEC 26925 and ISO/IEC 29642:

Maximum PI Sum 8 (Max PI Sum 8)

DVD-RAM disks defined in ISO/IEC 17592:

Maximum Byte Error Rate (Max BER)

CD-R disks and CD-RW disks defined in ECMA-394 and ECMA-395, respectively:

Maximum C1 Ave 10 (Max C1 Ave 10)

7.1.3.2 RSER

Per ISO/IEC 30190, ISO/IEC 30191, ISO/IEC 30192 and ISO/IEC 30193, a Random Symbol Error Rate (RSER) is defined as the SER where all erroneous bytes contained in burst errors of length ≥40 bytes are counted neither in the numerator nor in the denominator of the SER calculation:

$$\frac{\sum_{i=1}^{N}\left(E_{a_i} - E_{b_i}\right)}{N \times 75\,392 - \sum_{i=1}^{N} E_{b_i}}$$

where

E_{a_i} is the number of all erroneous bytes in LDC Block i;

E_{b_i} is the number of all erroneous bytes in burst errors ≥40 bytes in LDC Block i;

N is the number of LDC Blocks.

RSER shall be averaged over any 10 000 consecutive LDC Blocks with the condition that all Blocks are recorded either in a continuously-written sequence or in a discontinuously-written sequence excluding disk defects.

A burst error is defined as a sequence of bytes where there are not more than two correct bytes between any two erroneous bytes.

For determining burst errors, the bytes shall be ordered in the same sequence as they were recorded on the disk. The length of a burst error is defined as the total number of bytes counting from the first erroneous byte that is preceded by at least three correct bytes to the last erroneous byte that is followed by at least three correct bytes.

The number of erroneous bytes in a burst is defined as the actual number of bytes in that burst that are not correct (see example in Figure 1).

The maximum value of the RSER measured over the area specified in 7.5 (Max RSER) shall not exceed 10^{-3}.

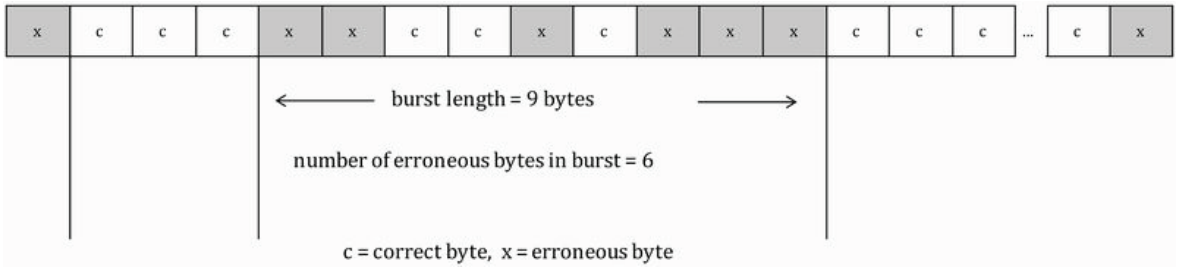

Figure 1 — Example of burst error

7.1.3.3 PI Sum 8

Per ISO/IEC 16448 or ISO/IEC 16449, a row in an ECC block that has at least 1 byte in error constitutes a PI error. PI Sum 8 is measured over any eight consecutive ECC blocks. The maximum number of PI errors, also called Max PI Sum 8, before error correction, measured over the area specified in 7.5, shall not exceed 280.

7.1.3.4 BER

The number of erroneous symbols shall be measured in any consecutive 32 ECC blocks in the first pass of the decoder before correction. The BER is the number of erroneous symbols divided by the total number of symbols included in the 32 consecutive ECC blocks. The maximum value of the BER measured over the area specified in 7.5 (Max BER) shall not exceed 10^{-3}.

7.1.3.5 C1 Ave 10

ISO/IEC 10149 specifies that the BLER averaged over any 10 s shall be less than 3×10^{-2}. At the standard (1X) data transfer rate, the total number of blocks per second entering the C1-decoder is 7 350.

Thus, the number of C1 errors per second before error correction which is averaged over any 10 s is called C1 Ave 10. The maximum value measured over the area specified in 7.5 (Max C1 Ave 10) shall not exceed 220.

7.1.4 Data quality

Data quality is checked by plotting the median rank of the estimated time-to-failure values with a best-fit line for each stress condition. The lines are then checked for reasonable parallelism.

7.1.5 Regression

The log predicted time-to-failure values shall be calculated using linear regression.

Multiple linear regression is used for the Eyring method and linear regression is used for the Arrhenius method.

7.2 Test specimen

The sample disks shall represent the construction, materials, manufacturing process, quality and variation of the final process output.

Consideration shall be made for shelf life. Longer shelf time of optical disks before recording and testing can impact test results. Shelf time shall be a representative of normal usage.

In case the support of disk manufacturer is available, it is recommended to use the disks gathered from as many production lots as possible.

7.3 Recording conditions

7.3.1 General

Before disks are entered into accelerated-ageing tests, they shall be recorded as optimally as is practicable according to the descriptions given in the related standard. Optimum Power Control (OPC) during the writing process shall serve as the method to achieve minimum data errors. It is generally assumed that optimally-recorded disks will yield the longest estimated lifetime. Disks are deemed acceptable for entry into the ageing tests when their data errors and all other disk parameters are found to be within their respective standard's specification limits.

The choice of recording hardware is at the discretion of the recording party. It may be based either on a commercial drive or a specialty recording tester. It shall be capable of producing recordings that meet all specifications.

The recording speed used for testing shall be reported.

NOTE It is expected that the lifetime of data on a disk can be affected by recording conditions including recording speed.

7.3.2 Recording test environment

When performing recordings, the air immediately surrounding the disk shall have the following properties:

Temperature:	23 °C to 35 °C;
Relative humidity:	45 % to 55 %;
Atmospheric pressure:	60 kPa to 106 kPa.

No condensation on the disk shall occur. Before testing, the disk shall be conditioned in this environment for 48 h minimum. It is recommended that, before testing, the entrance surface be cleaned according to the instructions of the manufacturer of the disk.

7.4 Playback conditions

7.4.1 Playback tester

Specimen disks shall be read as described in the relevant format standards identified in Clause 2.

7.4.2 Playback test environment

When measuring the data errors, the air immediately surrounding the disk shall have the following properties:

Temperature:	23 °C to 35 °C;
Relative humidity:	45 % to 55 %;
Atmospheric pressure:	60 kPa to 106 kPa.

Unless otherwise stated, all tests and measurements shall be made in this test environment.

