PRE-PUBLISHED **Standard** ECMA-413

Data Migration Method for BD Recordable and BD Rewritable Disks

Contents

Introduction

In 2009, International Standard for a data migration method for writable DVD disks (ISO/IEC 29121) was published.

As a test method for the estimation of lifetime of writable DVD disks had been required to set practical interval between periodic performance tests for the data migration, Ecma TC31 and ISO/IEC JTC 1/SC 23 worked jointly to specify a test method for estimation of lifetime of writable CD and DVD disks. And Ecma Standard (ECMA-396) and International Standard (ISO/IEC 16963) were published in 2010 and 2011 respectively.

In 2013, ISO/IEC 29121 2nd Edition to specify the interval between the periodic performance tests derived from the estimated lifetime of writable DVD disks was published.

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

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

As writable BD 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 writable BD disks is being required.

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

The 2nd Edition of ECMA-413 introduces a number of typographical corrections and clarifications to the previous edition.

This Ecma Standard was developed by Technical Committee 31 and was adopted by the General Assembly of June 2017.

Data Migration Method for BD Recordable and BD Rewritable Disks

1 Scope

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

This Ecma Standard specifies:

- the test methods including test area, test interval, test drive, test preparation, and test execution

- the test result evaluation in an initial performance test and a periodic performance test

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

ISO/IEC 29121   *Information technology – Digitally recorded media for information interchange and storage – Data migration method for optical disks for long-term data storage*

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

[SOURCE: ECMA-396:2017, 3.1]

3.2
B_{mig} **Life**
lifetime for use of data migration and same as $B_{0.000\ 1}$ Life which is 0,000 001 quantile of the lifetime distribution (i.e. 0,000 1 % failure time) or 99,999 9 % survival lifetime

NOTE   See Annex A.

3.3
B_5 **Life**
5 percentile of the lifetime distribution (i.e. 5 % failure time) or 95 % survival lifetime

[SOURCE: ECMA-396:2017, 3.4]

3.4
$(B_5$ **Life)$_L$**
95 % lower confidence bound of B_5 Life

[SOURCE: ECMA-396:2017, 3.5]

3.5
B_{50} **Life**
50 percentile of the lifetime distribution (i.e. 50 % failure time) or 50 % survival lifetime

[SOURCE: ECMA-396:2017, 3.6]

3.6
Controlled storage-condition
well-controlled storage conditions with full-time air conditioning (25 °C and 50 % relative humidity), which can extend the lifetime of data stored on optical disks

[SOURCE: ECMA-396:2017, 3.7]

3.7
data migration
process to copy data from one storage device or medium to another

3.8
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 writable BD disks. See ISO/IEC 30190, ISO/IEC 30191, ISO/IEC 30192 and ISO/IEC 30193.

3.9
error rate
rate of errors on the recorded disk measured before error correction is applied

3.10
Eyring method
accelerated-aging model based on the combined effects of temperature and relative humidity

[SOURCE: ECMA-396:2017, 3.8]

3.11
initial performance test
test of the recording performance of data recorded on a disk before storing

3.12
LDC Block
ECC Block using Long-Distance Code

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

3.13
lifetime
time that information is retrievable in a system

3.14
Maximum Data Error
greatest level of data error measured anywhere in one of the relevant areas on the disk

[SOURCE: ECMA-396:2017, 3.13]

NOTE   This is Max RSER.

3.15
Max RSER
maximum Random Symbol Error Rate (RSER)

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

3.16
periodic performance test
periodic test of the recording performance of data recorded on a disk during the storage

3.17
retrievability
ability to recover physical information as recorded

[SOURCE: ECMA-396:2017, 3.14]

3.18
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.

3.19
system
combination of hardware, software, storage medium, and documentation used to record, retrieve, and reproduce information

[SOURCE: ECMA-396:2017, 3.20]

3.20
uncorrectable error
error in the playback data that could not be corrected by the error correcting decoders

3.21
writable BD disk
BD Recordable disk defined in ISO/IEC 30190 or ISO/IEC 30191, or BD Rewritable disk defined in ISO/IEC30192 or ISO/IEC30193

4   Abbreviated terms

BIS   Burst-Indicating Subcode

ECC   Error-Correction Code

LDC   Long-Distance Code

RSER   Random Symbol Error Rate

SER   Symbol Error Rate

5   Conformance

BD Recordable disk tested by this test method shall conform to ISO/IEC 30190 or ISO/IEC 30191.

BD Rewritable disks tested by this test method 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 document are capitalized.

7 Test methods

7.1 General

The necessity of data migration is checked in the initial performance test and the periodic performance tests. Depending on the test result of the initial performance test and the periodic performance test, the necessity of the data migration is judged. When data are recorded on disks, the initial recording performance shall be examined as the initial performance test. During the storage, the recording performance of data recorded on disks shall be periodically examined as the periodic performance tests.

7.2 Test area

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.

NOTE   See Annex B.

7.3 Test interval for periodic performance test

If a disk with a specified B_{mig} Life as lifetime is used, the maximum interval between periodic performance tests shall be set a half of B_{mig} Life.

If a disk with a specified B_{mig} Life as lifetime is used and it has been stored since the initial performance test for B_{mig} Life and more, it should be tested every three years or less. Such tests should be limited to a maximum of two iterations.

If a disk with an unspecified lifetime is used it should be tested every three years or less. Generational changes of the system, including reading devices, the file structures and/or applications, that occur during the normal migration interval can affect readability in addition to the quality of the disk itself. For safety, or if the stored data have high value, the user may choose shorter intervals for migration than normal. If the user sets the shorter interval for migration, the data migration should be carried out at that interval regardless of the test result.

If the test interval is very long, a sampling check of the stored disks should be carried out at shorter intervals. The occurrence of retrievability problems or long read times can indicate an immediate need for detailed testing.

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

NOTE   See Annex C.

7.4 Test drive

7.4.1 General

For BD Recordable disks of 25,0 Gbytes or 50,0 Gbytes defined in ISO/IEC 30190, the test drive shall comply with ISO/IEC 30190.

For BD Recordable disks of 100,0 Gbytes, 128,0 Gbytes or 200,0 Gbytes defined in ISO/IEC 30191, the test drive shall comply with ISO/IEC 30191.

For BD Rewritable disks of 25,0 Gbytes or 50,0 Gbytes defined in ISO/IEC 30192, the test drive shall comply with ISO/IEC 30192.

For BD Rewritable disks of 100,0 Gbytes or 128,0 Gbytes defined in ISO/IEC 30193, the test drive shall comply with ISO/IEC 30193.

The test drive shall have the capability to measure Max RSER.

7.4.2 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.

7.5 Test preparation

Prior to conducting tests, 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 C. 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 C.

Before testing disks, the test drive shall be calibrated by using the calibration disk prepared by the test drive manufacturer.

7.6 Test execution

On testing disks, care handling of the disks shall be taken to avoid introducing unexpected defects.

Test results shall be judged by Max RSER.

8 Test result evaluation

8.1 Initial performance test result evaluation

The initial recording performance is categorized as Level 1, 2 and 3 by Max RSER as shown in Table 1 (see Annex D).

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 drive used for recording the data should be verified because Max RSER depends on the performance of both disks and drives. If the drive has not the performance required, the 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	Max RSER
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	$> 1,0 \times 10^{-3}$

8.2 Periodic performance test result evaluation

The recording performance at the periodic performance test is categorized as Level 4, 5 and 6 by Max RSER 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 Max RSER 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	Max RSER
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 disks during their use, storage, handling, or transportation. Causes of deterioration and their effects are noted in Annex C. For long-term storage, the recommendations in Annex E 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)

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 Controlled storage-conditions (25 °C /50 % relative humidity).

In ECMA-396, the estimated lifetime is defined variously as B_{50} Life, B_5 Life and the 95 % lower confidence bound of B_5 Life (= $(B_5$ Life$)_L$) and described as follows.

$$B_{50} \text{ Life} = \exp(\ln B_{50})$$

$$= \exp(\beta_0 + \beta_1 x_{10} + \beta_2 x_{20}),$$

$$B_5 \text{ Life} = \exp(\ln B_5)$$

$$= \exp(\beta_0 + \beta_1 x_{10} + \beta_2 x_{20} - 1{,}64\sigma),$$

where, (x_{10}, x_{20}) denotes the Controlled storage-condition (25 °C and 50 % relative humidity).

Also, the 95 % lower confidence bound of B_5 Life becomes

$$(B_5 \text{ Life})_L = \exp(\ln B_5 - 1{,}64\sigma).$$

β_0, β_1, β_2 and estimated variance of residual errors σ 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 reach 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 using B_{50} Life and B_5 Life as follows:

$$B_{mig}\text{Life}= B_{0,000\,1}\text{Life}= \exp\left(\ln\hat{B}_{50} - 4,75\,\hat{\sigma}\right)= \exp\left(\ln\hat{B}_{50} - 4,75\frac{\ln\hat{B}_{50}-\ln\hat{B}_5}{1,64}\right)= \exp\left(2,9\ln\hat{B}_5 - 1,9\ln\hat{B}_{50}\right)$$

In actual storage conditions, the temperature and relative humidity can deviate from the Controlled storage-condition of 25 °C/50 % relative humidity, which changes the estimated lifetime. In this case, the estimated lifetime should be adjusted according to the estimated lifetime at the actual storage conditions.

Annex B
(informative)

Test area

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 is recommended.

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 C
(informative)

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

C.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.

C.2   Disk structure

BD Recordable and BD Rewritable disks comprise a recording substrate 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.

C.3   Causes of deterioration

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

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 E.

C.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.

C.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 Error Correction Code has a very high burst correction capability, a large dust particle can cause this capability to be exceeded.

C.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 D
(informative)

Max RSER criteria for BD Recordable and BD Rewritable disks

The Max RSER value of 10^{-3} was adopted as suitable 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} [1][2]. The same Max RSER value of 10^{-3} is adopted as the criteria of Level 3 and 6 for Maximum Data Error of BD Recordable and BD Rewritable disks.

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 F.

Annex E
(informative)

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

E.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.

E.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 E.1.

Table E.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 E.2.

Table E.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.

E.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 F
(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.

Bibliography

[1] White Paper Blu-ray Disc™ Format BD-ROM 9th August, 2015 [viewed 2015-12-1] available from http://www.blu-raydisc.com/Assets/Downloadablefile/White%20Paper%20BD-ROM_Part1_9th_20150806_clean.pdf

[2] White Paper Blu-ray Disc™ Format General 4th August, 2015 [viewed 2015-12-1] available from http://www.blu-raydisc.com/Assets/Downloadablefile/White_Paper_General_4th_20150817_clean.pdf