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Information technology — Digitally recorded media for information interchange and storage — Data migration method for DVD-R, DVD-RW, DVD-RAM, +R, and +RW disks

Technologies de l'information — Supports enregistrés numériquement pour échange et stockage d'information — Méthode de migration de données pour disques DVD-R, DVD-RW, DVD-RAM, +R, et +RW

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Foreword

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Introduction

Many organizations now use optical disks for long-term storage of information. It is assumed that a disk selected for recording has already been qualified for that purpose. It is therefore important to be able to verify that data has been recorded correctly and remains readable for the required amount of time. Previous ISO standards clearly defined requirements for interchange, but did not contain requirements for longevity.

Longevity is limited both by disk degradation and by technology obsolescence. Interchange must be regularly verified to assure that information on existing recorded disks will continue to be recoverable. Users may have a maintenance policy that protects disks against unanticipated failure or use, such as by making one archival copy, another to function as a backup or master, and another for routine access. Hardware support life cycles typically vary between 5 to 10 years and technology lifecycles usually end after 20 years. Consequently, recordings that require a longer lifecycle may have to be transferred to upgraded platforms every 10 to 20 years.

Optical disks for long-term storage should be evaluated. Significant longevity differences may exist for disks from different manufacturers and also between disks from the same manufacturer. It is preferable that the disks for long-term preservation should have a long life expectancy, which can be estimated according to ISO/IEC 10995.

Disks with an initially poor quality do not offer sufficient headroom to avoid reaching the unrecoverable error threshold before the next scheduled inspection, which for archival disks is to be avoided. This means that a disk of high initial recorded quality that maintains this condition for life is expected to have superior longevity.

Because errors in read data are corrected at error correction decoder, it is impossible to detect degradation without detecting raw error rate or raw error number. The raw error can be detected with standard test drive. Quality of the disk can be specified by the number of erroneous inner parity with DVD-R, DVD-RW, +R, and +RW disks. That of DVD-RAM disk is defined by byte error rate. Deterioration can be monitored by checking the raw error numbers and must continue to be monitored. Methods described in this standard define a quality control policy that can non-destructively identify degradation, and thereby support timely and effective corrective action.

DVD-R, DVD-RW, DVD-RAM, +R, and +RW disks are based on the technology now widely known as DVD in the market; i.e. the use of red Laser Diode, the use of two 0,6 mm thick substrates bonded together by an adhesive layer to protect the disks from dust combined with Write Once recording layers (DVD-R, +R) or Phase Change recording layers (DVD-RW, DVD-RAM, +RW), the use of a 0,60 or 0,65 NA objective lens to ensure good spatial margins required for a professional data archive solution, and the use of dual recording layers with a spacer between them in addition to conventional single recording layer.

Information technology — Digitally recorded media for information interchange and storage — Data migration method for DVD-R, DVD-RW, DVD-RAM, +R, and +RW disks

1 Scope

This International Standard provides specifications of the data migration method for archival data storage which allow manufacturers storage systems that use DVD-R (ISO/IEC 23912:2005), DVD-RW (ISO/IEC 17342:2004), DVD-RAM (ISO/IEC 17592:2004), +R (ISO/IEC 17344:2006 and ISO/IEC 25434:2007), and +RW (ISO/IEC 17341:2006 and ISO/IEC 26925:2006) disks for information storage to classify disk longevity potential on the basis of initial performance requirements and to allow users to monitor continuing conformance with the error limits required for its class identified by the manufacturer of the drive/disk. Digital data can be migrated to a next new disk without loss from the present disk as far as the data errors are completely corrected before and during the migration and the copy of the data is allowed.

The methodology for data migration does not apply to disks with short archival storage time but to disks with long archival storage time. Disks with shorter archival storage time have more rapid degradation and require more frequent periodical tests. In addition, degradation of recorded data has a complex failure mechanism. Archival storage time, therefore, varies depending not only on temperature and humidity but also on many other effects, such as exposure to light, corrosive gases, contaminations, handling, and variation in playback subsystems. Consequently, severer storage environment requires more frequent periodical tests. Frequency of periodical tests is based on the quality of the disks for storing data and the storage environment.

2 Normative references

The following referenced documents 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 10995:2008 *Information technology — Digitally recorded media for information interchange and storage — Test method for the estimation of the archival lifetime of optical media*

ISO/IEC 16448:2002 *Information technology — 120 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)*

3 Terms and definitions

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

3.1
archival
having ability of a medium or system to maintain the retrievability of recorded information for a specified extended period of years

3.2
BER max
maximum byte error rate at any consecutive 32 ECC blocks on a disk as measured in the first pass of the decoder before correction

3.3
data migration
process to copy data from one storage device or medium to another

3.4
error correction code
ECC
mathematical computation yielding check bytes used for the detection and correction of errors in data

NOTE For DVD-R, DVD-RW, DVD-RAM, +R, and +RW disks, the Reed-Solomon product code defined in ISO/IEC 16448:2002 for DVD-ROM systems is applied.

3.5
error rate
rate of errors on the recorded disk measured before error correction is applied

3.6
initial performance test
test of the recording performance of data recorded on a disk before storing

3.7
life expectancy
estimated lifetime

3.8
lifetime
time that information is retrievable in a system

3.9
PIE SUM 8 max
maximum inner parity error at any consecutive 8 ECC blocks on a disk as measured in the first pass of the decoder before correction

NOTE See ISO/IEC 16448:2002, ISO/IEC 23912:2005, ISO/IEC 17341:2005, ISO/IEC 17342:2004 and ISO/IEC 17344:2006.

3.10
periodical performance test
periodical test of the recording performance of data recorded on a disk during the storage

3.11
retrievability
ability to recover physical information as recorded

3.12
stress
temperature and relative humidity variables to which the recorded disk is exposed for the duration of test intervals

3.13
storage time
time that a disk is being stored since data is recorded on the disk

3.14
substrate
transparent layer of the disk, provided for mechanical support of the recording or recorded layer, through which the optical beam accesses the recordable / recorded layer

3.15
system
combination of hardware, software, storage medium and documentation used to record, retrieve and reproduce information

3.16
uncorrectable error
error in the playback data that could not be corrected by the error correcting decoders

4 Test methods

4.1 Test parameters

For DVD-R, DVD-RW, +R, and +RW disks, the maximum inner parity error shall be measured at any consecutive 8 ECC blocks (PIE SUM 8 max) in the first pass of the decoder before correction.

For a DVD-RAM disk, the maximum Byte error rate (BER max) shall be measured (see Annex C).

The objective of this test method is to establish a practical estimation of the retrievability of the recorded data on a disk without producing uncorrectable errors, in response to time at controlled stress conditions to produce accelerated aging.

In this case, measuring the PIE SUM 8 max or the BER max is principal method to estimate actual retrievability of a disk instead of measuring other parameters to confirm the disk quality specified in each specifications.

4.2 Test Drive

Test drive shall comply with ISO/IEC 16448 for DVD-R, DVD-RW, +R, and +R disks and ISO/IEC 17592 for DVD-RAM disk or shall be equivalent. It shall have capability to measure the PIE SUM 8 max for DVD-R, DVD-RW, +R, and +RW disks and the BER max for a DVD-RAM disk, respectively.

4.2.1 Test drive calibration

The test drive shall be calibrated by using a calibration disk prepared by the test drive manufacturer based on the calibration procedure defined by the manufacturer. The calibration shall be done at the intervals recommended by the manufacturer.

4.2.2 Test preparation

Prior to conducting tests, the disks shall be visually examined to determine whether it contains dust, finger prints, or other contaminants. If appropriate, such contaminants shall be removed in accordance with the disk manufacturer's recommendations. Certain options are contained in Annex A. Microscopic examination may reveal physical deterioration, such as delamination and porosity of the protective coating.

4.2.3 Test execution

Before testing disks, the test drive shall be verified by checking the calibration disk supplied with the test drive or publicly verified. If the drive passes the calibration check, the disk to be checked shall be tested by the test drive.

Test results shall be judged by the PIE SUM 8 max for DVD-R, DVD-RW, +R, and +RW disks or the BER max for a DVD-RAM disk.

4.3 Test area

The entire recorded area of all the disks should be tested in order to confirm the readability of the data (see Annex E).

5 Test result evaluation

5.1 Initial performance test result evaluation

When data is recorded on disks, the initial recording performance on the whole recorded area shall be checked. The initial recording performance is categorized in Level 1, 2 and 3 by PIE SUM 8 max for DVD-R, DVD-RW, +R, and +RW disks and BER max for DVD-RAM as shown in Table 1 (see Annex C).

At least, the initial recording performance shall be within Level 1. Disks showing the initial recording performance of Level 2 should not be used for archival use and those of Level 3 are out of the specification and shall not be used.

If the initial recording performance is worse than Level 1, the performance of the disk and drive used for recording the data should be verified because PIE SUM 8 max and BER max depend both on the performance of disks and drives. If the drive is not good, the drive should be replaced. If the disk is not good, another lot of disks should be used.

Table 1 — Category of initial recording performance

Level	Status	DVD-R, DVD-RW, +R, +RW	DVD-RAM
1	Recommended	< 140	$< 5{,}0X10^{-4}$
2	Should not be used	140 – 280	$5{,}0X10^{-4} – 1{,}0X10^{-3}$
3	Shall not be used	> 280	$> 1{,}0X10^{-3}$
Recording performance indicator		PIE SUM 8 max	BER max

5.2 Periodical performance test result evaluation

Disks used for storing data should be periodically checked with the test frequency described in Clause 6. The recording performance at the periodical performance test is categorized in Level 4, 5 and 6 by PIE SUM 8 max for DVD-R, DVD-RW, +R, and +RW disks and BER max for DVD-RAM as shown in Table 2 (see Annex C).

If the recording performance is within Level 4, the performance of the disk is good enough to be continuously used.

If the recording performance is within Level 5, the data stored on the disk shall be migrated to another disk as soon as possible.

If the recording performance is in Level 6, the data stored on the disk shall be copied to another disk immediately as far as the data can be retrieved, Please note that PIE SUM 8 max and BER max higher in Level 6 may disable to retrieve the data due to uncorrectable errors.

Data migration flow for the initial performance test and periodical performance test is shown in Figure 1.

Table 2 — Category of recording performance at periodical performance test

Level	Status	DVD-R, DVD-RW, +R, +RW	DVD-RAM
4	Use as it is	< 200	$< 7{,}1X10^{-4}$
5	Migrate data as soon as possible	200 – 280	$7{,}1X10^{-4} – 1{,}0X10^{-3}$
6	Migrate data immediately	> 280	$> 1{,}0X10^{-3}$
Recording performance indicator		PIE SUM 8 max	BER max

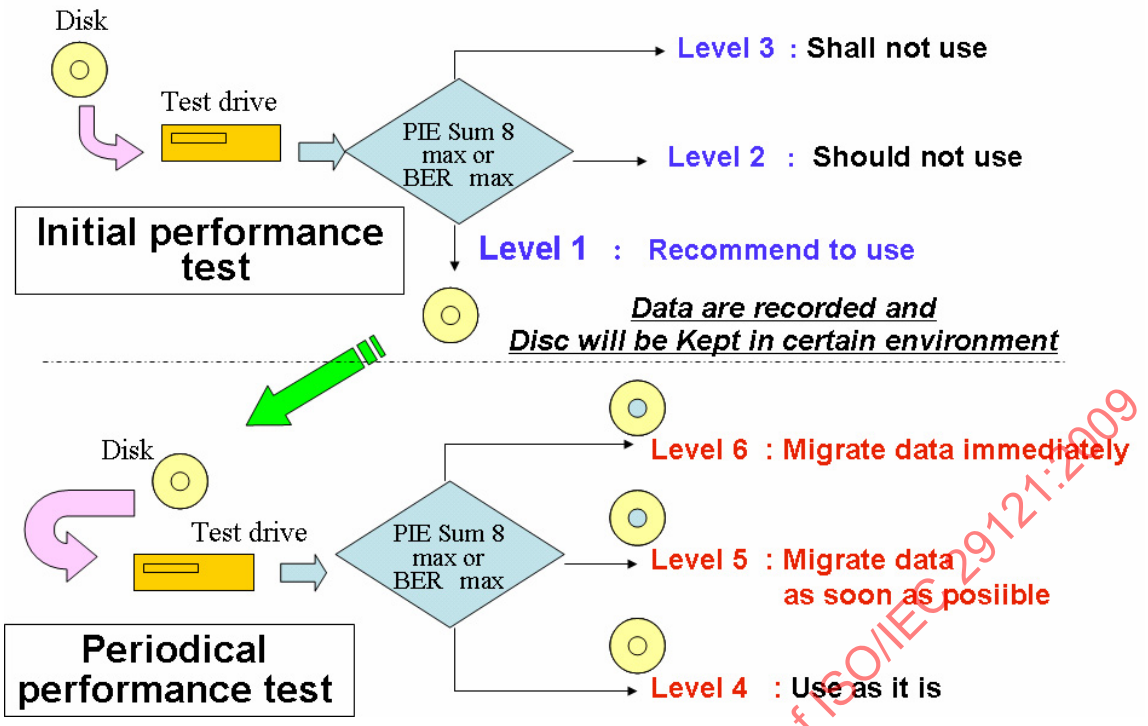

Figure 1 — Data migration flow for DVD-R, DVD-RW, DVD-RAM, +R, and +RW disks

6 Test frequency

Disks should be checked every three years or less. If the disk has the life expectancy at the storage condition and the total storage time is close to the life expectancy, it is preferable that the disk should be treated as in Level 5 and the corresponding action should be taken.

Disks having characteristics well that are stored under conditions described in Annex B, are carefully handled, and are read infrequently may require testing only every few years. A history of satisfactory longevity with similar disks would encourage longer intervals between testing.

The occurrence of retrievability problems or long read times may indicate a need for immediate testing.

When tests indicate deterioration of one disk, additional tests may be performed on other disks of the same type, age, or lot to ascertain their condition. Replacement of all similarly affected disks should be considered if such additional tests indicate significant problems.

7 Prevention of deterioration

Necessary precautions shall be taken to reduce the possibility of deterioration, in order to assure the integrity of the disks during their use, storage, handling, or transportation. Causes of deterioration and their effects are noted in Annex A. For long-term storage, the recommendations in Annex B should be implemented.

Disks intended for long-term storage should not be left in readers, nor remain exposed to light, dust, or to extremes of temperature or humidity.

Annex A
(informative)

Causes of deterioration for DVD-R, DVD-RW, DVD-RAM, +R, and +RW disks

A.1 Deterioration

DVD-R, DVD-RW, DVD-RAM, +R, and +RW disks are composed of recording layer and reflective layer. Deterioration of the recording and reflective layers may happen in the following environments;

- store in high temperature and/or high humidity
- store under sun light or UV light
- store in high density of corrosive gas (hydrogen sulfide, etc.)
- store in fluctuating environments (temperature change, humidity change, etc.)

In addition, laser incident surface may be damaged or contaminated during use.

A.2 Disk structure

DVD-R, DVD-RW, DVD-RAM, +R, and +RW disks comprise a recording substrate covered with recording layer and reflective layer bonded to a dummy substrate for a single sided disk or another recording substrate for a double sided disk. Tilt of the two substrates is controlled to minimise distortions associated with changes in ambient conditions. The adhesive material selected for the bonding of the two disks is selected to minimise stresses from the bonding process.

DVD-R and +R disks adopt organic dye recording layer, whereas DVD-RAM, DVD-RW and +RW disks adopt inorganic phase change recording layer.

A.3 Causes of deterioration

Recording layer and reflective layer may deteriorate during long term storage in extreme environment as indicated in A.1 above.

Recording layer may be deteriorated by corrosion, crack, decomposition, etc. As a result, reflectivity and recording signals are deteriorated. Recorded marks may be also deformed during long term storage in such an extreme environment. For phase change disks, a part of amorphous recorded marks may be crystallized and the recorded marks may shrink. For dye disks, recorded marks are made by fading of dye material and deformation of recording layer. The deformation of the recording layer may be relaxed and signal modulation decreases.

Reflective layer may be deteriorated by corrosion, crack, decomposition, etc. As a result, reflectivity and recording signals are deteriorated.

As with all optical disks, small defects are allowed at the time of manufacture. Over a long period of time under extreme environmental exposure these defects may grow. The growth of these defects as well as the deterioration of recording layer and reflective layer as mentioned above can be shown to follow Arrhenius laws and this method can be used to confirm the predicted lifetime of DVD-R, DVD-RW, DVD-RAM, +R, and +RW

disks. The residual error correction capability referred to in section 5.2 is designed to ensure that data is still readable throughout the expected life of the disks.

Storage in fluctuating environments may deteriorate mechanical property, such as tilt, axial and radial runnout.

The damage or contamination on laser incident surface can obscure the recording layer and create dropouts in the data. Additionally, particulate damage or contamination may cause transients in the servo signals used by the drive to maintain focus and tracking to the required accuracy. One of the most frequent causes of uncontrolled contamination is the casual cleaning of disks using unapproved materials and procedures. Cleaning of disks should only be carried out in accordance with the procedures contained in Annex B.

A.4 Nature of deterioration

The operating environment will determine the nature of the deterioration. In the case of disks used in a library this environment is well controlled, however, operation of disks in stand-alone drives will potentially subject the disks to a wider range of contamination and environmental extremes. In particular, disks left in uncontrolled storage may be subject to physical abuse or contamination in contravention of manufacturers' recommendations.

A.5 Effects of deterioration

The combination of beam obscuration and possible disturbance to the servo signals will be to generate a dropout in the data reaching the decoder. While the error correction code has a very high burst correction capability (greater than 6 mm), a large dust particle may cause this capability to be exceeded.

Annex B
(informative)

Recommendations on handling, storage and cleaning conditions for DVD-R, DVD-RW, DVD-RAM, +R, and +RW disks

B.1 Handling

The fragile protective coating on the label surface is vulnerable to damage and must be protected together with the readout surface. Carefully handle the disk, touching only the outer edge and inner hole. Never touch readout surface.

Disks must be protected from dust and debris. This is especially important for recordable and rewritable disks during the recording process. The use of a deionizing environment is recommended to neutralize static charges on the disk that can attract and retain loose contaminants.

B.2 Storage

For general storage such as in an office environment, it is recommended to limit the storage environment to the ranges given in Table B.1.

Table B.1 — Recommended conditions for general storage

Ambient Condition	Recommended Range
Temperature	5º C to 30º C
Relative humidity	15% to 80%
Absolute humidity	1 g/m^3 to 24 g/m^3
Atmospheric pressure	75 kPa to 106 kPa
Temperature gradient	10ºC per hour maximum
Relative humidity gradient	10% per hour maximum

If long-term storage is desired, the storage conditions should be more tightly controlled and it is recommended to limit the storage environment to the ranges given in Table B.2.

Table B.2 — Recommended conditions for controlled storage

Ambient Condition	Recommended Range
Temperature	10º C to 25º C
Relative humidity	40% to 60%
Absolute humidity	1 g/m^3 to 14 g/m^3
Atmospheric pressure	75 kPa to 106 kPa
Temperature gradient	10ºC per hour maximum
Relative humidity gradient	10% per hour maximum

There shall be no condensation of moisture on the disk. Cool and dry archival storage is preferred. To maintain the desirable temperature and humidity fluctuation tolerance levels, and to protect against high intensity light and pollutants, archival storage of DVD-R, DVD-RW, DVD-RAM, +R, and +RW disks in clean insulated records containers is suggested. Dust or debris in operational or storage locations should be minimized by appropriate maintenance and monitoring procedures, especially when recording disks.

B.3 Cleaning

Prior to performing cleaning operations of disks containing useful data, tests should be carried out on disks of the same type and from the same supplier that do not contain any useful data, in order to ensure that no adverse reaction will occur.

Loose contaminants may be removed by short, one second bursts of clean, dry air, avoiding expulsion of cold propellants. If the manufacturer has not supplied any cleaning information, organic polymer substrate disks can be cleaned using a lint-free cloth of a non-woven fabric and either clean or soapy water. Do not use detergents or solvents such as alcohol. All wiping actions should be in a radial direction, taking care not to exert isolated pressure or to scratch the disks. Never use abrasives. Do not use acrylic liquids, waxes, or other coatings on either surface.

Annex C
(informative)

Relation between BER and PIE SUM 8

The byte error rate BER is the number of erroneous bytes divided by the total number of bytes. Because the length of one code word of the inner code is 182, probability of erroneous inner code word N_{pi} can be expressed by binomial probability on the assumption that errors occur at random, and it is

$$N_{pi} = \sum_{i=1}^{182} {}_{182}C_i \times p^i \times (1-p)^{182-i} \quad (1)$$

The number of PI errors in 8 ECC blocks N_{pis8} can be expressed by formula (2) because the length of the outer code word is 208, as shown in Figure C.1.

$$N_{pis8} = 208 \times 8 \times N_{pi} \quad (2)$$

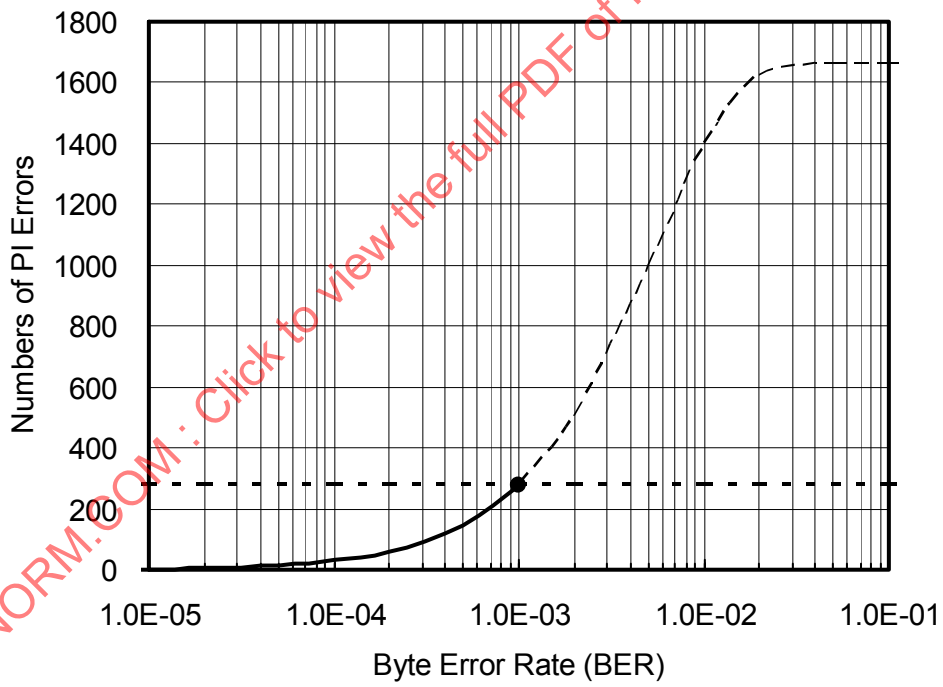

Figure C.1 — Relationship between BER and PIE SUM 8