INTERNATIONAL STANDARD

ISO/IEC 16963

Second edition
2015-03-15

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

Reference number
ISO/IEC 16963:2015(E)

ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

Published in Switzerland

Contents

Page

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).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO and IEC shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/IEC JTC 1, *Information technology*, SC 23, *Digitally recorded media for information interchange and storage*.

This second edition cancels and replaces the first edition (ISO/IEC 16963:2011), which has been technically revised.

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 vs recordable compact disks and DVD systems. The first edition of this International Standard 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 International Standard, 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 this second edition of the International Standard. Additional details for lifetime estimation are also incorporated.

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 International Standard specifies an accelerated aging 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 committee in the future as required.

This International Standard 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, 25 °C and 50 % RH, representing full-time air conditioning. The Eyring method is used to estimate the lifetime under this storage condition;
  - a Harsh storage-condition, 30 °C and 80 % RH, 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 lifetimes.

2 Conformance

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

3 Normative references

The following referenced documents in whole or in part, are normatively referenced in this document and are indispensable for the application 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 10149, *Information technology — Data interchange on read-only 120 mm optical data disks (CD-ROM)*

ISO/IEC 16448, *Information technology — 120 mm DVD — Read-only disk*

ISO/IEC 16449, *Information technology — 80 mm DVD — Read-only disk*

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 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 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 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 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 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 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 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 per disk) and Quadruple Layer (128,0 Gbytes per 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*

4 Terms and definitions

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

4.1
Arrhenius method
accelerated aging model based on the effects of temperature only

4.2
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 hours

4.3
Basic stress-condition
accelerated-aging conditions for estimating the lifetime of data stored on optical disks with a reasonable amount of time and labour

4.4
B_5 Life
5 percentile of the lifetime distribution (i.e. 5 % failure time) or 95 % survival lifetime

4.5
$(B_5\ \text{Life})_L$
95 % lower confidence bound of B_5 Life

4.6
B_{50} Life
50 percentile of the lifetime distribution (i.e. 50 % failure time) or 50 % survival lifetime

4.7
Controlled storage-condition
well-controlled storage conditions with full-time air conditioning (25 °C and 50 % RH) which can extend the lifetime of data stored on optical disks

4.8
Eyring method
accelerated-aging model based on the combined effects of temperature and relative humidity

4.9
data error
measured error on a sample disk before error correction is applied

4.10
Harsh storage-condition
most-severe conditions in which users handle and store the optical disks (30 °C and 80 % RH) under which the lifetime of data stored on optical disks may be reduced

4.11
incubation
process of enclosing and maintaining controlled test-sample environments

4.12
LDC Block
ECC Block of BDs using Long-Distance Code

[SOURCE: ISO/IEC 30190:2013, 13.6]

4.13
Maximum Data Error
measured data error 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.

4.14
retrievability
ability to recover physically-recorded information as recorded

4.15
Rigorous stress-condition
accelerated-aging conditions for estimating the lifetime of data stored on optical disks with higher confidence

4.16
shelf life
maximum time an unrecorded disk can be stored under specific conditions and still meet the performance requirements specified

4.17
shelf time
time spent on the shelf

4.18
stress
temperature and relative humidity variables to which the sample is exposed during the *incubation* (4.11) sub-intervals

4.19
system
combination of hardware, software, storage medium, and documentation used to record, retrieve, and reproduce information

5 Conventions and notations

5.1 Representation of 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.

5.2 Variables

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

5.3 Names

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

6 List of acronyms

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
RH	Relative Humidity

NOTE The same meaning as “relative humidity” and used for the unit with %.

RSER	Random Symbol Error Rate
SER	Symbol Error Rate
SL	Single Layer
TL	Triple Layer

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 International Standard is based on the following assumptions for applicability to the optical disks to be tested:

— the life-distribution of the disks is appropriately modeled by a statistical distribution,

— the Eyring method can be used to model aging 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 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/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 not counted, neither in the numerator nor in the denominator of the SER calculation:

$$\frac{\sum_{i=1}^{N}\left(E_{a_i} - E_{b_i}\right)}{N \times 75392 - \sum_{i=1}^{N} E_{b_i}}$$

where

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

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

N 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}.

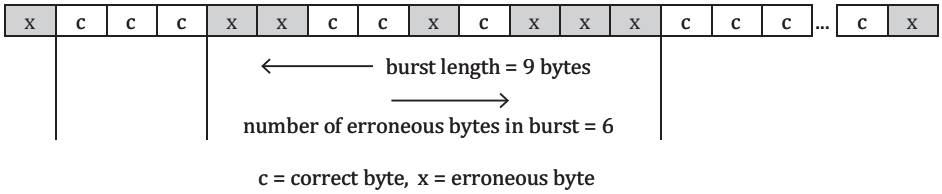

Figure 1 — Example of burst error

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 8 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 seconds 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 seconds 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 may impact test results. Shelf time shall be representative of normal usage.

NOTE 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-aging tests, they shall be recorded as optimally as is practicable according to the descriptions given in the related standard. OPC (Optimum Power Control) 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 aging 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 may 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 hrs 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 3.

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.

7.4.3 Calibration

The test equipment should be calibrated as needed or prescribed by its manufacturer using calibration disks approved by said manufacturer before disk testing. A control disk should be maintained at ambient conditions, and its data error should be measured at the same time the stressed disks are measured, both initially and after each stress sub-interval.

The mean and standard deviation of the control disk shall be established by collecting at least five measurements. Should any individual data error differ from the mean by more than three times the standard deviation, the problem shall be corrected and all data collected since the last valid control point shall be re-measured.

7.5 Disk testing locations

7.5.1 Rigorous stress-condition testing

All data areas on a disk shall be tested.

7.5.2 Basic stress-condition testing

Testing locations shall be a minimum of three bands spaced evenly across the inner, middle and outer radius regions on the disk as indicated in Table 1. The total testing area shall represent a minimum of 5 % of the disk capacity. For BD disks, each of the three test bands in each layer shall have more than 10 000 LDC Blocks. For DVD disks and +R / +RW disks, each of the three test bands in each layer shall have more than 750 ECC blocks for 80 mm disks, or 2 400 ECC blocks for 120 mm disks. For CD disks, each of the three test bands shall have more than 5 900 sectors.

Table 1 — Nominal radii of three test bands (Unit; mm)

	BD Recordable disk/ BD Rewritable disk (SL/ DL/ TL/ QL) (inner radius)	DVD-R / DVD-RW / +R / +RW disk (SL / DL) (Inner radius)		DVD-RAM disk		CD-R / RW disk (inner radius)
	120 mm	80 mm	120 mm	80 mm	120 mm	120 mm
Band 1	25,0	25,0	25,0	24,1 to 25,0	24,1 to 25,0	25,0
Band 2	40,0	30,0	40,0	29,8 to 38,8	39,4 to 40,4	40,0
Band 3	55,0	35,0	55,0	34,6 to 35,6	54,9 to 55,8	55,0

NOTE For Multi-layer disks it is recommended that additional test band(s) at the outer diameter covering data in the transition(s) between layers in the disk be included in the test.

8 Accelerated stress test

8.1 General

Accelerated stress testing is used in order to estimate the lifetime of the optical disk. All information needed for this testing is provided in this document.

8.2 Stress conditions

8.2.1 General

Stress conditions for this test method are increases in temperature and/or relative humidity. The stress conditions are intended to accelerate the chemical reaction rate from what would occur normally at ambient storage or usage conditions. The chemical reaction is expected to cause degradation in some desired material property that eventually leads to disk failure.

Regarding use of the Eyring method, five stress conditions shall be used for Rigorous stress-condition testing and the minimum number of specimens that shall be used for those stress conditions are shown in Table 2. The four stress conditions that shall be used for Basic stress-condition testing and the minimum numbers of specimens are shown in Table 3. Additional specimens and conditions may be used, if desired for improved precision.