Standard ECMA-413

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Data migration method for BD recordable and BD rewritable disks

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Introduction

In 2013, International Standards for physical formats of BD recordable and BD rewritable disks (ISO/IEC 30190, 30191, 30192 and 30193) were published.

To include the test method for the estimation of lifetime of BD recordable and BD rewritable disks, ECMA-396 2nd Edition and ISO/IEC 16963 2nd Edition were published in 2014 and 2015 respectively.

As BD recordable and BD rewritable disks have large capacity and are excellent in long-term data preservation, they have been spreading widely as data storage for long-term data preservation in personal and professional usage. And the data migration method for BD recordable and BD rewritable disks is being required.

The purpose of this Ecma Standard is to specify the data migration method for BD recordable and BD rewritable disks.

This 4th Edition of ECMA-413 is harmonized with ISO/IEC 29121 4th Edition[1]. It includes the following changes from the previous edition:

- the ambient conditions for the measurement of maximum data error have been added;
- the requirements for test drives have been changed considering the use condition of users;
- the requirements for the estimated lifetime have been defined more clearly;
- the requirements for the periodic performance test have been defined more clearly;
- the migration interval determined by the user, X_{mig} interval, has been introduced.

This Ecma Standard was developed by Technical Committee 31 and was adopted by the General Assembly of June 2022.

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Data migration method for BD recordable and BD rewritable disks

1 Scope

This Ecma Standard specifies the data migration method which can sustain the recorded data on BD recordable and BD rewritable disks for long-term data preservation.

This Ecma Standard includes:

- a data migration method of BD recordable and BD rewritable disks for long-tern data preservation;
- test methods for an initial performance test and a periodic performance test, including ambient condition, test area, test interval, test drive, test preparation, and test execution; and
- test result evaluation in the initial performance test and the periodic performance test.

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.

ECMA-396:2017 *Test Method for the Estimation of Lifetime of Optical Disks for Long-term Data Storage* (ISO/IEC 16963:2017)

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*

3 Terms and definitions

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

3.1
B_{mig} life
lifetime (3.12) for use of *data migration* (3.6) and identical as $B_{0.000\,1}$ life which is 0,000 001 quantile of the *lifetime* (3.12) distribution (i.e. 0,000 1 % failure time) or 99,999 9 % survival lifetime

NOTE See Annex A.

3.2
***B_5* life**
5 percentile of the *lifetime* (3.12) distribution (i.e. 5 % failure time) or 95 % survival lifetime

[SOURCE: ECMA-396:2017, 3.4]

3.3
(*B_5* life)$_L$
95 % lower confidence bound of *B_5 life* (3.2)

[SOURCE: ECMA-396:2017, 3.5]

3.4
***B_{50}* life**
50 percentile of the *lifetime* (3.12) distribution (i.e. 50 % failure time) or 50 % survival lifetime

[SOURCE: ECMA-396:2017, 3.6]

3.5
controlled storage-condition
well-controlled storage conditions with full-time air conditioning (25 °C and 50 % relative humidity), which can extend the *lifetime* (3.12) of data stored on optical disks

[SOURCE: ECMA-396:2017, 3.7]

3.6
data migration
process to copy data from one storage device or medium to another

3.7
error correction code
ECC
mathematical computation yielding check bytes used for the detection and correction of errors in data

NOTE An LDC+BIS code is applied to BD recordable and BD rewritable disks. See ISO/IEC 30190, ISO/IEC 30191, ISO/IEC 30192, and ISO/IEC 30193.

3.8
error rate
rate of errors or error count measured on the signal at the input of error-correction decoder, which represents raw-error rate of data recorded on a disk

3.9
Eyring method
accelerated-aging model based on the combined effects of temperature and relative humidity

[SOURCE: ECMA-396:2017, 3.8]

3.10
harsh storage-condition
most-severe conditions in which users handle and store the optical disks (30 °C and 80 % RH) under which the *lifetime* (3.12) of data stored on optical disks can be reduced

[SOURCE: ECMA-396:2017, 3.10]

3.11
initial performance test
first test of the *error rate* (3.8) of data recorded on a disk before storing

3.12
lifetime
time that information is retrievable in a *system* (3.17)

3.13
maximum random symbol error rate
$RSER_{max}$
greatest level of random symbol error rate (RSER) measured on the signal in one of the relevant areas on a disk at the input of error-correction decoder, which excludes burst errors of length greater than or equal to 40 bytes

NOTE 1 See ECMA-396, ISO/IEC 30190, ISO/IEC 30191, ISO/IEC 30192, and ISO/IEC 30193.

NOTE 2 Each RSER for measuring RSERmax shall be averaged over any 10 000 consecutive LDC blocks with the condition that all blocks are recorded in a continuously written sequence or in a discontinuously written sequence excluding disk defects.

3.14
periodic performance test
periodic test of the *error rate* (3.8) of data recorded on a disk during the storage

3.15
retrievability
ability to recover information as recorded

[SOURCE: ECMA-396:2017, 3.14]

3.16
substrate
layer which may be transparent or not, provided for the mechanical support of the recording layer(s)

NOTE See ISO/IEC 30190, ISO/IEC 30191, ISO/IEC 30192, and ISO/IEC 30193.

3.17
system
combination of hardware, software, storage medium, and documentation used to record, retrieve, and reproduce information

[SOURCE: ECMA-396:2017, 3.20]

3.18
uncorrectable error
error in the read-out data that cannot be corrected by the error-correction decoders

3.19
X_{mig} interval
migration interval (year) which is determined by user

NOTE See Annex B.

4 Abbreviated terms

BIS burst-indicating subcode

ECC error correction code

LDC long-distance code

RSER random symbol error rate

5 Conformance

A BD recordable disk subject to this Ecma Standard shall conform to ISO/IEC 30190 or ISO/IEC 30191.

A BD rewritable disk subject to this Ecma Standard shall conform to ISO/IEC 30192 or ISO/IEC 30193.

6 Conventions and notations

6.1 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.

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 Ecma Standard are capitalized.

7 General

Information is physically recorded on a disk as digital data. Although it is inevitable to cause errors in the physical recording process, error correction technologies can retrieve the physically recorded information completely from the read-out raw data with acceptable errors. If the errors in the read-out raw data exceed the error correcting capability, some of information is lost and the original information cannot be retrieved. The main cause of the errors is the physical deterioration of a disk. The deterioration can be measured by monitoring the error rate, and the original information can be migrated to a new disk in advance of an appearance of uncorrectable errors. Using the data migration method described in this Ecma Standard, the physically recorded information can be stored without loss of the original information, then the retrievability is maintained for a long time.

In order to check the error rate of data recorded on a BD recordable or BD rewritable disk, the maximum random symbol error rate ($RSER_{max}$) shall be measured using a test drive. (see Annex C for additional information).

When data are recorded on a disk, the error rate shall be checked with the initial performance test. Depending on the test result of the initial performance test, the disk is judged to be used for long-term data preservation.

The error rate of data recorded on those disks shall be periodically checked in the storage duration with the periodic performance test unless the data are migrated to new disks before the first periodic performance test. Depending on the test result of the periodic performance test, the necessity of the data migration is judged.

In order to determine the test interval for the periodic performance test, $B_{\mathbf{mig}}$ life (see 8.4 for detailed definition) is used. ECMA-396 specifies an accelerated aging test method for estimating the lifetime of the retrievability of information stored on recordable or rewritable optical disks including the BD recordable and BD rewritable disks. ECMA-396 offers $B_{\mathbf{50}}$ life and $B_{\mathbf{5}}$ life, and $B_{\mathbf{mig}}$ life is introduced using $B_{\mathbf{50}}$ life and $B_{\mathbf{5}}$ life (see Annex A for detailed definitions). ECMA-396 shall be the reference test method for the lifetime estimation of disks.

Users of this Ecma Standard can determine the migration interval (X_{mig} interval) (see Annex B for detailed specifications) with no relation to the estimated lifetime of the disk. In case the X_{mig} interval is introduced, follow the procedure defined in Annex B.

The data migration is carried out when the recording performance is judged insufficient to continue to be used in the periodic performance test. However, if generational changes of the system, including reading devices, the file structures, and applications, occur during the storage, it might be easy to retrieve the stored data no longer. Or, if the stored data have high value or worth, some users might like to migrate after a shorter interval for safety. In consideration of such as these factors, the migration interval, irrespective of the recording performance, may be determined by the user.

8 Test methods

8.1 General

In the initial performance test and the periodic performance tests, $RSER_{max}$ shall be measured (see Annex C for additional information).

8.2 Ambient condition

The ambient condition is the surrounding condition in a room where a test drive is located. The ambient conditions for the initial performance test and the periodic performance test are as follows:

- temperature: 15 °C to 30 °C;

- relative humidity: 20 % to 75 %.

8.3 Test area and sample disk

The test area is the recorded area to be tested in a disk.

In the initial performance test, the entire recorded area of all the disks shall be tested in order to confirm the readability of the data.

In the periodic performance tests, the entire recorded area of all the disks should be tested in order to confirm the readability of the data. Although the integrity of the data becomes lower, the user may reduce the test area and/or the number of sample disks based on a certain sampling method, considering the value of information (see Annex D for additional information). For the reduction of test area, see ECMA-396:2017, 7.5, for additional information. The number of sample disks should be enough to guarantee statistical effectiveness. If the sample disks have different attributes such as disk standards, recording conditions or storage conditions, the disks should be divided into groups of disks considering the attributes so that the sampling can be applied on each group with the statistical effectiveness.

8.4 Test interval for periodic performance test

In order to determine the test interval for the periodic performance test, B_{mig} life is used.

B_{mig} life shall be calculated according to Annex A, and B_{50} life and B_5 life or B_{50} life and standard deviation, σ, shall be provided (see Clause 7). The test interval shall be determined according to Annex B.

In case B_{mig} life is not available as shown below, the test interval should be three years or less. Relaxation of the test interval causes the risk of data loss and failure in the data migration. In case such a risk is unacceptable, the test interval of three years or less is strongly recommended.

− The estimated lifetime data is not provided.

− The estimated lifetime data is provided but lacks the statistical accuracy.

The ambient storage-condition for the lifetime estimation should be the controlled storage-condition or the harsh storage-condition. The estimated lifetime is affected by the storage condition. If the actual storage-condition is far from the controlled storage-condition or the harsh storage-condition, the estimated lifetime may be adjusted (see Annex E for additional information).

Disks having well-defined characteristics that are stored under conditions described in Annex F 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.

NOTE See Annex G.

8.5 Test drive

8.5.1 General

The test drive shall have the capability to measure $RSER_{max}$.

The test drive shall have the capability to evaluate the error rate level specified in the initial performance test and the periodic performance test.

There are two cases of the test drive. One is that the drive serves both as a test drive and a recorder which records the data on the disk. The other is that the test drive is different from the recorder. For both cases, the data recorded on the disk by the recorder shall fulfil the error rate level specified in the initial performance test and the periodic performance test.

NOTE The measuring circuit for RSER described in ISO/IEC 30191 and ISO/IEC 30193 is different from that described in ISO/IEC 30190 and ISO/IEC 30192, especially in HF signal pre-processing circuit. See ISO/IEC 30190:2021, Annex H, and ISO/IEC 30191:2021, Annex H, for additional information.

8.5.2 Test drive check

The test drive shall be checked by using a reference disk prepared by the test drive manufacturer or the user, so that it fulfils the requirements in 8.5.1. When using the reference disk prepared by the test drive manufacturer, the check of the test drive shall be done at the interval recommended by the manufacturer. When using the disk prepared by the user, it is recommended that the check of the test drive is done at an appropriate interval set by the user.

8.6 Test preparation

Prior to conducting tests, the test drive shall be verified by the procedure defined in 8.5.2. If the drive does not pass the verification, the test drive shall not be used for the test.

The disks shall be visually examined to determine whether they contain dust, fingerprints, or other contaminants. If there are dust, fingerprints, or other contaminants and appropriate, such contaminants shall be removed in accordance with the disk-manufacturer’s recommendations. Certain options are contained in Annex G. Microscopic examination can reveal physical deterioration, such as delamination and porosity of the protective coating. Visual examination may be omitted for disks in cases with dedicated design.

NOTE See Annex G.

8.7 Test execution

The disk to be checked shall be tested by the test drive verified with the reference disk.

On testing disks, care handling of the disks shall be taken in order to avoid introducing unexpected defects (see Annex H for additional information). Test result evaluation

8.8 General

In the initial performance test and the periodic performance tests, the test results shall be judged by $RSER_{max}$.

8.9 Initial performance test result evaluation

The initial recording performance is categorized as Level 1, 2 and 3 by $RSER_{max}$ as shown in Table 1.

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

If the initial recording performance is worse than Level 1, the performance of the disk and test drive used for recording the data should be verified because $RSER_{max}$ depends on the performance of both disks and test drives. If the test drive has not the performance required, the test drive should be replaced. If the disk has not the performance required, another lot of disks should be used.

Table 1 — Category of initial recording performance

Level	Status	$RSER_{max}$
1	Recommended	$< 5,0 \times 10^{-4}$
2	Should not be used	$5,0 \times 10^{-4}$ to $1,0 \times 10^{-3}$
3	Shall not be used	$> 1,0 \times 10^{-3}$

8.10 Periodic performance test result evaluation

The recording performance at the periodic performance test is categorized as Level 4, 5 and 6 by $RSER_{max}$ as shown in Table 2.

If the recording performance is within Level 4, the disk is good enough to continue to be 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 $RSER_{max}$ in Level 6 is high enough to disable retrieval the data without uncorrectable errors.

Table 2 — Category of recording performance at periodic performance test

Level	Status	$RSER_{max}$
4	Use as it is	$< 7,1 \times 10^{-4}$
5	Migrate data as soon as possible	$7,1 \times 10^{-4}$ to $1,0 \times 10^{-3}$
6	Migrate data immediately	$> 1,0 \times 10^{-3}$

9 Prevention of deterioration

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

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

Annex A
(normative)

Calculation for B_{mig} life using B_{50} life and B_5 life

A.1 Optical disks for long-term data storage

A disk with a specified lifetime should be used for long-term data storage.

A.2 Lifetime estimation

The lifetime of a disk is derived from the measurements specified in ECMA-396. The Eyring method is used for lifetime estimation under the controlled storage-condition with 25 °C temperature and 50 % relative humidity.

In ECMA-396, the estimated lifetimes are defined variously as B_{50} life, B_5 life and the 95 % lower confidence bound of B_5 life (= (B_5 life)$_L$) and are described as Formulae (A.1) to (A.3).

$$B_{50\text{ life}} = \exp\left(\ln\hat{B}_{50}\right) = \exp\left(\hat{\beta}_0 + \hat{\beta}_1 x_{10} + \hat{\beta}_2 x_{20}\right), \quad (A.1)$$

$$B_{5\text{ life}} = \exp\left(\ln\hat{B}_5\right) = \exp\left(\hat{\beta}_0 + \hat{\beta}_1 x_{10} + \hat{\beta}_2 x_{20} - 1{,}64\hat{\sigma}\right), \quad (A.2)$$

$$B_{(5\text{ life})\mathrm{L}} = \exp\left[\left(\ln\hat{B}_5\right)_{\mathrm{L}}\right] = \exp\left[\ln\hat{B}_5 - 1{,}64\sqrt{\mathrm{var}\left(\ln\hat{B}_5\right)}\right]. \quad (A.3)$$

Where, $B_{50\text{ life}}$, $B_{5\text{ life}}$ and $B_{(5\text{ life})L}$ are the variables of B_{50} life, B_5 life and (B_5 life)$_L$ respectively. x_{10} and x_{20} are the temperature-dependent factor and the relative-humidity–dependent factor at the controlled storage-conditions. And $\hat{\beta}_0, \hat{\beta}_1, \hat{\beta}_2$ and estimated variance of residual errors $\hat{\sigma}$ are obtained using regression analysis of time-to-failure data.

A.3 B_{mig} life for long-term data storage

The estimated lifetime of B_5 life means 5 % of the products reaches failure. It is widely used in other contexts. However, from the viewpoint of the reliability of long-term storage to retain the integrity of the original data, it is not appropriate to use B_5 life as the estimated lifetime when determining a test interval and deciding on data migration.

BD recordable and BD rewritable disks adopt an inorganic phase-change recording layer. For some types of BD recordable disks an organic dye recording layer is also used instead of an inorganic phase-change recording layer.

In the case of data migration, it is necessary to have a sufficiently low failure probability. The time at which one millionth of the products reach failure is defined the estimated lifetime to determine test intervals and migration interval. $B_{0{,}000\,1}$ life is 0,000 001 quantile of the lifetime distribution (i.e. 0,000 1% failure time) and expressed as B_{mig} life. B_{mig} life can be calculated by using B_{50} life and B_5 life as Formulae (A.4) and (A.5):

$$B_{0{,}000\,1\text{ life}} = \exp\left(\ln\hat{B}_{0{,}000\,1}\right) = \exp\left(\ln\hat{B}_{50} - 4{,}75\hat{\sigma}\right) = \exp\left(\ln\hat{B}_{50} - 4{,}75\frac{\ln\hat{B}_{50} - \ln\hat{B}_5}{1{,}64}\right) \quad (A.4)$$

$$= \exp\left(2{,}9\ \ln\hat{B}_5 - 1{,}9\ \ln\hat{B}_{50}\right),$$

$$B_{\text{mig life}} = \frac{B_{0.000\ 1\ \text{life}}}{24 \times 365} = \frac{\exp\left(2{,}9\ \ln\hat{B}_5 - 1{,}9\ \ln\hat{B}_{50}\right)}{8\ 760}. \qquad \text{(A.5)}$$

Where, $B_{\mathbf{0,000\ 1\ life}}$ and $B_{\mathbf{mig\ life}}$ are the variables of $B_{\mathbf{0,000\ 1}}$ life and $B_{\mathbf{mig}}$ life in years.

In actual storage conditions, the temperature and relative humidity can deviate from the controlled storage-condition, which changes the estimated lifetime. In this case, the estimated lifetime should be adjusted according to the estimated lifetime at the actual storage conditions as specified in Annex E.

Annex B
(normative)

Guidelines for test interval and data migration

B.1 General

This annex describes guidelines for choosing the test interval and performing the data migration not only for disks whose lifetime is estimated and known, but also for disks whose lifetime is unknown.

According to this document, disks are periodically tested and when disks errors exceed the specified values in Table 2, data migration is carried out. Therefore, if the estimated lifetime of disks is long enough, the migration interval of disks can also be increased.

However, if generational changes of the system, including reading devices and/or the file structures and/or applications, occur during the migration interval, there is a possibility that the stored data are not easily retrieved. Moreover, if the stored data have high value, the user can prefer to migrate after a shorter interval for safety. In consideration of these factors as stated above, the migration interval is defined as X_{mig} interval (years) and this value is determined by the user of this Ecma Standard.

In Annex A, the estimated lifetime for test interval and data migration is defined as B_{mig} life (equals $B_{0,000\,1}$ life: 0,000 1 % failure time). Half of B_{mig} life or less shall be set as the test interval and the periodical performance test is carried out. After reaching B_{mig} life, in case the test result is equal to Level 4 in Table 2, the next test interval shall be set to three years or less. In this case, it is recommended to limit the test to twice.

If the test interval is long, it is recommended to carry out sampling check of the disks in appropriate timing.

B.2 Examples of test interval and data migration

The following are examples of the test intervals of the periodic performance tests and the data migration in five cases with different X_{mig} intervals.

Here, X_{mig} and $B_{mig\ life}$ are shown as the variables for X_{mig} interval and B_{mig} life in years, respectively.

In all cases, the initial performance test result is equal to Level 1 (recommended) in Table 1 (other than Level 1, the disk should not be used or shall not be used). And the periodic performance test result is equal to Level 4 (use as it is) in Table 2 (other than Level 4, the data migration is performed as soon as possible or immediately).

a) X_{mig} is less than or equal to $B_{mig\ life}/2$:

- The test interval of the first and only periodic performance test is set to X_{mig}. And the data migration is carried out at the first periodic performance test despite the test result.

b) X_{mig} is greater than $B_{mig\ life}/2$, and less than or equal to $B_{mig\ life}$:

- The test interval of the first periodic performance test is set to $B_{mig\ life}/2$.

- The test interval of the second periodic performance test is set to X_{mig} - $B_{mig\ life}/2$. And the data migration is carried out at the second periodic performance test despite the test result.

c) X_{mig} is greater than $B_{mig\ life}$, and less than or equal to $B_{mig\ life}$ + 3:

- The test interval of the first and second periodic performance tests is set to $B_{mig\ life}/2$.

- The test interval of the third periodic performance test is set to $X_{\mathbf{mig}}$ - 2 × $B_{\mathbf{mig\ life}}$/2. And the data migration is carried out at the third periodic performance test despite the test result.

d) $X_{\mathbf{mig}}$ is greater than $B_{\mathbf{mig\ life}}$ + 3, and less than or equal to $B_{\mathbf{mig\ life}}$ + 2 × 3:

- The test interval of the first and second periodic performance tests is set to $B_{\mathbf{mig\ life}}$/2.

- The test interval of the third periodic performance test is set to three years.

- The test interval of the fourth periodic performance test is set to $X_{\mathbf{mig}}$ - 2 × $B_{\mathbf{mig\ life}}$/2 - 3. And the data migration is carried out at the fourth periodic performance test despite the test result.

e) $X_{\mathbf{mig}}$ is greater than $B_{\mathbf{mig\ life}}$ + 2 × 3:

- The test interval of the first and second periodic performance tests is set to $B_{\mathbf{mig\ life}}$/2.

- The test interval of the third and fourth periodic performance tests is set to three years. And the data migration is carried out at the fourth periodic performance test despite the test result.

B.3 Specific calculation examples

Case 1

In case the $B_{\mathbf{mig}}$ life of the disk is equal to 20 years, the $\mathrm{X}_{\mathbf{mig}}$ interval is set to 25 years. This case corresponds to d) in B.2.

- Suppose the test result of the initial performance test is equal to Level 1.
- The test interval of the first periodic performance test is 10 years. Suppose the test result is Level 4.
- The test interval of the second periodic performance test is also 10 years. Suppose the test result is Level 4.
- The test interval of the third periodic performance test is three years. Suppose the test result is Level 4.
- The test interval of the fourth periodic performance test is two years. And the data migration is carried out in spite of the test result of this periodic performance test.

Case 2

In case the $B_{\mathbf{mig}}$ life of the disk is equal to 50 years, the $\mathrm{X}_{\mathbf{mig}}$ interval is set to 25 years. This case corresponds to a) in B.2.

- Suppose the test result of the initial performance test is equal to Level 1.
- The test interval of the first and only periodic performance test is 25 years. And the data migration is carried out in spite of the test result of this periodic performance test.

Annex C
(informative)

$RSER_{max}$ criteria for BD recordable and BD rewritable disks

ECMA-396 adopts the $RSER_{max}$ value of 10^{-3} for evaluating the time-to-failure in accelerated stress testing of BD recordable and BD rewritable disks. The ECC used for BD recordable and BD rewritable disks is powerful enough and has better error-correction capability than that of DVD at RSER = 10^{-3} [2][3]. Therefore, the $RSER_{max}$ value of 10^{-3} is adopted as the criteria of Level 3 and 6.

RSER excludes burst errors of length ≥ 40 bytes. But it is still affected by bursts shorter than 40 bytes.

If the RSER increases unexpectedly (especially near the outer edge of disk), it is recommended to wipe off any dust or fingerprints and re-measure the RSER.

NOTE See Annex H.

Annex D
(informative)

Test area and sample disk for periodic performance test

The entire recorded area of all the disks should be tested in order to confirm the readability of the data. Because disks should have uniform recording performance over the whole recording area, periodic tests of partial recording areas can suggest the average degradation of the recording surface, which obeys the Eyring acceleration model or Arrhenius acceleration model. However, local degradation caused by defects, etc. might not be detected by the partial test. Consequently, the test of the entire recorded area of all disks or all disks in all groups is recommended for important information.

Although the integrity of the data becomes lower as the testing area is reduced, the user can want to reduce the test area and the number of the disks to be tested according to the value of information and the number of the disks to be tested.

Generally, the integrity of the data will be proportional to the percentage of the test area because of defective, uncertain, or unpredictable behaviour of data errors, unless the quality or property of the recorded or stored data on the entire disk are known. But the integrity of the data will be improved even by the partial test when some effective information reduces uncertainty or entropy.

If the time-to-failure to be used for the lifetime estimation has other than a lognormal distribution, appropriate statistical estimation is required based on the distribution.

NOTE The above estimation cannot be applied to the time-to-failure originated by local defects.

Annex E
(informative)

Guideline for adjustment of the estimated lifetime to higher stress conditions

In actual storage conditions, the temperature and relative humidity can deviate from the controlled storage-condition with 25 °C temperature and 50 % relative humidity, which changes the estimated lifetime. In this case, the estimated lifetime at the controlled storage-condition should be adjusted to the estimated lifetime at the actual storage conditions as described below.

The estimated lifetime B_5 life, based on the Eyring method, is derived in Formula (A.2).

If the storage temperature and relative humidity differ from the controlled storage-conditions, B_5 life is replaced with B_5 life$_{(m,n)}$, expressed by Formula (E.1), where m and n denote numerals representing the temperature and the relative humidity respectively.

x_{1m} and x_{2n} represent the temperature-dependent factor at temperature m and the relative-humidity–dependent factor at relative humidity, n, respectively in Formulae (E.1) and (E.2).

B_5 life in Formula (A.2) is also described as B_5 life$_{(0,0)}$ in this annex, applying Formula (E.1):

$$B_{5\ \mathrm{life},(m,n)} = \exp\left(\hat{\beta}_0 + \hat{\beta}_1 x_{1m} + \hat{\beta}_2 x_{2n} - 1{,}64\hat{\sigma}\right). \quad \text{(E.1)}$$

Then, the adjustment coefficients normalized by B_5 life ($A_{\mathrm{d}(m,n)} = B_{5\ \mathrm{life},\ (m,n)}/B_{5\ \mathrm{life}}$) are derived using Formula (E.2):

$$A_{\mathrm{d}(m,n)} = \frac{\exp\left(\hat{\beta}_0 + \hat{\beta}_1 x_{1m} + \hat{\beta}_2 x_{2n} - 1{,}64\hat{\sigma}\right)}{\exp\left(\hat{\beta}_0 + \hat{\beta}_1 x_{10} + \hat{\beta}_2 x_{20} - 1{,}64\hat{\sigma}\right)} = \exp\left[\hat{\beta}_1(x_{1m} - x_{10}) + \hat{\beta}_2(x_{2n} - x_{20})\right]. \quad \text{(E.2)}$$

Corresponding to ECMA-396, an example computation of the adjustment coefficients, $A_{\mathrm{d}(m,n)}$, for the estimated lifetime, B_5 life (Year) (B_5 life/24/365), is shown in Table E.1. It is calculated by changing the temperature from 25 °C to 30 °C in unit of 1 °C and the relative humidity from 50 % to 80 % in units of 5 %, under the condition that B_{50} life (Year) at the controlled storage-condition is 1 110 years and B_5 life (Year) is 893 years.

Table E.1 shows that the estimated lifetime shortens abruptly when the storage conditions of temperature and relative humidity become more severe than the controlled storage-condition even in the recommended conditions for general storage shown in Table F.1. For example, the estimated lifetime at storage conditions, the temperature and relative humidity of the harsh storage-condition with 30 °C temperature and 80 % relative humidity shortens by about 1/6 compared with that of the controlled storage-condition. Therefore, careful consideration should be given to the actual storage conditions.

In addition, in order to calculate the adjustment coefficients for a disk, the estimated lifetime of the population to which the disk belongs and the estimation values of the coefficients based on the Eyring method are needed. Except for the case where life estimation using ECMA-396 is performed, it is recommended to inquire of the disk manufacturer as to the adjustment coefficients of the disk.

Table E.1 — Adjustment coefficients for the estimated lifetime

Temperature (*m*) \ Relative humidity (*n*)		0	1	2	3	4	5	6
		50 %	55 %	60 %	65 %	70 %	75 %	80 %
0	25 °C	1,00	0,86	0,74	0,64	0,55	0,47	0,41
1	26 °C	0,84	0,72	0,62	0,54	0,46	0,40	0,34
2	27 °C	0,70	0,61	0,52	0,45	0,39	0,33	0,29
3	28 °C	0,59	0,51	0,44	0,38	0,33	0,28	0,24
4	29 °C	0,50	0,43	0,37	0,32	0,27	0,24	0,20
5	30 °C	0,42	0,36	0,31	0,27	0,23	0,20	0,17

NOTE This is an example calculated by using the test data of ECMA-396:2017, Annex B

Annex F
(informative)

Recommendations on handling, storage and cleaning conditions for optical disks for long-term data storage

F.1 Handling

The fragile protective coating on the label surface is vulnerable to damage and should be protected together with the readout surface. It is recommended to handle the disk carefully, touching only the outer edge and inner hole. It is strongly recommended not to touch the readout surface.

Disks should 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.

F.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 F.1.

Table F.1 — Recommended conditions for general storage

Ambient condition	Recommended range
Temperature	5 ºC to 30 ºC
Relative humidity	15 % to 80 %
Absolute humidity	1 g/m³ to 24 g/m³
Atmospheric pressure	75 kPa to 106 kPa
Temperature gradient	10 °C 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 F.2.

Table F.2 — Recommended conditions for controlled storage

Ambient condition	Recommended range
Temperature	10 ºC to 25 ºC
Relative humidity	30 % to 50 %
Absolute humidity	3 g/m³ to 12 g/m³
Atmospheric pressure	75 kPa to 106 kPa
Temperature gradient	10 ºC per hour maximum
Relative humidity gradient	10 % per hour maximum

There should be no condensation of moisture on the disk. Cool and dry storage condition is preferred. To maintain the desirable temperature and humidity fluctuation tolerance levels, and to protect against high intensity light and pollutants, storage of optical disks for long term data storage 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.

F.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 can be removed by short, one second bursts of clean, dry air, avoiding expulsion of cold propellants. Even 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. It is recommended not to 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. It is strongly recommended not to use abrasives. It is recommended not to use acrylic liquids, waxes, or other coatings on either surface.

Annex G
(informative)

Causes of deterioration for optical disks for long-term data storage

G.1 Deterioration

Optical disks for long-term data storage are composed of recording layers and reflective layers. Deterioration of the recording and reflective layers can occur in the following environments;

−storage at high temperature and/or high humidity

−storage under sun light or UV light

−storage in a high density of corrosive gases (hydrogen sulphide, etc.)

−storage in fluctuating environments (temperature change, humidity change, etc.)

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

This deterioration will increase the error rate of disks.

G.2 Disk structure

BD recordable triple layer double-sided disk comprises two recording substrates bounded with each other. Otherwise, BD recordable and BD rewritable disks comprise a recording substrate. The recording substrate is covered with recording, reflective and over-coating resin layers.

BD recordable and BD rewritable disks adopt an inorganic phase-change recording layer. For some types of BD recordable disks an organic dye recording layer is also used instead of an inorganic phase-change recording layer.

G.3 Causes of deterioration

Recording and reflective layers can deteriorate during long-term storage in an extreme environment, as indicated in G.1 above.

Recording layers can be degraded by corrosion, cracking, decomposition, etc. As a result, reflectivity and quality of recording signals are degraded. Recorded marks can also be deformed during long-term storage in such an extreme environment. In the case of phase-change disks, amorphous recorded marks can be partially crystallized at random, and then fluctuations of the rim and change of the reflectivity of each mark can occur. Those phenomena result in reduction of the signal modulation or increase in the jitter noise. In the case of dye-type disks, a recorded mark is formed with a change in refractive index of the dye material or with physical deformation of the substrate material. On receiving environmental stress, discoloring of the dye material or a relaxation of the physical deformation can occur. Those phenomena also result in the reduction of signal modulation or an increase in jitter noise.

Reflective layers can be degraded by corrosion, cracking, decomposition, etc. As a result, reflectivity and the quality of recording signals are degraded.

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 can grow. The growth of defects as well as the deterioration of recording and reflective layers as mentioned above can be shown to follow Arrhenius laws and this method can be used to confirm the predicted lifetime of optical disks for long term data storage.

Storage in fluctuating environments can also degrade mechanical property, such as tilt, and axial or radial runout.

Damage or contamination on laser-incident surface can obscure the recording layer and create dropouts in the data. Additionally, particulate damage or contamination can 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 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 F.

G.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 can be subject to physical abuse or contamination in contravention of manufacturers' recommendations.

G.5 Effects of deterioration

The combination of beam obscuration and possible disturbance of the servo signals will be to generate a dropout in the data reaching the decoder. While the ECC has a very high burst correction capability, a large dust particle can cause this capability to be exceeded.

G.6 Unexpected deterioration

For protection from unexpected serious deterioration of the disks, it is recommended to have a backup system for the long-term data storage according to the characteristics and importance of the data.

Annex H
(informative)

Guideline for treatment of defects

When measuring disks, manual handling of disks is inevitable. In order to avoid introducing defects, it is important to take care not to leave fingerprints on the surface of disks, especially before recording initial data.

If a defect that cannot be removed such as a scratch is found, it is recommended to check the burst error if possible to make sure the data in a disk not to be uncorrectable in future.

It can be difficult to measure the burst errors of those disks for a commercially-available drive and may need to arrange a professional disk tester.

As a basic understanding of the specification value of defects in each standard of the optical disk for long-term data storage, it is not the critical value for error-correction ability but the value required for the disk on shipping and some allowance is kept for additional defects caused in actual use after shipping such as scratches, dust or fingerprints. Thus, the critical value for the burst errors to check the data retrievability should be set to larger than the specification value and assumed to be less than two times of it.

In the occasion of the initial performance test, if the burst error exceeds the following level, it is recommended to re-record the data to a new disk.

The number of burst errors with length ≥ 40 bytes exceeds 10 or the sum of the lengths of these burst errors exceeds 800 bytes.

In the occasion of the periodic performance test, if the burst error exceeds the following level, it is recommended to copy the data recorded on the disk to another new disk as soon as possible.

The number of burst errors with length ≥ 40 bytes exceeds 16 or the sum of the lengths of these burst errors exceeds 1 200 bytes.

In the case that the data storage system has a defect-management function, the data recorded on the defect area may be re-recorded or copied to the area reserved for the defect-management on the same disk.

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