INTERNATIONAL STANDARD

ISO/IEC 9171-2

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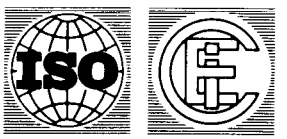
Information technology — 130 mm optical disk cartridge, write once, for information interchange —

Part 2:
Recording format

Technologies de l'information — Cartouche de disque optique de 130 mm, non-réinscriptible, pour l'échange d'information —

Partie 2: Format d'enregistrement



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FOREWORD

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

In the field of information technology, ISO and IEC have established a joint technical committee, ISO/IEC JTC 1. Draft International Standards adopted by the joint technical committee are circulated to national bodies for voting. Publication as an International Standard requires approval by at least 75 % of the national bodies casting a vote.

International Standard ISO/IEC 9171-2 was prepared by Joint Technical Committee ISO/IEC JTC 1, *Information technology.*

ISO/IEC 9171 consists of the following parts, under the general title: *Information technology — 130 mm optical disk cartridge, write once, for information interchange*:

Part 1: Unrecorded optical disk cartridge

Part 2: Recording format

Annexes B and C form an integral part of this of this part of ISO/IEC 9171. Annexes A and D are for information only.

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INTRODUCTION

ISO/IEC 9171 specifies the characteristics of 130 mm optical disk cartridges (ODC) of the type providing for information to be written once and read many times.

ISO/IEC 9171-1 specifies

- definitions of the essential concepts;
- the environment in which the characteristics are to be tested;
- the environment in which the cartridge is to be operated and stored;
- the mechanical, physical and dimensional characteristics of the case and of the optical disk;
- the optical characteristics and the recording characteristics for recording the information once and for reading it many times, so as to provide physical interchangeability between data processing systems.

ISO/IEC 9171-1 and ISO/IEC 9171-2, together with a standard for volume and file structure, provide for full data interchange between data processing systems.

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Information technology — 130 mm optical disk cartridge, write once, for information interchange —

Part 2:
Recording format

1 Scope

This part of ISO/IEC 9171 specifies two formats for the physical disposition of the tracks and sectors, the error correction codes, the modulation methods used for recording and the quality of the recorded signals.

2 Conformance

An optical disk is in conformance with Part 2 of this International Standard if it meets all mandatory requirements of clause 4 and either those of clause 5 or those of clause 6.

A prerequisite for conformance with this part of ISO/IEC 9171 is conformance with ISO/IEC 9171-1.

3 Conventions and notations

The following conventions and notations apply in this part of ISO/IEC 9171.

a) In each field the information is recorded so that the most significant byte (byte 0) is recorded first. Within each byte the least significant bit is numbered bit 0, the most significant bit (i.e. bit 7 in an 8-bit byte) is recorded first. This order of recording applies also to the data input of the error-correcting codes, to the cyclic redundancy code, and to their code output.

b) Unless otherwise stated, numbers are expressed in binary notation. Where hexadecimal notation is used, the hexadecimal digits are shown between parentheses.

c) Bit combinations are shown with the most significant bit to the left.

d) Negative values are expressed in TWO's complement notation.

e) The setting of bits is denoted by ZERO and ONE.

f) The name of entities, e.g. specific tracks, fields, etc., is shown with a capital initial.

g) List of Acronyms

ALPC	Auto Laser Power Control
AM	Address Mark
CAV	Constant Angular Velocity
CRC	Cyclic Redundancy Check
DDS	Disk Definition Structure
DMP	Defect Management Pointers
DMT	Defect Management Track
ECC	Error Correction Code
ID	Identifier
ODC	Optical Disk Cartridge
ODF	Offset Detection Flag
PA	Postamble
PEP	Phase-Encoded Part
RLL (2,7)	Run Length Limited (Code)

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R-S	Reed-Solomon (Code)
R-S/LDC	Reed-Solomon Long Distance Code
SFP	Standard Formatted Part
SM	Sector Mark
VFO	Variable Frequency Oscillator
4/15(Modulation)	Conversion table of 8-bit bytes to 15-Channel bit representation on the disk

4 Features common to both formats

4.1 Track Geometry

4.1.1 Track shape

Each track shall form a 360° turn of a continuous spiral.

4.1.2 Direction of rotation

The disk shall rotate counter-clockwise as viewed by the objective lens. The tracks shall spiral outward.

4.1.3 Track pitch

Except in the PEP Zone, the track pitch shall be:

For Format A : 1,60 µm ± 0,10 µm
For Format B : 1,50 µm ± 0,08 µm

4.1.4 Track number

Each track shall be identified by a track number.

Track 0 shall be located at radius 30,00 mm ± 0,10 mm.

The track numbers of tracks located at radii larger than that of track 0 shall be increased by 1 for each track.

The track numbers of tracks located at radii smaller than that of track 0 shall be negative and decrease by 1 for each track. Track-1 shall be identified by (FFFF).

4.2 Formatted Zone

The Formatted Zone shall extend from radius 27,00 mm to radius 61,00 mm and shall be divided as follows. The following dimensions are given as reference only and are nominal values.

- Reflective Zone	27,00 mm to 29,00 mm
- Control Track PEP Zone	29,00 mm to 29,50 mm
- Transition Zone For SFP	29,50 mm to 29,52 mm
- Inner Control Track SFP Zone	29,52 mm to 29,70 mm
- Inner Manufacturer Zone	29,70 mm to 30,00 mm
. Guard Band	29,70 mm to 29,80 mm
. Manufacturer Test Zone	29,80 mm to 29,90 mm
. Guard Band	29,90 mm to 30,00 mm
- User Zone	30,00 mm to 60,00 mm
- Outer Manufacturer Zone	60,00 mm to 60,15 mm
- Outer Control Track SFP Zone	60,15 mm to 60,50 mm
- Lead-Out Zone	60,50 mm to 61,00 mm

This part of ISO/IEC 9171 does not specify the format of the Reflective Zone, except that it shall have the same recording layer as the remainder of the Formatted Zone.

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The Transition Zone For SFP is an area in which the format changes from the PEP Zone without servo information to a zone including servo information.

The Inner Manufacturer Zone is provided to allow the media manufacturer to perform tests on the disk, including write operations, in an area located away from recorded information. In this zone the information in the tracks from track-1 to track-8 is not specified by this part of ISO/IEC 9171 and shall be ignored in interchange, except when using format B where track-2 is used for defect management.

The purpose of the Guard Bands is to protect and buffer the areas that contain information from accidental damage when the area between the Guard Bands is used for testing or calibration of the optical system.

The User Zone shall start with track 0 and end with track N.

The Outer Manufacturer Zone shall comprise 95 tracks and shall begin one track after the last user track (track N, see bytes 384 and 385 of the SFP Zone). In this zone the information in the tracks from track (N + 1) to track (N + 8) is not specified by this part of ISO/IEC 9171 and shall be ignored in interchange.

The Outer Control Track SFP Zone shall begin at track N + 96 (see bytes 8 and 9 in the SFP Zone) and shall continue up to radius 60,5 mm.

The Lead-Out Zone is used for the manufacturing purposes and shall not be used for write, read or positioning purposes.

From radius 29,52 mm to radius 61,00 mm the Formatted Zone shall be provided with tracks containing servo and address information.

4.3 Control tracks

The three zones

- Control Track PEP Zone
- Inner Control Track SFP Zone
- Outer Control Track SFP Zone

shall be assigned for recording control track information.

The control track information shall be recorded in two different formats, the first format in the Control Track PEP Zone, and the second in the Inner and Outer Control Track SFP Zones.

The Control Track PEP Zone shall be recorded using low frequency phase-encoded modulation.

The Inner and Outer Control Track SFP Zones shall each consist of a band of tracks recorded by the same modulation method and format as is used in the User Zone.

4.4 Control Track PEP Zone

This zone shall not contain any servo information. All information in it shall be pre-recorded in phase-encoded modulation. The marks in all tracks of the PEP Zone shall be radially aligned, so as to allow information recovery from this zone without radial tracking being established by the drive.

4.4.1 Recording in the PEP Zone

In the PEP Zone there shall be 561 to 567 PEP bit cells per revolution. A PEP bit cell shall be 656 ± 1 Channel bits long. A PEP bit is recorded by writing marks in either the first or the second half of the cell.

A mark shall be nominally two Channel bits long and shall be separated from adjacent marks by a space of nominally two Channel bits.

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A ZERO shall be represented by a change from marks to no marks at the centre of the cell and a ONE by a change from no marks to marks at this centre.

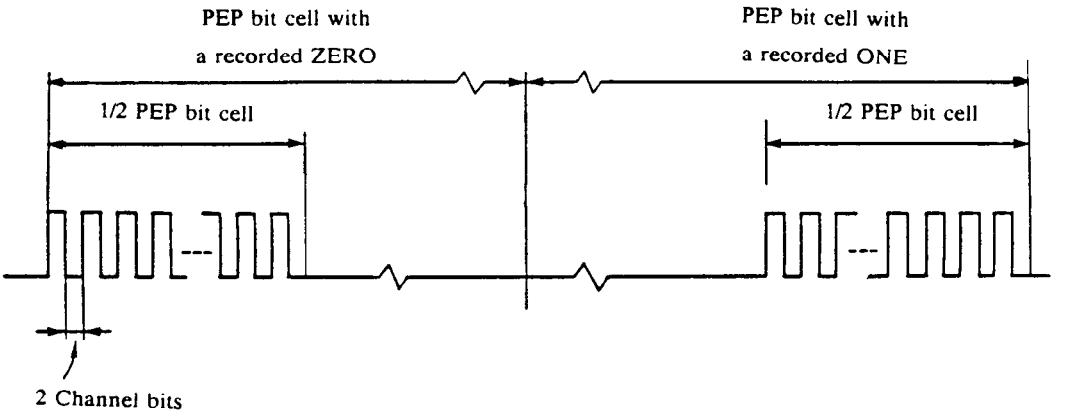

Figure 1 - Example of phase-encoded modulation in the PEP Zone

4.4.2 Cross-track loss

The density of tracks and the shape of marks in the PEP Zone shall be such that the cross-track loss shall meet the requirements:

$$\left(\frac{I_{mmax}}{I_{mmin}} \right) < 2{,}0$$

The signal I_m is the maximum amplitude in a group of three successive marks. I_{mmax} is the maximum value and I_{mmin} is the minimum value of I_m obtained over one revolution. I_{mmax} shall be greater than 0,4 I_0. The effect of defects shall be ignored.

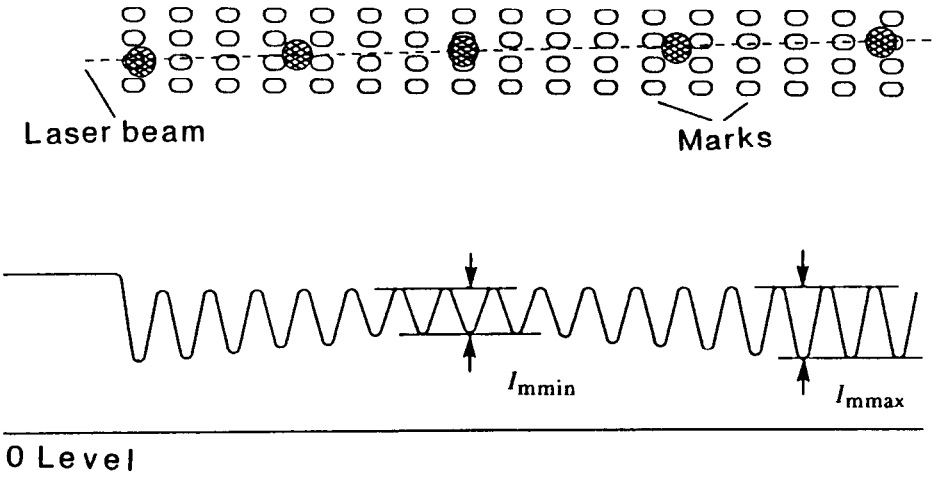

Figure 2 - Path of the laser beam crossing tracks, and the resulting PEP signals

4.4.3 Format of the tracks of the PEP Zone

Each track in the PEP Zone shall have three sectors as shown in figure 3. The numbers below the fields indicate the number of PEP bits in each field.

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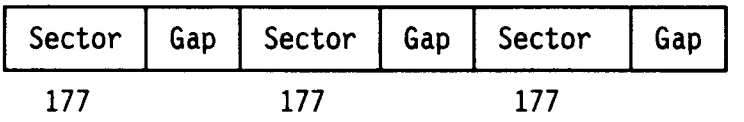

Figure 3 - Track format in the PEP Zone

The gaps between sectors shall be unrecorded areas having a length corresponding to 10 to 12 PEP bit cells.

4.4.3.1 Format of a sector

Each sector of 177 PEP bits shall have the following layout.

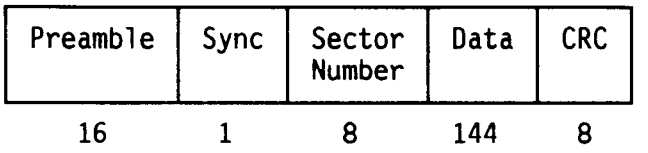

Figure 4 - Sector Format in the PEP Zone

4.4.3.1.1 Preamble

This field shall consist of 16 ZERO bits.

4.4.3.1.2 Sync

This field shall consist of 1 ONE bit.

4.4.3.1.3 Sector Number

This field shall consist of eight bits specifying the sector number in binary notation from 0 to 2.

4.4.3.1.4 Data

This field shall comprise 18 8-bit bytes numbered 0 to 17. These bytes shall specify the following.

Byte 0

Bit 7 — when set to ZERO shall mean Format A,
when set to ONE shall mean Format B.

Bits 6 to 4 — shall be set to 000 indicating a constant angular velocity (CAV).

Other settings of these bits are prohibited by this part of ISO/IEC 9171 (see also Annex A).

Bit 3 — shall be set to ZERO

Bits 2 to 0 — when set to 000 shall mean RLL (2,7) mark position modulation,
when set to 100 shall mean 4/15 modulation.

Other settings of these bits are prohibited by this part of ISO/IEC 9171.

Byte 1

Bit 7 — shall be set to ZERO

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Bits 6 to 4 specify the error correction code:
when set to 000 shall mean R-S LDC degree 16, and 10 interleaves,
when set to 001 shall mean R-S LDC degree 16, and 5 interleaves,
when set to 100 shall mean R-S product code (48,44,5) x (14,12,3)

Other settings of these bits are prohibited by this part of ISO/IEC 9171.

Bit 3 shall be set to ZERO

Bits 2 to 0 these bits shall specify in binary notation the power n of 2 in the following formula which expresses the number of user bytes per sector

$$256 \times 2^n$$

Values of n other than 1 or 2 are prohibited by this part of ISO/IEC 9171.

Byte 2

This byte shall specify in binary notation the number of sectors in track 0.

Byte 3

This byte shall specify the manufacturer's specification for the base line reflectance R of the disk when measured according to 13.2.1 of ISO/IEC 9171-1. It is specified as a number n between 0 and 100, such that

$$n = 100\,R$$

Byte 4

This byte shall specify whether the recording is on-land or in-groove, and shall indicate the signal amplitude and the polarity of the pre-recorded marks.

The absolute value of the signal amplitude is given as a number n either between -50 and -20 or between +20 and +50, such that:

$$n = 50\,I_p\,/I_o$$

where I_p is the signal from the low frequency pre-recorded marks and I_o is the signal from an unrecorded, ungrooved area (see 13.4 of ISO/IEC 9171-1).

Bit 7 when set to ZERO shall mean on-land recording,
when set to ONE shall mean in-groove recording.

Bits 6 to 0 shall express this number n. If bit 6 is set to ZERO this number is positive. If bit 6 is set to ONE this number is negative and expressed in TWO's complements.

If this number is positive it indicates low-to-high recording, if it is negative it indicates high-to-low recording.

Byte 5

This byte shall specify the amplitude and polarity of user-written marks as a number n between -50 and +127 such as

$$n = 50\,I_u\,/I_{ot}$$

where I_u is the signal of the low frequency user-written marks and I_{ot} is the on-track signal from an unrecorded track.

Bits 7 to 0 shall express this number n. If bit 7 is set to ZERO this number is positive. If bit 7 is set to ONE this number is negative, and expressed in TWO's complements.

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If this number is positive it indicates low-to-high recording, if it is negative it indicates high-to-low recording.

Byte 6

This byte shall specify in binary notation a number n representing 20 times the maximum read power expressed in milliwatts which is permitted for reading the SFP Zone at a rotational frequency of 30 Hz and a wavelength of 825 nm. This number *n* shall be between 0 and 40.

Byte 7

The byte shall specify the media type.

0001 0000 shall mean an optical disk cartridge according to this part of ISO/IEC 9171.

Other settings of this byte are prohibited by this part of ISO/IEC 9171 (see also Annex A).

Byte 8

This byte shall specify the most significant byte of the track number of the track in which the Outer Control Track SFP Zone starts.

Byte 9

This byte shall specify the least significant byte of the track number in which the Outer Control Track SFP Zone starts.

Bytes 10 to 13

These bytes shall be set to (FF).

Bytes 14 to 17

The contents of these bytes are not specified by this part of ISO/IEC 9171. They shall be ignored in interchange.

4.4.3.1.5 CRC

The CRC character shall be computed over the Sector Number field and the Data field. The generator polynomial shall be

$$G(x) = x^8 + x^4 + x^3 + x^2 + 1$$

The residual polynomial R(x) shall be

$$R(x) = \left(\sum_{i=144}^{i=151} \overline{a}_i x^i + \sum_{i=0}^{i=143} a_i x^i \right) x^8 \mod G(x)$$

where a_i denotes a bit of the input data and $\overline{a}_i$ an inverted bit. The highest order bit of the Sector Number field is a_{151}.

The eight bits of the CRC are defined by

$$R_C(x) = \sum_{k=0}^{k=7} C_k x^k$$

where C_7 is recorded as the highest order bit of the CRC byte of the PEP sector.

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4.4.3.2 Summary of the format of the Data Field of a sector of the PEP Zone

Table 1 - Summary of the format of the Data field of a sector of the PEP Zone

Byte	Bit	7	6	5	4	3	2	1	0
0		Format	0	0	0	0	Modulation Code		
1		0	ECC			0	Number of user bytes		
2		Number of sectors in track 0							
3		Baseline reflectance at 825 nm							
4		L or G	Amplitude and polarity of pre-formatted data						
5		Amplitude and polarity of user-recorded data							
6		Max. read power for the SFP Zone at 30 Hz and 825 nm							
7		0	0	0	1	0	0	0	0
8		Start track of Outer SFP Zone, MSB of track number							
9		Start track of Outer SFP Zone, LSB of track number							
10		1	1	1	1	1	1	1	1
11		1	1	1	1	1	1	1	1
12		1	1	1	1	1	1	1	1
13		1	1	1	1	1	1	1	1
14		Not specified, ignored in interchange							
15		Not specified, ignored in interchange							
16		Not specified, ignored in interchange							
17		Not specified, ignored in interchange							

4.5 Control Track SFP Zones

The two Control Track SFP Zones shall be pre-recorded in the Standard User Data Format (see clauses 5 and 6).

Each sector of the SFP Zones shall include 512 bytes of information numbered 0 to 511 and grouped in five sections:

- a duplicate of the PEP information (18 bytes),
- media information (366 bytes),
- system information (64 bytes),
- bytes reserved for future standardization (32 bytes),

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- unspecified contents (32 bytes).

In the case of 1024-byte sectors these first 512 bytes shall be followed by 512 (FF)-bytes.

Both SFP Zones are filled with such sectors which all contain the same information. The DMP bytes (see 5.2.11.2 and 6.2.5) of each sector may not conform to this part of ISO/IEC 9171.

4.5.1 Duplicate of the PEP information

Bytes 0 to 17 shall be identical with the 18 bytes of the Data field of a sector of the PEP Zone.

4.5.2 Media information

Bytes 18 to 359 specify read and write parameters at three laser wavelengths L_1, L_2 and L_3. The base line reflectance R_1, R_2 and R_3 is specified for each wavelength. The read and write powers are specified for four different rotational frequencies N_1, N_2, N_3 and N_4 for each wavelength. For each N four sets of write powers are given: three sets for constant pulse width and one set for constant power. Each set contains three values for the inner, middle and outer radius.

Bytes 18 to 27 and 31 to 34 are mandatory. They specify the conditions for L_1 = 825 nm and N_1 = 30 Hz. Bytes 28 to 30 and 48 to 359 are optional. They shall either specify the information indicated or be set to (FF).

All values specified in bytes 18 to 359 shall be such that the requirements of clause 13 of ISO/IEC 9171-1 are met.

Bytes 360 to 383 shall be set to (FF).

Byte 18

This byte shall specify the wavelength L_1 in nanometres as a number n between 0 and 255 such that

$$n = 1/5\ L_1$$

This byte shall be set to n = 165 for optical disk cartridges according to this part of ISO/IEC 9171.

Byte 19

This byte shall specify the baseline reflectance R_1 at wavelength L_1 as a number n between 0 and 100 such that

$$n = 100\ R_1$$

Byte 20

This byte shall specify the rotational frequency N_1 in hertz as a number n such that

$$n = N_1$$

This byte shall be set to n = 30 for optical disk cartridges according to this part of ISO/IEC 9171.

Byte 21

This byte shall specify the maximum read power P_1 in milliwatts for the user zone as a number n between 0 and 40 such that

$$n = 20\ P_1$$

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The following bytes 22 to 30 specify, at constant pulse width, the write power P_w in milliwatts indicated by the manufacturer of the disk. P_w is expressed as a number n between 0 and 255 such that

$$n = 5\ P_w$$

In these bytes T' stands for the constant pulse width, T for the time length of one Channel bit and r for the radius considered.

Byte 22

This byte shall specify P_w for:

$T' = T \times 1{,}00$
$r = 30$ mm

Byte 23

This byte shall specify P_w for:

$T' = T \times 1{,}00$
$r = 45$ mm

Byte 24

This byte shall specify P_w for:

$T' = T \times 1{,}00$
$r = 60$ mm

Byte 25

This byte shall specify P_w for:

$T' = T \times 0{,}50$
$r = 30$ mm

Byte 26

This byte shall specify P_w for:

$T' = T \times 0{,}50$
$r = 45$ mm

Byte 27

This byte shall specify P_w for:

$T' = T \times 0{,}50$
$r = 60$ mm

Byte 28

This byte shall specify P_w for:

$T' = T \times 0{,}25$
$r = 30$ mm

Byte 29

This byte shall specify P_w for:

$T' = T \times 0{,}25$
$r = 45$ mm

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Byte 30

This byte shall specify P_w for:

$T' = T \times 0{,}25$
$r = 60$ mm

Byte 31

This byte shall specify a constant write power P_w in milliwatts as a number n between 0 and 255 such that

$$n = 5 P_w$$

Byte 32

This byte shall specify the write pulse width T_p in nanoseconds expressed by a number n between 0 and 255 such that

$$n = T_p$$

for the constant write power specified by byte 31 and at a radius $r = 30$ mm.

Byte 33

This byte shall specify the write pulse width T_p in nanoseconds expressed by a number n between 0 and 255 such that

$$n = T_p$$

for the constant write power specified by byte 31 and at a radius $r = 45$ mm.

Byte 34

This byte shall specify the write pulse width T_p in nanoseconds expressed by a number n between 0 and 255 such that

$$n = T_p$$

for the constant write power specified by byte 31 and at a radius $r = 60$ mm.

Bytes 35 to 47

These bytes shall be set to (FF).

(See also Annex A).

Byte 48

This byte shall specify, at wavelength L_1, the rotational frequency N_2 in hertz as a number n between 0 and 255 such that

$$n = N_2$$

Byte 49

This byte shall specify the maximum read power P_2 in milliwatts for the User Zone as a number n between 0 and 255 such that

$$n = 20 P_2$$

Bytes 50 to 62

For the values specified in bytes 18, 19, 48 and 49, bytes 50 to 62 shall specify the parameters indicated in bytes 22 to 34.

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Bytes 63 to 75

These bytes shall be set to (FF).

Byte 76

This byte shall specify, at wavelength L_1, rotational frequency N_3 in hertz expressed as a number n between 0 and 255 such that

$$n = N_3$$

Byte 77

This byte shall specify the maximum read power P_3 in milliwatts for the user zone, as a number n between 0 and 255 such that

$$n = 20\ P_3$$

Bytes 78 to 90

For the values specified in bytes 18, 19, 76 and 77, bytes 78 to 90 shall specify the parameters indicated in bytes 22 to 34.

Bytes 91 to 103

These bytes shall be set to (FF).

Byte 104

This byte shall specify, at wavelength L_1, rotational frequency N_4 in hertz as a number n between 0 and 255 such that

$$n = N_4$$

Byte 105

This byte shall specify the maximum read power P_4 in milliwatts for the user zone as a number n between 0 and 255 such that

$$n = 20\ P_4$$

Bytes 106 to 118

For the values specified in bytes 18, 19, 104 and 105, bytes 106 to 118 shall specify the parameters indicated in bytes 22 to 34.

Bytes 119 to 131

These bytes shall be set to (FF).

Byte 132

This byte shall specify wavelength L_2 in nanometres as a number n between 0 and 255 such that

$$n = 1/5\ L_2$$

Byte 133

This byte shall specify the baseline reflectance R_2 at wavelength L_2 as a number n between 0 and 100 such that

$$n = 100\ R_2$$

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Bytes 134 to 245

The allocation of information to, or the setting of, these bytes shall correspond to those of bytes 20 to 131. The values specified shall be for L_2 (byte 132) and R_2 (byte 133).

Byte 246

This byte shall specify wavelength L_3 in nanometres as a number n between 0 and 255 such that

$$n = 1/5\ L_3$$

Byte 247

This byte shall specify the baseline reflectance R_3 at wavelength L_3 as a number n between 0 and 100 such that

$$n = 100\ R_3$$

Bytes 248 to 359

The allocation of information to, or the setting of, these bytes shall correspond to those of bytes 20 to 131. The values specified shall be for L_3 (byte 246) and R_3 (byte 247).

Bytes 360 to 383

These bytes shall be set to (FF).

(See also Annex A).

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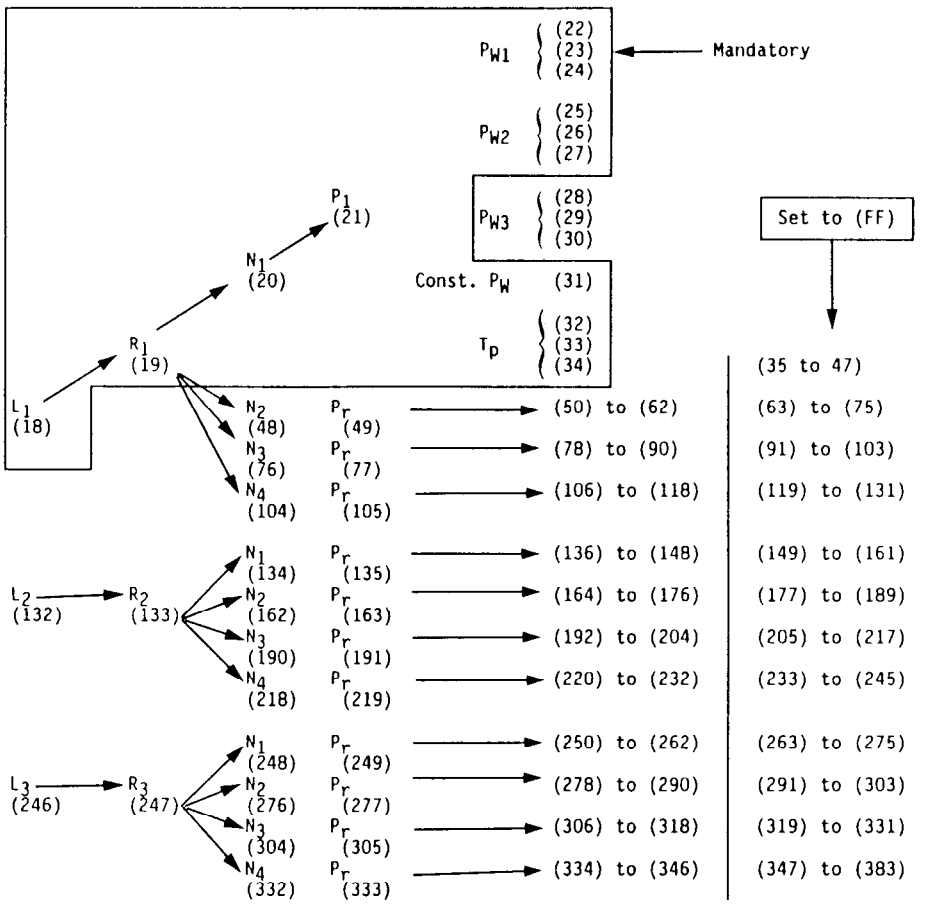
Table 2 - Summary of media information in the SFP Zone



4.5.3 System Information

Bytes 384 and 385 specify in binary notation the track number N of the last track in the User Zone. The total number of tracks in this zone is (N + 1).

Byte 384

This byte shall specify the most significant byte of this number.

Byte 385

This byte shall specify the least significant byte of this number.

Bytes 386 to 479

These bytes shall be set to (FF).

(See also Annex A).

4.5.4 Unspecified Content

The contents of bytes 480 to 511 are not specified by this part of ISO/IEC 9171. They shall be ignored in interchange.

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4.6 Requirements for Interchange

4.6.1 Equipment for writing

The disk under test shall have been written with arbitrary data by a disk drive for data interchange use in the operating environment. Data shall be recorded in such a way that the requirements of 4.6.5 are met.

4.6.2 Test equipment for reading

4.6.2.1 General

The read test shall be performed on a test drive in the test environment. The rotational frequency of the disk when reading shall be 30,0 Hz ± 0,3 Hz.

The direction of rotation shall be counter-clockwise when viewed from the objective lens.

4.6.2.2 Optical characteristics of the read head

a)	wavelength λ of the laser	: 825 nm $^{+\ 15\ nm}_{-\ 10\ nm}$
b)	wavelength over numerical aperture	: 1,59 µm ± 0,04 µm
c)	polarization of the light	: circular
d)	filling of the lens aperture	: 1,0 max.
e)	variance of the wavefront at the recording layer	: $\lambda^2/180$ max.

4.6.2.3 Read power

a) the read power for the PEP Zone shall not exceed 0,50 mW,

b) the read power for the SFP Zone shall not exceed the value given in byte 6 of the PEP Zone (4.4.3.1.4),

c) the read power for the User Zone shall not exceed the value given in byte 21 of the SFP Zone (4.5.2).

4.6.2.4 Tracking

The open-loop transfer function H for radial and axial tracking shall be

$$H = \frac{(2\pi f_0)^2}{c\,s^2}\left(\frac{1+\frac{sc}{2\pi f_0}}{1+\frac{s}{2\pi f_0 c}}\right)$$

within an accuracy such that $|1+H|$ does not deviate more than ± 20% from its nominal value in a bandwidth from 30 Hz to 10 kHz, where $s = i2\pi f$.

The constant c shall be 3. The open-loop 0 dB frequency f_0 shall be 1250 Hz for the axial servo and 1740 Hz for the radial servo. The open-loop DC gain of the axial servo shall be at least 100 dB.

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4.6.2.5 Read channel

a) Read amplifier

The read amplifier after the photo detector shall have a flat response from 100 kHz to 14,8 MHz within ± 1 dB.
Amplitude saturation shall not occur.

b) Conversion of analog signals to Channel bits

The signals from the read amplifier shall be converted into Channel bits. The converter shall work properly for signals where the amplitude I_L of the lowest occurring frequency is such that

$$\frac{|I_L|}{I_{ot}} \geq 0{,}8 \times \frac{|I_u|}{I_{ot}}$$

and the amplitude I_H of the highest occurring frequency is such that

$$\frac{I_H}{I_L} \geq 0{,}4$$

within any sector.

I_{ot} is the signal obtained from an unrecorded track when read-on-track; I_u is the signal value specified in byte 5 of the PEP Zone.

c) Conversion of Channel bits to user bytes

The Channel bit patterns shall be converted into 8-bit bytes, including user data, check bytes, etc. (see 5.2.13 and 6.2.4.1).

4.6.3 Requirements for tracking

The focus of the read head shall not jump tracks voluntarily.

4.6.4 Requirements for user data

4.6.4.1 A byte error shall be a user byte in which one or more bits have a wrong setting, as detected by the error detection and correction circuits.

4.6.4.2 Any sector accepted as valid during the writing process shall not contain byte errors not correctable by the correction algorithm (see 6.2.3 and Annex C).

4.6.4.3 Any sector not accepted as valid during the writing process shall have been rewritten according to the rules for defect management.

4.6.4.4 The rewrite criterion for a sector is not specified in this part of ISO/IEC 9171. The rewrite percentage, which reflects the quality of the disk, is not specified either, and shall be a matter of agreement between purchaser and supplier.

4.6.5 Requirement for interchange

An interchanged optical disk cartridge meets the requirements for interchangeability if it meets the requirements of 4.6.3 and 4.6.4 when it is written on an interchange drive according to 4.6.1 and read on a test drive according to 4.6.2.

5 Format A

This format is based on a composite continuous servo tracking method.

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5.1 Track layout

5.1.1 Tracking

Format A is characterized by continuous tracking centred between adjacent grooves that are preformed on the disk (land tracking), or continuous tracking centred in a single groove (groove tracking), with the specific method being identified by byte 4 of the Control Track PEP Zone.

There shall be no groove in the ODF Marks. Pre-recorded marks may be obtained by discontinuity of the grooves. In all other areas the tracks shall have continuous grooves.

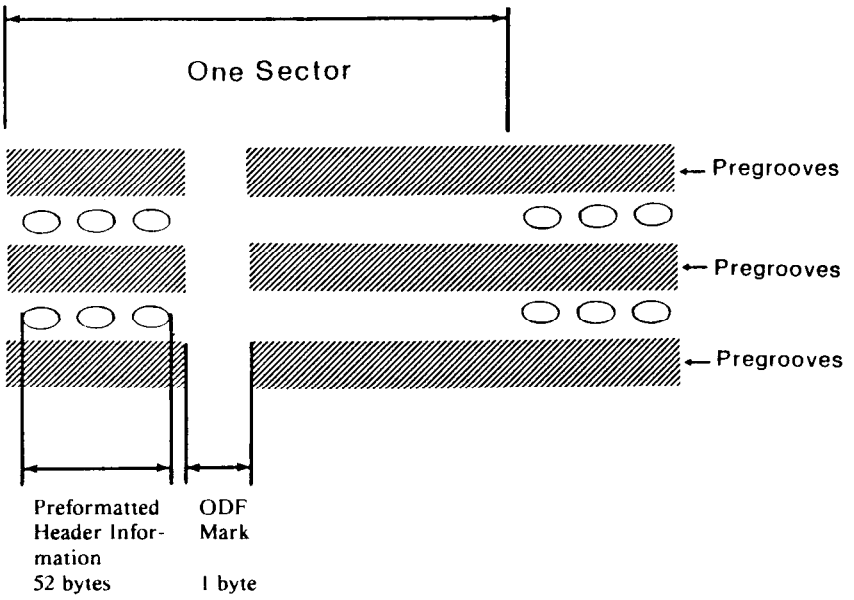

Figure 5 - Example of sector with offset detection flag for on-land recording (schematic)

5.1.2 Characteristics of pre-recorded information

The characteristics of the signals read shall apply either to land or to groove recording and shall refer to signals obtained at the optical head. Each of these characteristics shall be measured under the conditions specified in 13.1.1 and 13.1.2 as well as 13.3 of ISO/IEC 9171-1.

5.1.2.1 Groove-related signals

The following three requirements shall be met (see figure 6):

- **Cross-track maximum signal ratio**

  $0{,}70 \leq (I_1 + I_2)\ \max / I_0 \leq 1{,}00$

  where $(I_1 + I_2)$ is the sum output of the split photo diode detector when the beam crosses unrecorded tracks, and I_0 is the signal obtained from an unrecorded, ungrooved area.

- **Push-pull ratio**

  $0{,}40 \leq (|I_1 - I_2|) / I_0 \leq 0{,}65$

  where $(I_1 - I_2)$ is the peak-to-peak amplitude of the differential output of the photodiode detector when the beam crosses unrecorded tracks.

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- **Cross-track signal modulation ratio**

  $0{,}30 \leq [(I_1 + I_2)\text{max} - (I_1 + I_2)\text{min}] / I_o \leq 0{,}60$

  Over the whole disk this ratio shall not vary by more than 3 dB.

  The phase depth of the grooves shall be less than 180°.

  The on-track signal I_{ot} (see 13.3 of ISO/IEC 9171-1) equals either $(I_1 + I_2)\text{min}$ or $(I_1 + I_2)\text{max}$.

5.1.2.2 Sector Mark signal

The Sector Mark signal shall meet the requirement

$$|I_{sm}| / I_o \geq 0{,}50$$

where I_{sm} is the peak-to-peak amplitude of the read signal from the Sector Mark.

5.1.2.3 VFO signals

The VFO signals shall meet the requirement

$$|I_{vfo}| / I_o \geq 0{,}25$$

where I_{vfo} is the peak-to-peak amplitude of the read signal in the VFO area.

In addition the following condition shall be satisfied for each sector:

$$|I_{vfo} / I_{pmax}| \geq 0{,}5$$

where I_{pmax} is the maximum signal in the Header of that sector from pre-formatted marks which are not Sector Marks.

5.1.2.4 Parameters of the read characteristics

Figure 6 shows the different parameters for the read characteristics.

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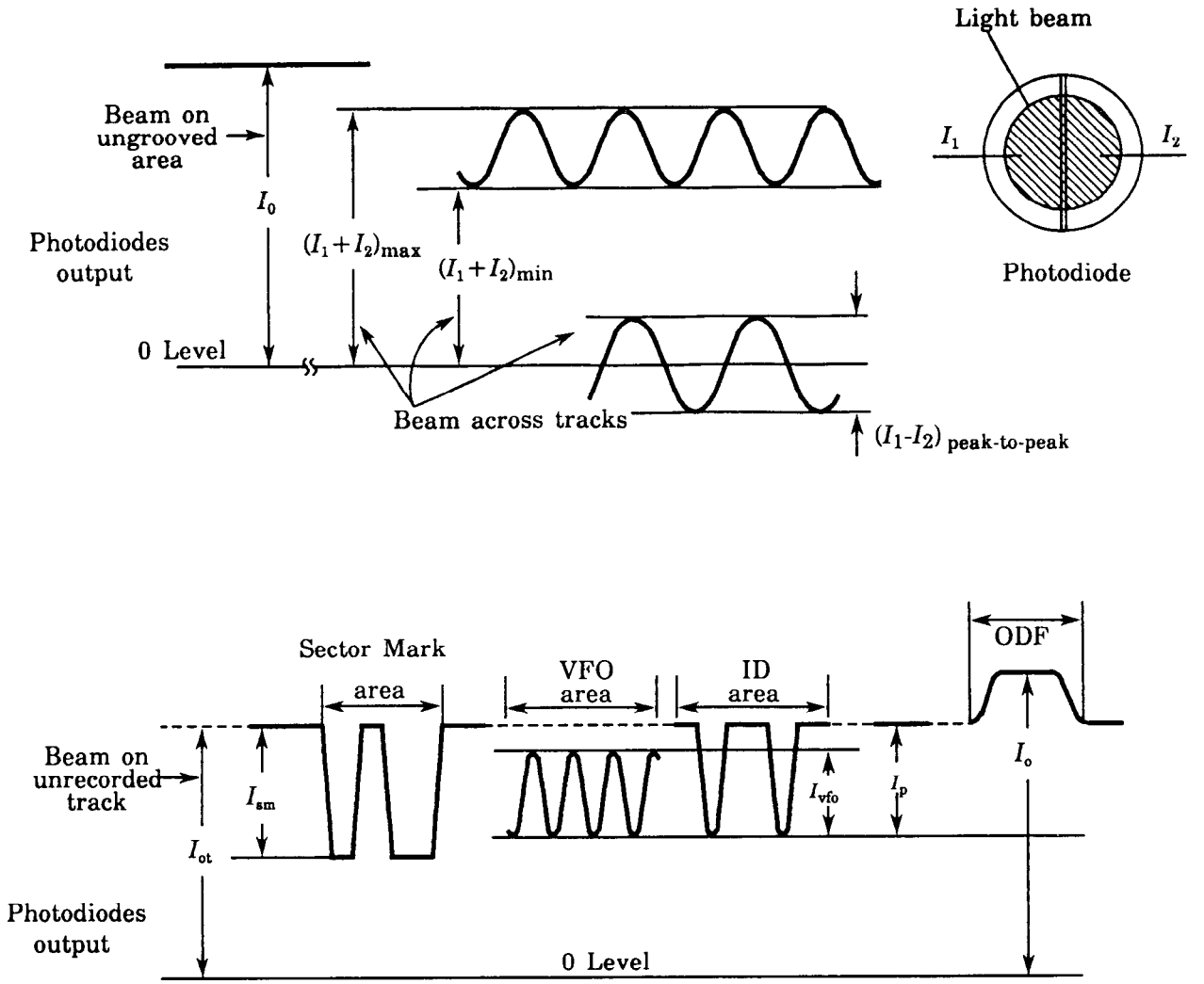

Figure 6 - Illustration of various parameters for read characteristics

5.2 Sector Format

Sectors shall have one of the two layouts shown in figure 7 and figure 8 depending on the number of user bytes in the Data field (see 5.2.11). When the sectors contain 1024 user bytes, there shall be 17 sectors per track, numbered 0 to 16; when the sectors contain 512 user bytes, there shall be 31 sectors per track numbered 0 to 30. The number of user bytes per sector is specified by byte 1 of the PEP and the SFP Zones. The pre-formatted area of 52 bytes, the Header, is the same for both types of Data field.

Each bit of an 8-bit byte shall be represented on the disk by two Channel bits (see 5.2.13).

In figure 7 and figure 8 the numbers above and below the fields indicate the number of bytes in each field.

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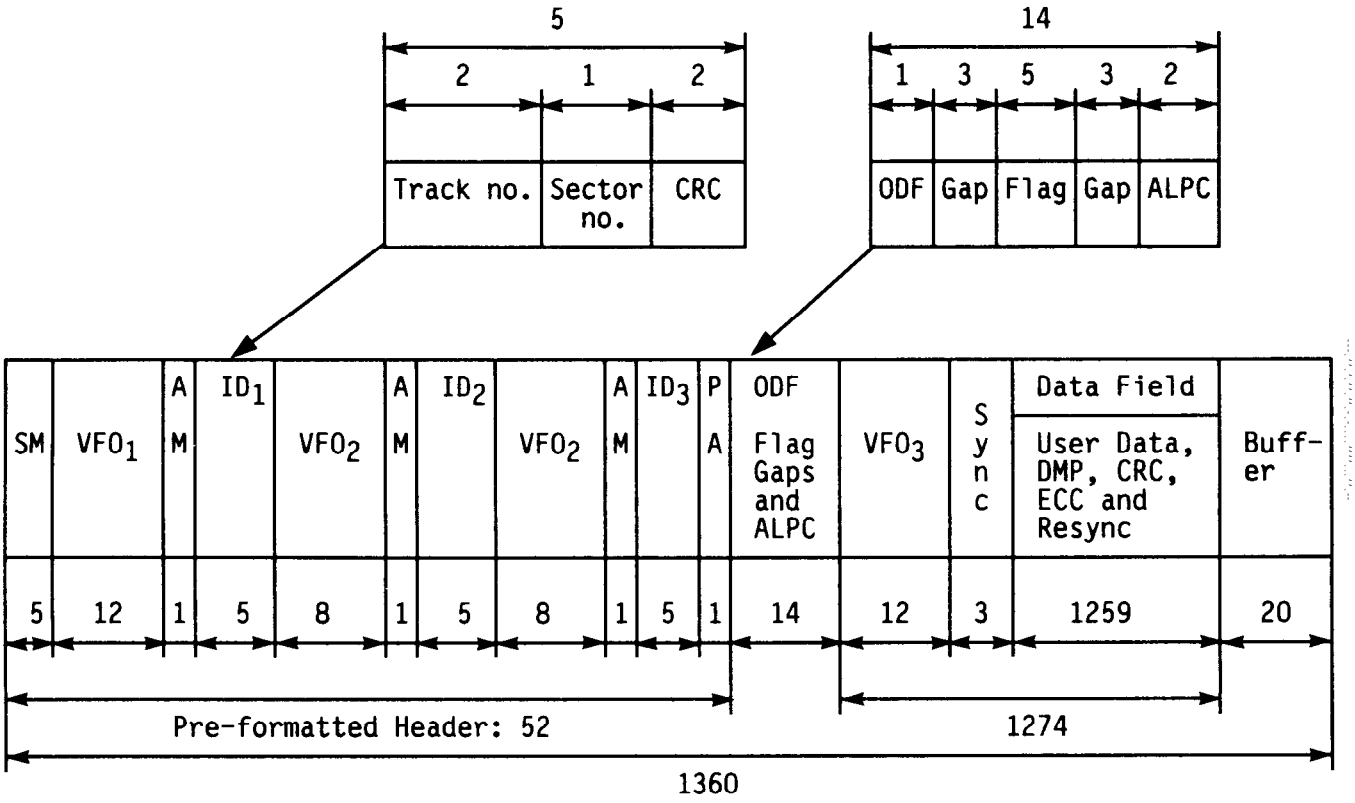

Figure 7 - Sector format for 1024 user bytes

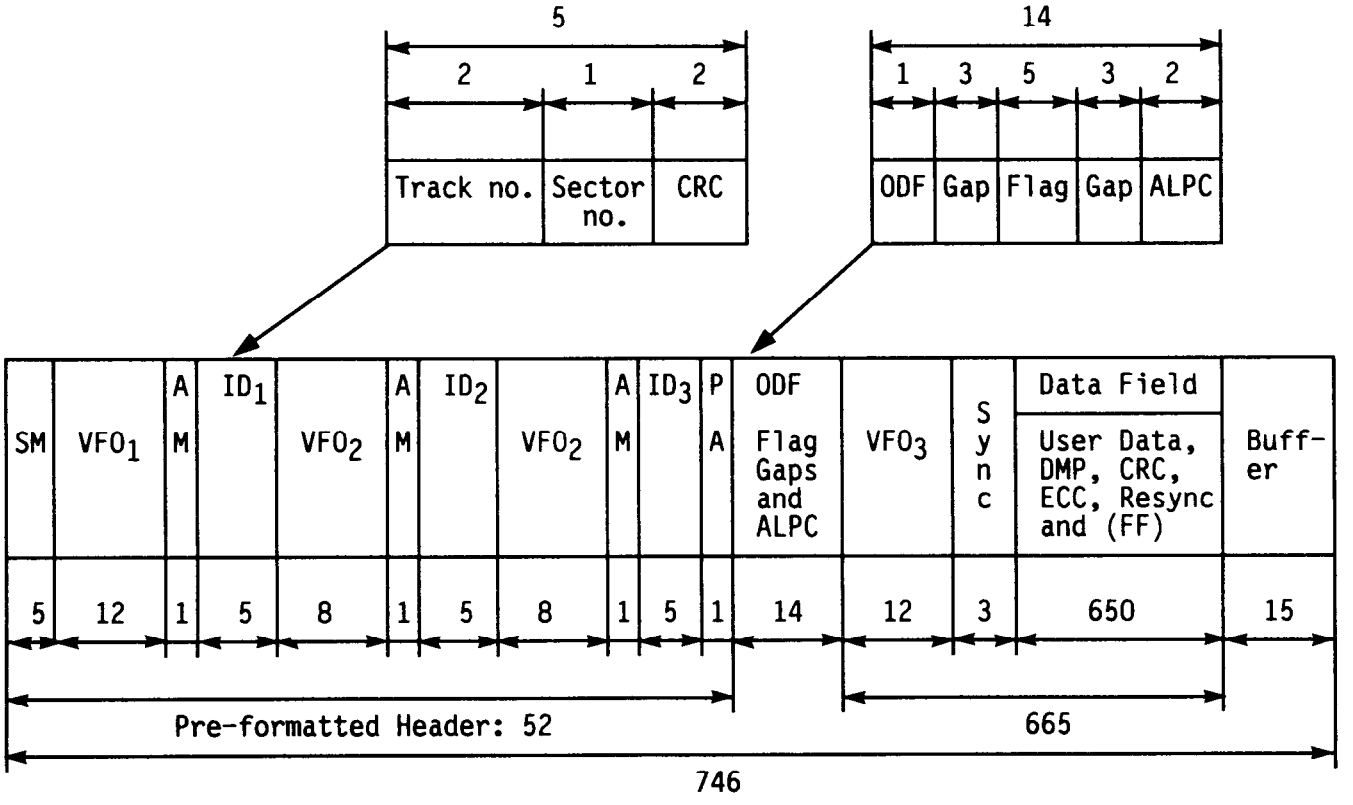

Figure 8 - Sector format for 512 user bytes

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5.2.1 Sector Mark (SM)

The Sector Mark shall have a length of 5 bytes and shall consist of pre-recorded, continuous, long marks of different Channel bits length followed by a lead-in to the VFO_1 field. This pattern does not exist in data.

The Sector Mark pattern shall be as shown in figure 9, where T corresponds to the time length of one Channel bit. The polarity of the signal obtained from a mark is specified by byte 4 of the PEP Zone. The long mark pattern shall be followed by the Channel bit pattern: 00X0010010 where X is not specified.

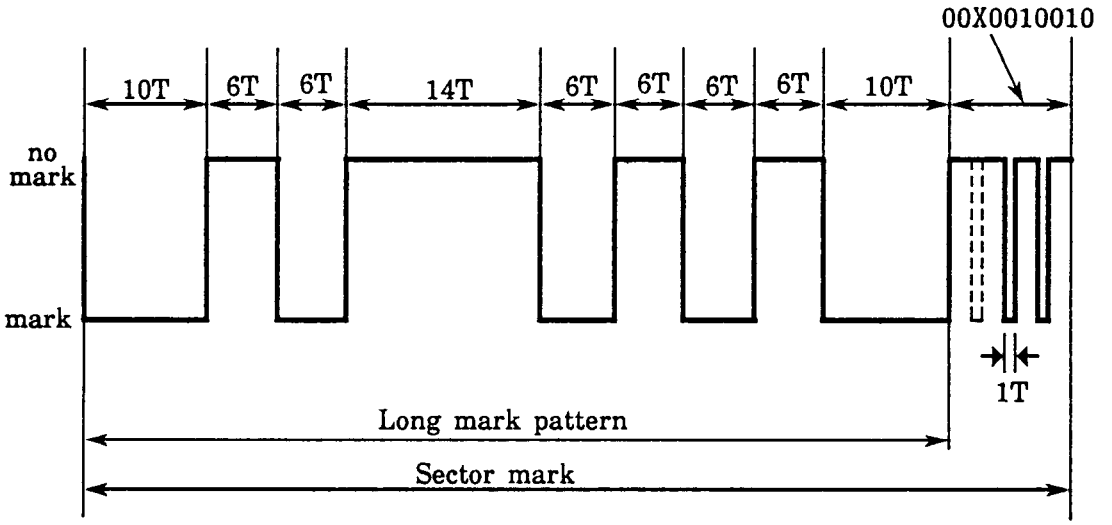

Figure 9 - Sector Mark pattern with negative polarity

5.2.2 VFO areas

There shall be four areas designated VFO_1, VFO_2 and VFO_3 to lock up the VFO. The recorded information for VFO_1 and VFO_3 is identical in length and pattern. VFO_2 shall be recorded with one of two patterns differing only in the 1st bit and shall be 4 bytes shorter than VFO_1 and VFO_3.

Since there are three ID fields, and RLL (2,7) modulation coding is used, the pattern chosen for each VFO_2 will depend on the last byte of the CRC recorded in the preceding ID field (see 5.2.13).

The continuous channel bit pattern for VFO areas shall be:

VFO_1 : 192 Channel bits = 01001001001 010010
VFO_2 : 128 Channel bits = 10010010010 010010
VFO_2 : 128 Channel bits = 00010010010 010010
VFO_3 : 192 Channel bits = 01001001001 010010

5.2.3 Address Mark (AM)

The AM is a channel bit pattern not used in RLL (2,7) and is a run-length violation for RLL (2,7). This 16-bit Channel bit pattern shall be:

0100 1000 0000 0100

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5.2.4 ID fields

These fields shall each consist of five bytes.

1st Byte

This byte shall specify the most significant byte of the track number.

2nd Byte

This byte shall specify the least significant byte of the track number.

3rd Byte

Bit 7 and 6 shall specify the ID number.

When set to 00 shall mean the ID1 field,
when set to 01 shall mean the ID2 field,
when set to 10 shall mean the ID3 field.

Bit 5 shall be ZERO.

Bits 4 to 0 shall specify the sector number.

4th and 5th Bytes

These two bytes shall specify a 16-bit CRC computed over the first three bytes of this field (see Annex B). The generating polynomial shall be

$$G(x) = x^{16} + x^{12} + x^5 + 1$$

The initial setting of the CRC register shall be all ONEs.

5.2.5 Postamble (PA)

This field shall consist of one byte following the ID3 field. Due to the use of the RLL (2,7) encoding scheme (see 5.2.13), the framing of the last byte of CRC in the ID3 field is uncertain within a few bit times. The Postamble allows the last byte of CRC to achieve closure and permits the ID field to end always in a predictable manner. This is necessary in order to locate the following field (ODF) in a consistent manner.

5.2.6 Offset Detection Flag (ODF)

This field shall be an area equal in length to 16 Channel bits with neither grooves nor pre-formatted data.

5.2.7 Gap

This field shall consist of an unrecorded area equal in length to 48 Channel bits.

5.2.8 Flag

This field is intended to prevent inadvertent write operations over previously written data. When the sector does not contain user data, this field shall be unrecorded. When the sector does contain user data, this field shall contain a continuous pattern of 80 user-written Channel bits as follows:

100100100100100100 ...

5.2.9 ALPC

This field shall consist of an initially unrecorded area equal in length to 32 Channel bits. It is intended for testing the laser power level.

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5.2.10 Sync

This field shall be an area equal in length to 48 Channel bits and shall contain the Channel bit pattern:

0100 0010 0100 0010 0010 0010 0100 0100 1000 0010 0100 1000

5.2.11 Data field

This field shall consist of either:

- 1259 bytes comprising
  - 1024 user bytes
  - 12 bytes for DMPs
  - 223 bytes for CRC, ECC and Resync

or

- 650 bytes comprising
  - 512 user bytes
  - 12 bytes for DMPs
  - 124 bytes for CRC, ECC and Resync
  - 2 (FF)-bytes.

The disposition of these bytes in the Data field is specified in Annex C.

5.2.11.1 User bytes

These bytes are at the disposal of the user for recording information. There are 1024 or 512 such bytes depending on the sector format.

5.2.11.2 Defect Management Pointers (DMP)

This field shall consist of twelve bytes denoted by Px,y, where x = 1,2,3 and y = 1,2,3,4. It is used to specify the relationship between a replacement sector and the replaced sector found defective (see 5.3). A defective sector is a sector for which the ECC and/or the CRC has detected uncorrectable erroneous data. This relationship is expressed by means of pointers. The format of a pointer $P_{x,y}$ is as follows.

1st byte ($P_{x,1}$)	2nd byte ($P_{x,2}$)	3rd byte ($P_{x,3}$)	4th byte ($P_{x,4}$)
MSB of track number	LSB of track number	Sector number	(FF)

Figure 10 - Format of a DMP

In each sector there shall be three such pointers $P_{1,y}$ $P_{2,y}$ $P_{3,y}$.

In each defective sector the pointers shall be recorded as follows:

Pointer $P_{1,y}$ shall specify the address of this sector
Pointer $P_{2,y}$ shall specify the address of the first replacement sector available
Pointer $P_{3,y}$ shall have the same content as $P_{2,y}$.

In each replacement sector the pointers shall be recorded as follows:

Pointer $P_{1,y}$ shall specify the address of this sector
Pointer $P_{2,y}$ shall specify the address of the defective sector

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Pointer $P_{3,y}$ shall have the same contents as $P_{2,y}$.

5.2.11.3 CRC and ECC

The computation of the check bytes of the CRC and ECC shall be as specified in Annex C.

5.2.11.4 Resync

The Resync fields shall be inserted between the bytes of the Data field as specified in Annex C.

5.2.12 Buffer

This field shall have a nominal length equal to 320 Channel bits (figure 7) or to 240 Channel bits (figure 8). Up to 16 additional Channel bits may be written in this field to allow completion of the RLL (2,7) coding scheme (see 5.2.13). The remaining length is to allow for motor speed tolerances and other electrical and/or mechanical tolerances.

Note - In the case of 512-byte sectors, the length of the Buffer has to be adjusted to enable the same clock frequency to be used as for 1024-byte sectors. The average length of a Buffer is 236,7 Channel bits. For the 31 sectors of a track, 17 sectors should have a Buffer of 236 Channel bits and 14 sectors should have a Buffer of 238 Channel bits.

5.2.13 Recording code

The 8-bit bytes in three ID fields and in the Data fields, except for Resync bytes, shall be converted to Channel bits on the disk according to table 3. All other fields of the sector have already been defined in terms of Channel bits. Each ONE Channel bit shall be recorded as a mark produced by switching on the laser at the appropriate power and pulse width.

The encoding method shall be the run-length limited (RLL) code known as RLL (2,7).

Table 3 - Conversion of input bits to channel bits

Input bits	Channel bits
10	0100
010	100100
0010	00100100
11	1000
011	001000
0011	00001000
000	000100

When data is followed by VFO_2 the latter shall be regarded as starting with bit pattern 010 before converting to Channel bits.

When data is followed by a Resync field, the latter shall be regarded as starting with bit pattern 011 before converting to Channel bits.

After a Resync field the RLL (2,7) coding shall start anew with the first bit of the next byte of input data.

5.3 Defect management

This part of ISO/IEC 9171 specifies a defect management scheme using Defect Management Pointers (DMPs) and a linear replacement algorithm.

The User Zone on each side of the disk contains two Defect Management Areas (DMAs) at the beginning of the zone and two DMAs at the end of the zone. Each DMA contains a Disk

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Structure Table (DST) with information on the structure of the disk. The area between the two groups of DMAs shall contain a Data Zone for recording user data and a Secondary Spare Area for recording replacement sectors.

5.3.1 Media initialization

The Data Zone shall be divided into g groups of equal size. Each group shall comprise n data sectors followed by m Primary Spare Sectors. Sectors of the Data Zone not belonging to a group shall be located after the last group. The location of the first group and the value of g, n and m shall be recorded in the DST. The location and the length of the Secondary Spare Area shall also be recorded in the DST. There is no certification of the medium prior to use.

5.3.2 Write procedure

When writing sectors in a group, the three DMPs of these sectors shall be written at the same time. The first pointer $P_{1,y}$ shall contain the address of the sector being written, the second and third pointer $P_{2,y}$ and $P_{3,y}$ shall both contain the address of the first Primary Spare Sector of that group. If a data sector in a group is found to be defective, it shall be rewritten in the first available Primary Spare Sector of that group. If there are no Primary Spare Sectors left in this group, the defective sector shall be rewritten in the first available Secondary Spare Sector in the Secondary Spare Area. If the replacement sector is found to be defective, the sector shall be rewritten in the next available spare sector. The DMPs of the replacement sector shall contain the address of the replacement sector itself and the address of the original data sector it replaces.

5.3.3 Layout of the User Zone

The User Zone shall contain four Defect Management Areas (DMAs) in track No. 0, 1, 2, N-2, N-1 and N, where N is the track number of the last track in the User Zone. The length of each DMA is 25 sectors for 1024-byte sectors, and 46 for 512-byte sectors. The address of the first sector of each DMA is given by:

	1024-byte sector		512-byte sector	
	track No.	sector No.	track No.	sector No.
DMA_1	0	0	0	0
DMA_2	1	8	1	15
DMA_3	N-2	0	N-2	0
DMA_4	N-1	8	N-1	15

The last sector of track No. 2 and the last sector of track No. N are reserved for future use.

The first sector of each DMA shall contain the Disk Structure Table (DST) after initialization of the medium. The contents of the remaining sectors of the DMAs shall be ignored in interchange.

The secondary spare area shall be located either immediately after track 3 or immediately before track N-2. The size shall not exceed 252 tracks. The area shall start at sector No. 0 of the track specified in the DDS.

The first track of the Data Zone shall be the lowest numbered track not belonging to the DMA or the Secondary Spare Area. It shall have the logical track number 0. The Data Zone shall start at sector No. 0 of the track specified in the DST.

5.3.4 Disk Definition Structure (DDS)

The Disk Definition Structure (DDS) shall have a length of one sector. It shall specify the division of the Data Zone into groups and the start addresses of the first group and of the Secondary Spare Area. The DDS shall have been recorded after initialization.

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The following defect management information shall be recorded in each of the four DDS sectors.

Byte 0:	(0A), identifier of DDS
Byte 1:	(0A), identifier of DDS
Byte 2:	track No. of the first track of the first group (logical track No. 0)
Byte 3:	(10) indicating that the pointer defect management scheme has been used and that no Secondary Defect List has been recorded.
Bytes 4,5:	(MSB, LSB) of the number *y* of groups
Bytes 6 to 9:	(MSB, byte, byte, LSB) of the number *n* of data sectors per group
Bytes 10 to 13:	(MSB, byte, byte, LSB) of the number *m* of primary spare sectors per group
Bytes 14 to 21:	shall be set to (FF)
Bytes 22 to 29:	shall be either set to (FF) or as specified in Annex D.
Bytes 30 to 33:	(MSB, byte, byte, LSB) of track number of start of secondary spare area
Bytes 34 to 37:	(MSB, byte, byte, LSB) of number of sectors in secondary spare area
Bytes 38 to 1024	(for 1024-byte sector) or 512 (for 512-byte sector): reserved for future standardization

6 Format B

Format B is based on a sampled servo tracking method.

6.1 Track layout

6.1.1 Servo format

6.1.1.1 Each track contains pre-recorded headers and servo areas.

6.1.1.2 A servo area consists of two groups each 15 Channel bits long (figure 11).

6.1.1.3 The clock is derived from the repetition of a pre-recorded mark in position 12 of the second servo group (figure 11).

6.1.1.4 Focus can be obtained by any method, either in a continuous mode or preferably in a sampled mode, where the sample is taken in the Unique Distance Part of the servo area (figure 11).

6.1.1.5 The tracking error signal is derived from the signal amplitude difference at the first two wobble marks in the servo area. These wobble marks are located at positions 3 or 4 and position 8 in the first servo group (figure 11).

6.1.1.6 Fast-seek information is derived from the location of the first wobble mark in the first servo group. Every 16 tracks the position of the first wobble mark changes from position 3 to position 4 or from position 4 to position 3 (seek toggle).Tracks numbered [K + 16 (N - 1)], where K = 1 to 16, have the first wobble mark in position 3 if N is odd and in position 4 if N is even (figure 11).

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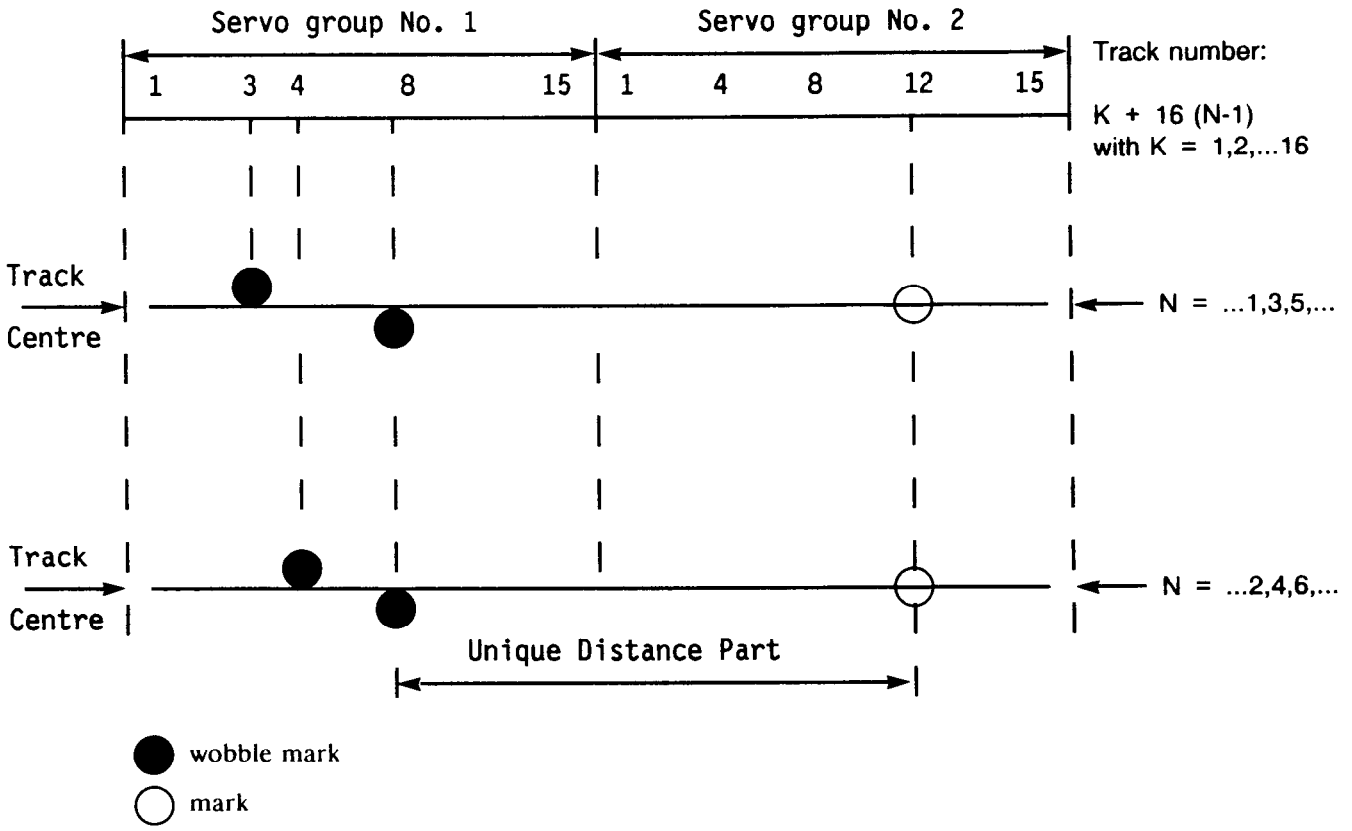

Figure 11 - Layout of the servo area

Note - For future performance improvements of access times, the scheme may be expanded by adding an extra pit at a location between No. 3 and No. 8 in servo group No. 1 with keeping compatibility with this format. Therefore this area should not be used as mirror mark on playback.

6.1.2 Properties of pre-recorded signals

6.1.2.1 The standard optical conditions for measuring the parameters are specified in 13.1.1 of ISO/IEC 9171-1.

6.1.2.2 The amplitude of pre-recorded signals, except for the wobble marks, whilst tracking at track centre shall be negative and their absolute value shall not be less than 0,40 I_O. Over a track the variation of this value shall be within 0,20 I_O, which is the signal obtained from an unrecorded area.

6.1.2.3 The full width at half maximum amplitude of all pre-recorded signals recorded at a frequency lower than 1,4 MHz at rotational frequency of 30 Hz shall be less than 2,3 times the length of a Channel bit.

6.1.2.4 The average signal amplitude of the first wobble mark (position 3 or 4) and the average signal amplitude of the second wobble mark (position 8) shall be negative and their absolute value shall

- be not less than 0,40 I_O whilst tracking on the line connecting them; the variation of this value over a track shall be within 0,20 I_O,
- be within 5% whilst tracking at track centre,

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- differ by (0,15 ± 0,05) I_0 whilst tracking with an offset of 0,10 μm from the track centre.

6.1.2.5 The wobble marks are located approximately 1/4 track pitch off the track centre. The first wobble mark (position 3 or 4) is offset towards the centre of the disk, the second wobble mark (position 8) towards the outer radius.

6.1.2.6 The displacement of the pre-recorded marks, from their intended position as determined by the repetition of the clock marks shall not exceed 0,1 Channel bit length.

6.1.2.7 The jitter of the clock marks shall not exceed:

- Track-to-track : 1/4 Channel bit
- In-track high frequency : 1/30 Channel bit
- In-track low frequency : 1/4 Channel bit.

6.2 Data structure

6.2.1 Track format

A track shall be divided into 32 sectors and shall start with sector 0 and end with sector 31.

6.2.2 Sector format

A sector shall be divided into 43 segments of 18 bytes each. The first two bytes of each segment shall be a servo area and the next 16 bytes of each segment shall contain data. The data in the first segment shall be the Sector Header of 16 bytes. The data in the remaining 42 segments constitute the Data Field of 42 x 16 = 672 bytes.

6.2.2.1 Sector Header

The Sector Header shall contain the following pre-recorded information (except in bytes 7 to 15) in 4/15 recording code.

Byte 0

Sync Mark: M1F in 4/15 recording code

Byte 1

Sector Number: (value 0 to 31)

Bytes 2 and 3

Track Number: (MSB, LSB)

Bytes 4 and 5

Track Number: LSB, MSB in ONE's complement

Byte 6

Track Number: LSB in ONE's complement

Bytes 7 to 12

unrecorded: unused

Bytes 13 to 15

Laser Power Control field: not pre-recorded

The Sync Mark allows the drive to obtain sector synchronization (see table 6 for the Channel bit pattern of M1F).

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The Sector Address constituted by the sector and track numbers together with the Track Number in ONE's complement and the additional Track Number LSB in ONE's complement facilitate fast and reliable random access.

Note - As the Sector header is not protected by ECC, it is expected that drives will maintain a running check of Sector Addresses during tracking.

The Laser Power Control field is intended to allow the drive to calibrate its write power. This field is initially unrecorded and may contain undefined data after use.

6.2.2.2 Data field

The Data field of a sector shall be subdivided into:

- user data
- Defect Management Pointers (DMP)

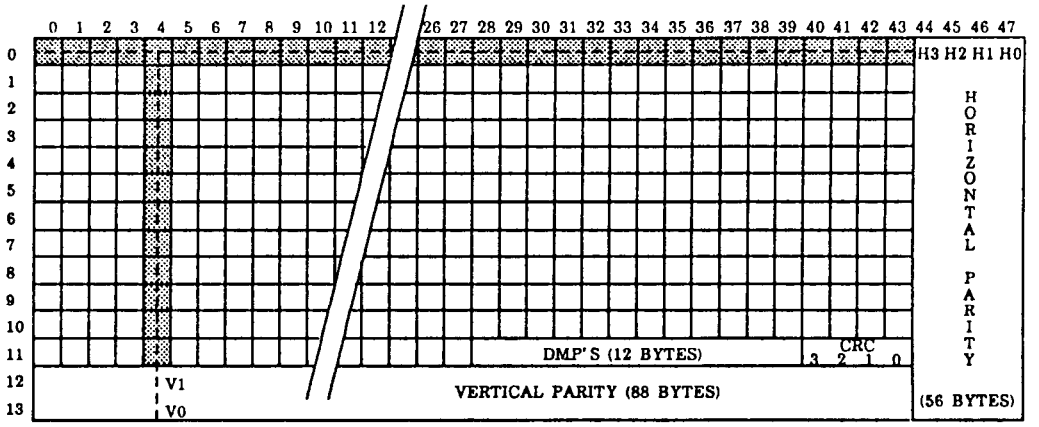
} 524 bytes, numbered 0 to 523

- error detection and correction data, 148 bytes

The number of DMP bytes is specified in the Defect Management Track (DMT); it shall be between 1 and 12 (see 6.2.5.5).

All bytes of the Data Field are equally protected by a Reed-Solomon error correction product code.

Transferred left-to-right, top-to-bottom



USER DATA	512
DMPs	12
CRC	4
HORIZONTAL PARITY	56
VERTICAL PARITY	88
	672 bytes

Figure 12 - Layout of a sector with 12 DMP bytes

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6.2.3 Error detection and correction

The error detection and correction data allows for various implementation strategies in the drive and controller. Depending on the type of applications and the type of media recommended, the correction strategy can be optimized for performance in the drive.

6.2.3.1 Error correction code

For error correction purposes, the data field (see figure 12) is mapped onto a two-dimensional matrix of 48 columns (vertical code words) and 14 rows (horizontal code words).

Each row is a Reed-Solomon code word of 48-byte symbols, four of which are parity. The four parity bytes H3, H2, H1 and H0 are located at the right most part of each row. The horizontal code word generator polynomial is

$$G(x) = \prod_{i=0}^{i=3} (x + \alpha^i)$$

in which α is the element of the Galois field generated by the primitive polynomial

$$G_p(x) = x^8 + x^4 + x^3 + x^2 + 1$$

The row parity bytes are the residual of the division of the information polynomial by the generator polynomial. The highest order symbol of the information polynomial shall be the data placed in the left most column while the lowest order symbol of it shall be the data placed in the column which is closest to the area for the parity check symbols.

The information polynomial does not contain powers 0 to 3 of α.

The highest order symbol of the residual polynomial shall be placed in the left most column of the area for the parity check symbols, while the zero-th order of it shall be placed in the right most column. Each column is a Reed-Solomon code word of 14 byte symbols, two of which are parity. The two parity bytes V1 and V0 are located at the bottom part of each column. The vertical code word generator polynomial is $(x + \alpha^0)(x + \alpha^1)$ in which α is the same as for the horizontal code words.

The column parity bytes are the residual of the division of the information polynomial by the generator polynomial.

The highest order symbol of the information polynomial shall be the data placed at the top row while the lowest order symbol of it shall be the data placed in the row which is closest to the area for the parity check symbols. The information polynomial does not contain powers 0 and 1 of α.

The highest order symbol of the residual polynomial shall be placed at the top row of the area for the parity check symbols while the zero-th order of it shall be placed in the bottom row. Each byte of the data field is part of two code words, one horizontal and one vertical.

The first byte received by the drive to form a two dimensional matrix shall be placed in the top left corner of the matrix; the successive bytes are allocated from left to right and from top to bottom forming a 12 x 44 matrix.

The data is written on the disk in horizontal code word symbol sequence (ascending order). This means that the first symbol in the data field of a sector is byte 0 of horizontal code

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word 0, the second symbol in the data field is byte 1 of horizontal code word 0, and the last symbol in the data field is byte 47 of horizontal code word 13.

6.2.3.2 Cyclic Redundancy Check (CRC)

For additional detection and correction capabilities, a CRC like information of 4 bytes is added. This CRC is computed only over the user data and the DMPs. The CRC symbols are defined as the parity symbols of a Reed-Solomon-like code word consisting of the 524 bytes of user data and DMPs as information bytes.

The code word generator polynomial is $(x + \alpha^4)(x + \alpha^5)(x + \alpha^6)(x + \alpha^7)$, where α is the same as defined for the horizontal Reed-Solomon code word.

6.2.4 Recording method

6.2.4.1 Recording code

The 4/15 recording code maps 1 byte of user data onto 15 Channel bits using only 4 written marks. The symbols in the 4/15 code are constructed in such a way that in the case of user data the most and least significant 4 bits of a byte are generated independent of each other, except in the case where one of these 4-bit bytes is equal to (F). Tables 4 and 5 show the 4/15 symbols for the user data.

Thirty combinations which obey the rules of the code are reserved for possible special functions. The 4/15 symbols for special functions are shown in table 6.

6.2.4.2 Accuracy of the position of user-written marks

The displacement of the user-written marks from their intended positions, as determined by the repetition of the clock marks, shall not exceed 0,1 Channel bit length. Identifiable contributions from irregularities in the media format, defects and media-related eccentricity are excluded.

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Table 4 - 4/15 recorded symbols for the least significant 4 bits of a user data byte

LSB	Mark positions														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
(0)	x				x										
(1)	x						x								
(2)	x								x						
(3)	x										x				
(4)	x												x		
(5)			x				x								
(6)			x						x						
(7)			x								x				
(8)			x										x		
(9)					x				x						
(A)					x						x				
(B)					x								x		
(C)							x				x				
(D)							x						x		
(E)									x				x		

MSB	LSB	Mark positions														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
(0)	(F)	x	x	x			x									
(1)	(F)	x	x	x					x							
(2)	(F)	x	x	x							x					
(3)	(F)	x	x	x									x			
(4)	(F)	x	x	x											x	
(5)	(F)			x	x	x			x							
(6)	(F)			x	x	x					x					
(7)	(F)			x	x	x							x			
(8)	(F)			x	x	x									x	
(9)	(F)					x	x	x			x					
(A)	(F)					x	x	x					x			
(B)	(F)					x	x	x							x	
(C)	(F)							x	x	x			x			
(D)	(F)							x	x	x					x	
(E)	(F)									x	x	x			x	
(F)	(F)								x	x	x			x		

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Table 5 - 4/15 recorded symbols for the most significant 4 bits of a user data byte

MSB	Mark positions														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
(0)		x				x									
(1)		x						x							
(2)		x								x					
(3)		x										x			
(4)		x												x	
(5)				x				x							
(6)				x						x					
(7)				x								x			
(8)				x										x	
(9)						x				x					
(A)						x						x			
(B)						x								x	
(C)								x				x			
(D)								x						x	
(E)										x				x	

MSB	LSB	Mark positions														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
(F)	(0)	x			x	x	x									
(F)	(1)	x					x	x	x							
(F)	(2)	x							x	x	x					
(F)	(3)	x									x	x	x			
(F)	(4)	x											x	x	x	
(F)	(5)			x			x	x	x							
(F)	(6)			x					x	x	x					
(F)	(7)			x							x	x	x			
(F)	(8)			x									x	x	x	
(F)	(9)					x			x	x	x					
(F)	(A)					x					x	x	x			
(F)	(B)					x							x	x	x	
(F)	(C)							x			x	x	x			
(F)	(D)							x					x	x	x	
(F)	(E)									x			x	x	x	
(F)	(F)								x	x	x			x		

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Table 6 - 4/15 recorded symbols reserved for special functions

FLAG	MSN	LSN	Mark positions														
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
M	(0)	(F)		x			x	x	x								
M	(1)	(F)		x					x	x	x						
M	(2)	(F)		x							x	x	x				
M	(3)	(F)		x									x	x	x		
M	(5)	(F)				x			x	x	x						
M	(6)	(F)				x					x	x	x				
M	(7)	(F)				x							x	x	x		
M	(9)	(F)						x			x	x	x				
M	(A)	(F)						x					x	x	x		
M	(C)	(F)								x			x	x	x		
M	(F)	(5)		x	x	x			x								
M	(F)	(6)		x	x	x					x						
M	(F)	(7)		x	x	x							x				
M	(F)	(8)		x	x	x									x		
M	(F)	(9)				x	x	x			x						
M	(F)	(A)				x	x	x					x				
M	(F)	(B)				x	x	x							x		
M	(F)	(C)						x	x	x			x				
M	(F)	(D)						x	x	x					x		
M	(0)	(0)	x	x	x	x											
M	(1)	(1)		x	x	x	x										
M	(2)	(2)			x	x	x	x									
M	(3)	(3)				x	x	x	x								
M	(4)	(4)					x	x	x	x							
M	(5)	(5)						x	x	x	x						
M	(6)	(6)							x	x	x	x					
M	(7)	(7)								x	x	x	x				
M	(8)	(8)									x	x	x	x			
M	(9)	(9)										x	x	x	x		
M	(A)	(A)											x	x	x	x	

6.2.5 Defect management

The defect management defines the method to handle defective sectors detected during the write and/or verify process. Small errors in a sector are corrected by the error detection and correction (EDAC) system during the read process (see 6.2.3). Large defects result in the retirement of the sector and a rewrite of its contents in a spare sector of an alternative area.

The defect management is based on a sector replacement scheme. The addresses of the rewritten sectors and their replacement sectors shall be recorded in maps. As an option, the connection between the sectors can also be given by pointers recorded in the sectors themselves.

6.2.5.1 Write procedure

The user zone of the disk shall be divided in up to 63 bands, each of which consists of three areas: a prime area for recording data, an alternative area for rewriting sectors and a map

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area for recording the link between the rewritten sector and the replacement sector. It is allowed to define overflow bands with only an alternative area and a map area.

Data shall be recorded in the sectors of a prime area. Sectors found defective during the write or verify process shall be retired. The defective sector shall be rewritten in the first available spare sector of the alternative area of the same band as the prime area. If this replacement sector is found to be defective, the sector shall be rewritten in the next available spare sector. If there are no spare sectors left in the alternative area of this band, the defective sector shall be rewritten sequentially in the alternative areas of the overflow bands. The addresses of the defective sector and the replacement sector shall be recorded in the map area of the band in which the replacement sector has been recorded. As an option, one can record pointers with the link information in the sectors (see 6.2.5.5).

6.2.5.2 Layout of the user zone

The user zone shall contain up to 63 bands, each of which shall consist of

- a prime area of zero or more tracks,
- an alternative area of four tracks, and
- a map area of four tracks.

A band with zero tracks of prime area is called an overflow band. The areas need not be consecutive, neither need the areas of a band be grouped together. The length and the location of the areas shall be recorded in the Defect Management Track (DMT). Each area shall start on sector 0 of a track and end on sector 31 of a track. The length of each alternative area restricts the number of rewrites in this area to 128.

6.2.5.3 Defect Management Track

The Defect Management Track (DMT) defines the location of the areas of each band in the user zone. It shall be recorded on track -2 and optionally duplicated on track 20001. The user data bytes of all sectors of the DMT shall be identical. They shall be recorded during mastering or by the drive when initializing the disk. The content of each DMT sector shall be:

Byte 0

Defect management mode, set to (00).

Byte 1

A number n between 0 and 11 giving the number of user data bytes in a sector as 512 + n.

Byte 2

A number m between 1 and 63 giving the number of bands in the user zone.

Bytes [3 + 8 (i - 1)] to [4 + 8 (i - 1)]

MSB followed by LSB of the track number of the first track of the map area of band i.

Bytes [5 + 8 (i - 1)] to [6 + 8 (i - 1)]

MSB followed by LSB of the track number of the first track of the alternative area of band i.

Bytes [7 + 8 (i - 1)] to [8 + 8 (i - 1)]

MSB followed by LSB of the track number of the first track of the prime area of band i. It shall be set to (FFFF) for an overflow band.

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Bytes [9 + 8 (i - 1)] to [10 + 8 (i - 1)]

Number of tracks in the primary area of band i. It shall be set to (FFFF) for an overflow band.

In the above formulae for the byte numbers i is an integer such that:

$$1 \leq i \leq m \leq 63$$

Unused bytes shall be set to (FF). If there is pre-recorded information in the User Zone (track 0 to 19999), the location of the bands shall be given by the manufacturer. In this case, the DMT shall be pre-recorded. Tables 7 and 8 show an example of a DMT sector and the corresponding layout of the disk.

6.2.5.4 Map area

The map area is written as a sequential file of sectors, starting at the first sector. The sectors contain information that links sectors of the alternative area to sectors of the prime area. The last written sector of a map area always contains all link information of the band. A sector can contain up to 128 map fields of 4 bytes each, where each map field contains one link. A defective sector in the map area shall be rewritten in the next available sector. The map fields are sorted in ascending order of the address of the prime area sector.

The format of a map sector shall be as follows:

Bytes 0 to 3	map field 1
Bytes 4(j-1) to (4j-1)	map field j, $2 \leq j \leq 127$
Bytes 508 to 511	map field 128
Bytes 512 to 522	DMP field, set according to byte 523
Byte 523	DMP identifier, set according to 6.2.5.5.

The format of a map field shall be as follows:

Bytes 0 to 2	Sector address of the rewritten sector in the prime area (MSB, LSB of the track number, sector number).
Byte 3	Sequence number of the replacement sector in the alternative area. The number will have a value from 0 to 127, corresponding to the absolute number of the sector in the alternative area.

Unused map fields shall be set to (FF).

6.2.5.5 Defect Management Pointers

The defect management scheme allows the optional use of pointers to link defective sectors and replacement sectors. These Defect Management Pointers (DMPs) can be stored in bytes 512 to 522 of the data field of each sector. Byte 1 of the DMT sectors gives the number of bytes in a sector that can be used for user data and the number of bytes reserved for DMPs. If more than 512 bytes of user data are recorded, the additional bytes shall be recorded immediately after byte 511. All user data bytes shall be transferred from or to the host. Unused DMP bytes shall be set to (FF).

Byte 523 shall contain the DMP identifier, indicating the meaning of the DMP bytes. Each meaning is indicated by two values, one for even and one for odd tracks. The different values allow for the detection of empty sectors with ECC; crosstalk from an adjacent track can be identified as invalid data since it has the wrong identifier value.

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The total number of possible meanings of the DMP identifier is 128. The four assigned meanings of byte 523 are:

(00) even tracks, (01) odd tracks

These numbers shall only be used in the prime areas, where they indicate that the DMP field of the sectors contain a forward pointer. Bytes 520 to 522 contain the address (MSB, LSB of the track number, sector number) of the sector in the alternative area where rewrites of defective sectors in the prime area may begin. This points initially to the first sector of the alternative area in this band. As alternative sectors are used for rewrites, this pointer can be updated to indicate the next available sector in the alternative area.

(02) even tracks, (03) odd tracks

These numbers shall only be used in the alternative areas, where they indicate a backward pointer. Bytes 520 to 522 contain the address (MSB, LSB of the track number, sector number) of the sector in the prime area of which this sector is a rewrite.

(04) even tracks, (05) odd tracks

These numbers can be used both in the prime, alternative and map areas, where they indicate a self-address and a logical block address (LBA). Bytes 517 to 519 contain the address (MSB, LSB of the track number, sector number) corresponding to the header address of this sector. Bytes 520 to 522 contain the LBA (LBA (MSB), LBA, LBA (LSB)) of the prime area sector in both the prime and alternative areas and contain (FF) in the map areas.

The LBA is the absolute sector number (0 to maximum) assigned consecutively on each side of the disk to each sector in the prime areas.

(FE) even tracks, (FF) odd tracks

DMPs not used.

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Table 7 - Example of a sector in the Defect Management Track (DMT)

Byte No.	Value	DMT entry (user data size = 520)
0	0	
1	8	
2	5	
3 and 4	9988	1
5 and 6	4990	
7 and 8	0000	
9 and 10	4990	
11 and 12	9992	2
13 and 14	9984	
15 and 16	4994	
17 and 18	4990	
19 and 20	9996	3
21 and 22	15002	
23 and 24	10012	
25 and 26	4990	
27 and 28	10000	4
29 and 30	19996	
31 and 32	15006	
33 and 34	4990	
35 and 36	10004	5
37 and 38	10008	
39 and 40	(FF)	
41 and 42	(FF)	
43 to 506	(FF)	6 to 63
507 to 522	(FF)	
523	(FF)	(track 20001)
	(FE)	(track -2)

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Table 8 - Logical disk format corresponding to the DMT sector of table 7

Track number	Band	Area description
-2	-	Defect Management Track
0 4989	No 1	Prime area
4990 4993	No 1	Alternative area
4994 9983	No 2	Prime area
9984 9987	No 2	Alternative area
9988 9991	No 1	Map area
9992 9995	No 2	Map area
9996 9999	No 3	Map area
10000 10003	No 4	Map area
10004 10007	No 5	Map area
10008 10011	No 5	Alternative area
10012 15001	No 3	Prime area
15002 15005	No 3	Alternative area
15006 19995	No 4	Prime area
19996 19999	No 4	Alternative area
20001	-	Defect Management Track

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Annex A
(informative)

Values to be implemented in future standards

This part of ISO/IEC 9171 specifies one value only for bytes which identify optical disk cartridges which conform to this part of ISO/IEC 9171. It is expected that further media types will be developed in future. It is therefore recommended to use the following values for these other media.

A.1 Byte 0 of the Control Track PEP Zone

Setting of bits 4 to 6:

001 should mean Constant Linear Velocity (CLV)

010 should mean Modified Constant Angular Velocity (MCAV)

011 should mean Modified Constant Linear Velocity (MCLV)

A.2 Byte 7 of the Control Track PEP Zone

The following bit pattern should have the indicated meaning:

0000 0000 Read-only ODCs (ROM)

0010 0000 Re-writeable ODCs of the type thermo-magneto optic (MO)

0011 0000 Re-writeable ODCs of the type phase change

1001 0000 Partial ROM of Write Once ODCs

1010 0000 Partial ROM of MO

1011 0000 Partial ROM of phase change.

Note that when the 8th bit is set to ONE, this indicates a partial ROM.

A.3 Bytes 35 to 47 of the SFP Zone

These bytes (and the corresponding bytes between byte 50 to byte 359) express erase power and erase pulse width under different conditions.

A.4 Bytes 360 to 383 of the SPF Zone

These bytes should be used to express magnetic field parameters.

A.5 Bytes 386 to 389 of the SFP Zone

These bytes should be used for the specification of speed stepping parameters for the MCAV recording mode.

Byte 386 should be used for the most significant byte of the number of tracks per band.

Byte 387 should be used for the least significant byte of the number of tracks per band.

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Byte 388 should be used for the number of clock steps per band.

Byte 389 should be used for the number of added sectors per band.

A.6 Bytes 390 to 392 of the SFP Zone

These bytes should be used for variable track pitch information.

A.7 Byte 393 of the SFP Zone

This byte should be used to indicate the radius of track 0.

A.8 Bytes 472 to 479 of the SFP Zone

These bytes should be used for specifying write strategy.

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Annex B
(normative)

CRC for ID fields of Format A

The sixteen bits of the CRC shall be computed over the first three bytes of the ID field. The generator polynomial shall be

$$G(x) = x^{16} + x^{12} + x^5 + 1$$

The residual polynomial shall be

$$R(x) = \left(\sum_{i=8}^{i=23} \bar{a}_i x^i + \sum_{i=0}^{i=7} a_i x^i \right) x^{16} \mod G(x)$$

where a_i denotes a bit of these first three bytes and $\bar{a}_i$ an inverted bit. The highest order bit of the first byte is a_{23}.

The sixteen bits C_k of the CRC are defined by

$$R_c(x) = \sum_{k=0}^{k=15} c_k x^k$$

where c_{15} is recorded as the highest order bit of the fourth byte in the ID field.

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Annex C
(normative)

Interleave, CRC, ECC, Resync for the Data field of Format A

C.1 Interleave

C.1.1 Interleave for 1024-byte sectors

The different bytes shall be designated as follows.

D_n are user data bytes
$P_{h,m}$ are DMP bytes
C_k are CRC check bytes
$E_{s,t}$ are ECC check bytes

These bytes shall be ordered in a sequence A_n in the order in which they shall be recorded on the disk. Depending on the value of n, these elements are:

for $1 \leq n \leq 1024$: $A_n = D_n$

for $1025 \leq n \leq 1036$: $A_n = P_{h,m}$

for $1037 \leq n \leq 1040$: $A_n = C_k$

for $1041 \leq n \leq 1200$: $A_n = E_{s,t}$

where:

$$h = int\left[\frac{n - 1025}{4}\right] + 1$$

$$m = [(n - 1025) \bmod 4] + 1$$

$$k = n - 1036$$

$$s = [(n - 1041) \bmod 10] + 1$$

$$t = int\left[\frac{n - 1041}{10}\right] + 1$$

In this notation *int* [x] denotes the largest integer smaller than x.

The first three parts of A_n are 10-way interleaved by mapping them onto a two-dimensional matrix B_{ij} with 104 rows and 10 columns. Thus

for $1 \leq n \leq 1040$: $B_{ij} = A_n$

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where:

$$i = 103 - int\left[\frac{n-1}{10}\right]$$

$$j = (n-1) \bmod 10$$

C.1.2 Interleave for 512-byte sectors

For 512-byte sectors the sequence of bytes shall be denoted by A'_n, the other notations shall be as specified in C.1.1. In addition the two (FF) bytes are shown as (FF).

for $1 \leq n \leq 512$: $A'_n = D_n$

for $513 \leq n \leq 524$: $A'_n = P_{h,m}$

for $525 \leq n \leq 526$: $A'_n = (FF)$

for $531 \leq n \leq 610$: $A'_n = E_{s,t}$

where:

$$h = int\left[\frac{n-513}{4}\right] + 1$$

$$m = [(n-513) \bmod 4] + 1$$

$$k = n - 526$$

$$s = [(n-531) \bmod 10] + 1$$

$$t = int\left[\frac{n-531}{5}\right] + 1$$

The first four parts of A'_n are 5-way interleaved by mapping them on a two-dimensional matrix B'_{ij} with 106 rows and 5 columns. Thus:

for $1 \leq n \leq 530$: $B'_{ij} = A'_n$

where:

$$i = 105 - int\left[\frac{n-1}{5}\right]$$

$$j = (n-1) \bmod 5$$

C.2 CRC

C.2.1 General

The CRC and the ECC shall be computed over the Galois field based on the primitive polynomial

$$G_p(x) = x^8 + x^5 + x^3 + x^2 + 1$$

The generator polynomial for the CRC bytes shall be

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$$G_c(x) = \prod_{i=136}^{i=139} (x + \alpha^i)$$

where the element $\alpha^i = (\beta^i)^{88}$, with β being a primitive root of $G_p(x)$. The value of the n-th bit in a byte is the coefficient of the n-th power of β, where $0 \leq n \leq 7$, when β is expressed on a polynomial basis.

C.2.2 CRC for 1024-byte sectors

The four check bytes of the CRC shall be computed over the user data and the DMP bytes.

The information polynomial shall be

$$I_c(x) = \left[\sum_{i=103}^{i=1} \left(\sum_{j=0}^{j=9} (B_{i,j})\, x^i \right)\right] + \sum_{j=0}^{j=5} (B_{o,j})\, x^o$$

The contents of the four check bytes C_k of the CRC are defined by the residual polynomial

$$R_c(x) = I_c(x)\, x^4 \quad \text{mod } G_c(x)$$

$$R_c(x) = \sum_{k=1}^{k=4} C_k\, x^{4-k}$$

The last equation specifies the storage locations for the coefficients of the polynomial.

C.2.3 CRC for 512-byte sectors

The four check bytes of the CRC shall be computed over the user data, the DMP bytes and the two (FF) bytes. The information polynomials shall be

$$I'_c(x) = \left[\sum_{i=105}^{i=1} \left(\sum_{j=0}^{j=4} (B'_{i,j})\, x^i \right)\right] + (B'_{o,o})\, x^o$$

The contents of the four CRC check bytes shall be calculated as specified in C.2.2, however using polynomial $I'_c(x)$.

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C.3 ECC

The primitive polynomial $G_p(x)$ and the elements α^i and β shall be as specified in C.2.1. The generator polynomial for the check bytes of the ECC shall be

$$G(x) = \prod_{i=120}^{i=135} (x + \alpha^i)$$

This polynomial is self-reciprocal. This property can be used to reduce the hardware size. The data input shall be MSB first. The initial setting of the ECC register shall be all ZEROs. The bits of the computed check bytes shall be inverted before they are encoded into Channel bits.

C.3.1 ECC for 1024-byte sectors

The 160 check bytes of the ECC shall be computed over the user bytes, the DMP bytes and the CRC bytes. The corresponding 10 information polynomials shall be:

$$I_{Ej}(x) = \sum_{i=0}^{i=103} (B_{i,j})\, x^i$$

where $0 \leq j \leq 9$.

The contents of the 16 check bytes $E_{s,t}$ for each polynomial $I_{Ej}(x)$ are defined by the residual polynomial

$$R_{E_j}(x) = I_{E_j}(x)\, x^{16} \mod G_E(x)$$

$$R_{E_j}(x) = \sum_{t=1}^{t=16} E_{j+1,t}\, x^{16-t}$$

The last equation specifies the storage locations for the coefficients of the polynomials.

C.3.2 ECC for 512-byte sectors

The 80 check bytes of the ECC shall be computed over the user data bytes, the DMP bytes, the two (FF) bytes and the CRC bytes. The corresponding 5 information polynomials shall be:

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$$I'_{Ej}(X) = \sum_{i=0}^{i=1\text{o}5} (B'_{i,j})\, X^i$$

where $0 \leq j \leq 4$.

The calculation of the 16 check bytes for each of the information polynomials $I'_{Ej}(x)$ shall be carried out as specified in C.3.1.

C.4 Resync

The Resync fields shall be inserted in the Data field to prevent loss of synchronization and to limit the propagation of errors in the user data. Whilst they are numbered consecutively all Resync fields are identical; they contain the following pattern of Channel bits

0010 0000 0010 0100

For 1024-byte sectors, a field RSn shall be inserted between bytes A_{20n} and A_{20n+1}, where $1 \leq n \leq 59$.

For 512-byte sectors, a field RSn shall be inserted between bytes A_{15n} and A_{15n+1}, where $1 \leq n \leq 40$.

C.5 Recording sequence for the Data field

The elements of the Data field shall be recorded on the disk according to sequence A_n or A'_n, as applicable, immediately following the Sync bytes and with the Resync bytes inserted as specified in clause C.4.

Figure C.1 and C.2 show in matrix form the arrangement of these elements. The sequence of recording is from left-to-right and top-to-bottom.

SB designates a Sync byte
D designates a user byte
RS designates a Resync byte
P designates a DMP byte
C designates a check byte for CRC
E designates a check byte for ECC
(FF) designates a (FF) byte

For 1024-byte sectors (figure C.1) the first 104 rows contain in columns 0 to 9 the user bates, the DMP bytes and the CRC check bytes. The next 16 rows contain only the ECC check bytes.

For 512-byte sectors (figure C.2) the first 106 rows contain in columns 0 to 4 the user bytes, the DMP bytes, the two (FF) bytes and the CRC check bytes. The next 16 rows contain only the ECC check bytes.

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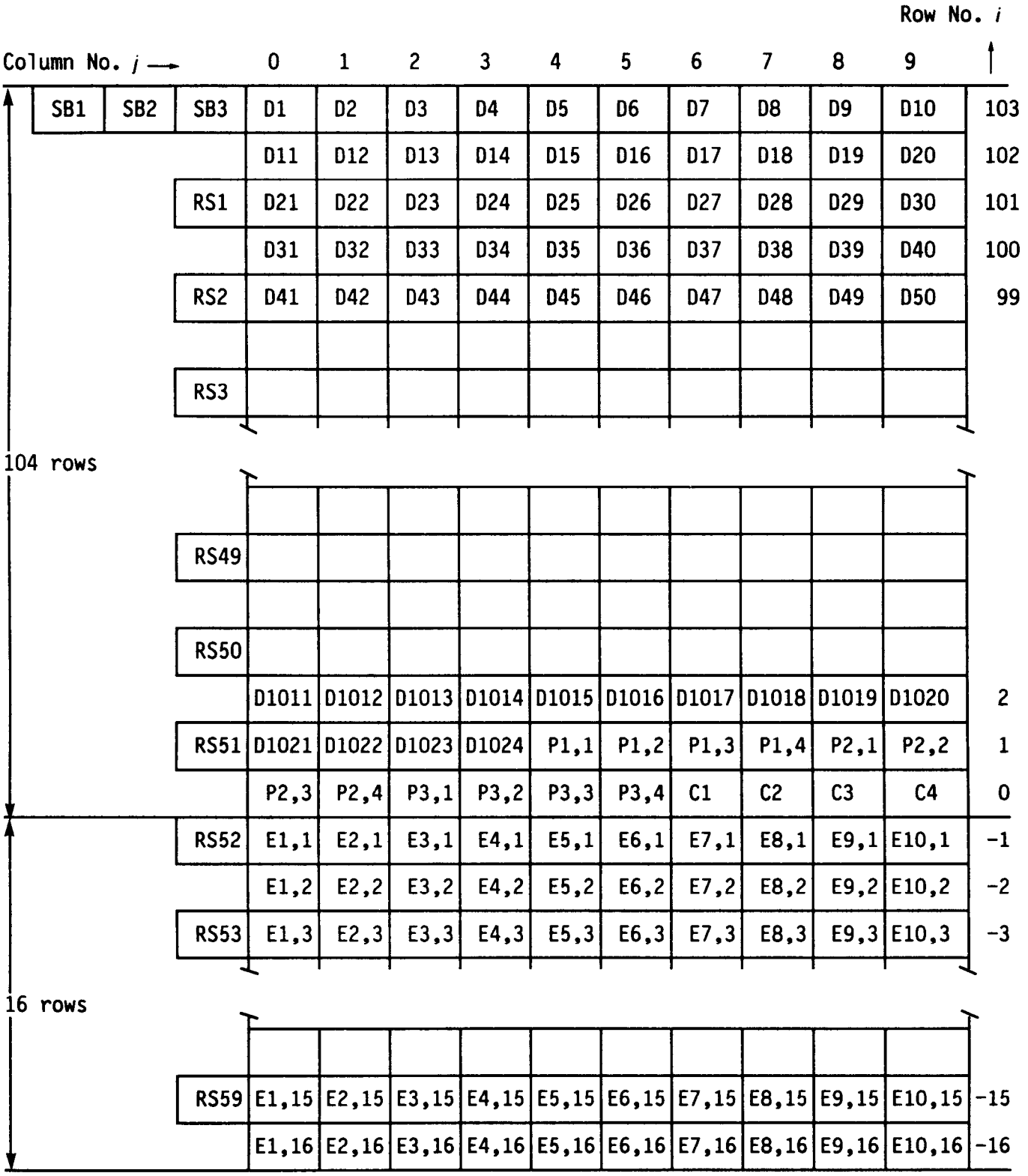

Figure C.1 - Data field configuration, 1024-bytes sectors, ECC with 10-way interleave

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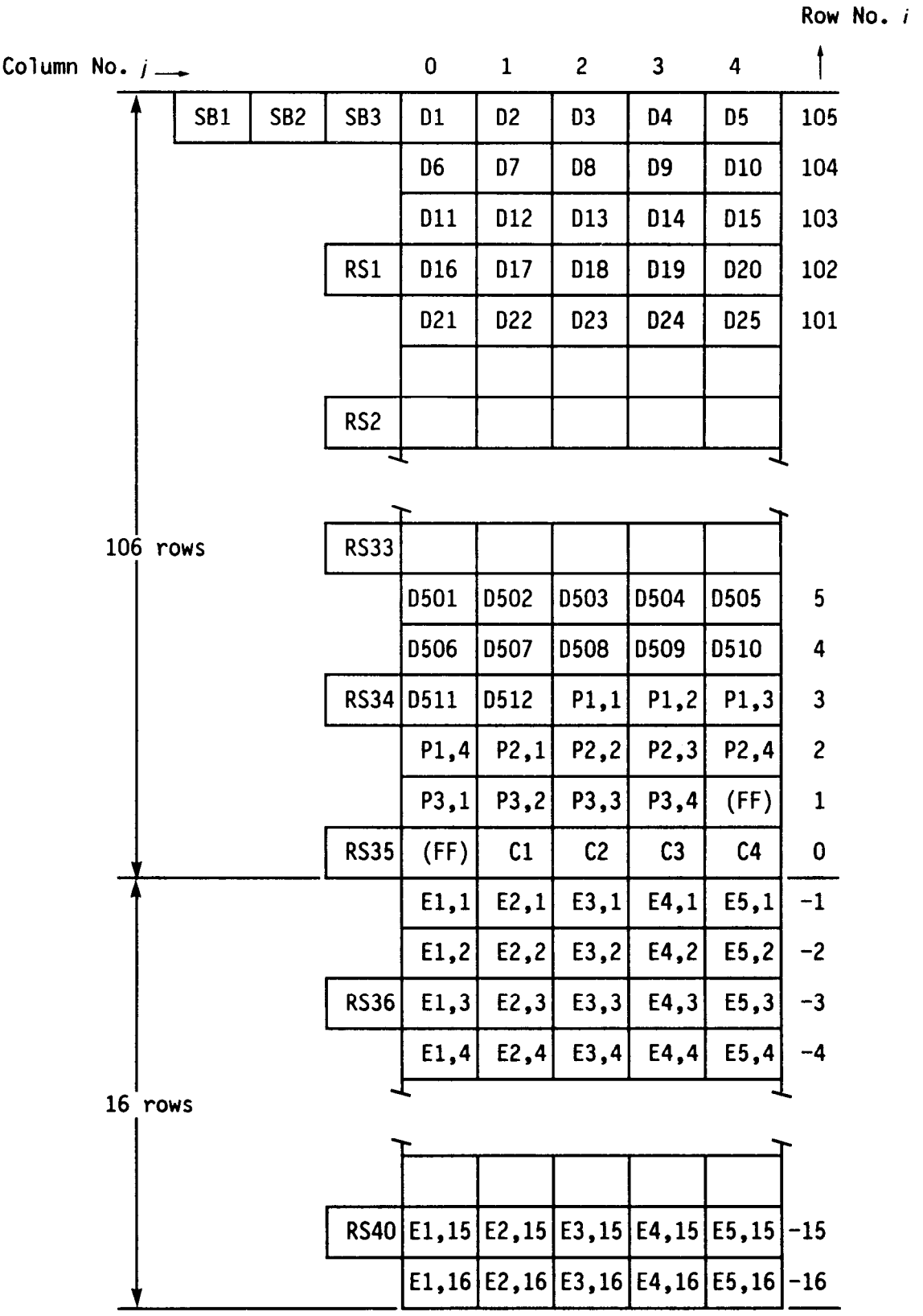

Figure C.2 - Data field configuration, 512-byte sectors, ECC with 5-way interleave

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Annex D
(informative)

Linear Replacement Map Defect Management (LDM)

This annex specifies an additional feature to the defect management scheme specified in this International Standard using a Linear Replacement Map (LDM) and a linear replacement algorithm. The LDM requires no certification of the medium prior to use and no Primary Defect List (PDL). The total number of defective sectors on a side of the disk shall not exceed 2048.

The User Zone on each side of the disk contains two Defect Management Areas (DMAs) at the beginning of the zone and two DMAs at the end of the zone. Each DMA contains a Disk Definition Structure (DDS) with information on the structure of the disk and a Secondary Defect List (SDL) with addresses for the defect management. The area inbetween the two groups of DMAs shall contain a data zone for recording user data, a secondary spare area for recording rewritten sectors and a Working Defect List (WDL) area for recording addresses for the defect management temporarily.

D.1 Media initialization

The data zone shall be divided into g groups of equal size. Each group shall comprise n data sectors followed by m primary spare sectors. Sectors of the data zone not belonging to a group shall be located after the last group. The location of the first group and the value of g, n and m shall be recorded in the DDS. The location and the length of the secondary spare area and the WDL area shall also be recorded in the DDS.

D.2 Write procedure

Before the write operation, the drive shall read the Secondary Defect List (SDL) and the newest WDL to construct defect map information of the medium.

When writing sectors in a group, the three DMPs of these sectors shall be written at the same time. The first pointer $P_{1,y}$ shall contain the address of the sector being written, the second and third pointers $P_{2,y}$ and $P_{3,y}$ shall both contain the address of the first primary spare sector of that group. If a data sector in a group is found to be defective, it shall be rewritten in the first available primary spare sector of that group. If there are no primary spare sectors left in this group, the defective sector shall be rewritten in the first available spare sector in the secondary spare area. If the replacement sector is found to be defective, the sector shall be rewritten in the next available spare sector. The DMPs of the replacement sector shall contain the address of the replacement sector itself and the address of the original data sector it replaces.

When the replacement is successful, the address of the defective sector and the address of the replacement sector shall be appended into the WDL together with the addresses of previous replacement information. The new WDL shall be recorded twice into a sector of the WDL area. If any of the two WDL sectors is found to be defective, both WDL sectors shall be rewritten in the next available sectors in the WDL area respectively.

When the number of replacement information in the WDL fills a whole sector, the contents of the newest WDL shall be recorded four times into a sector of each Defect Management Area (DMA) as the newly appended sector of the SDL.

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D.3 Read procedure

Before the read operation, the drive shall read the SDL and the newest WDL to construct the defect map information of the medium.

If the drive is specified to read the sector which was replaced, that replacement sector can be read directly according to the defect map information

D.4 Layout of the User Zone

The User Zone shall contain four Defect Management Areas (DMAs) in tracks No. 0, 1, 2, N-2, N-1 and N. N is the track number of the last track in the User Zone. The length of each DMA is 25 sectors for 1024-byte sectors and 46 for 512-byte sectors. The address of the first sector of each DMA is given by

	1024-byte sector		512-byte sector	
	track No.	sector No.	track No.	sector No.
DMA_1	0	0	0	0
DMA_2	1	8	1	15
DMA_3	N-2	0	N-2	0
DMA_4	N-1	8	N-1	15

The last sector in both track No. 2 and Track No. N shall be reserved for future use.

The first sector of each DMA shall contain the Disk Definition Structure (DDS) after initialization of the medium. The subsequent sectors of each DMA shall contain the Secondary Defect List (SDL) immediately after the DDS.

The secondary spare area shall be located either immediately after track No. 3 or immediately before the WDL area. The size of the area shall not exceed 252 tracks. The area shall start at sector No. 0 of the track specified in the DDS.

The Working Defect List (WDL) and the Secondary Defect List (SDL) are the defect maps for the LDM. The WDL area shall be located immediately before track No. N-2. The information in the WDL shall be recorded twice, once in the primary WDL area and once in the secondary WDL area. The primary WDL area shall start at sector No. 0 of the WDL area and the secondary WDL area shall start at the first sector of the latter half of the WDL area. The number of sectors in the WDL area shall be even. The WDL area shall have sufficient size to manage at least 2048 replacements.

The first track of the data zone shall be the lowest numbered track not belonging to the DMA or the secondary spare area. It shall have the logical track No. 0. The data zone shall start at sector No. 0 of the track specified in the DDS.

D.5 Disk Definition Structure (DDS)

The Disk Definition Structure (DDS) shall have the length of one sector. It specifies the division of the data zone in groups, and the start address of the first group and the secondary spare area. The DDS shall have been recorded after initialization.

The following information on the disk structure shall be recorded in each of the four DDSs.

Byte 0

This byte shall be set to (0A) as the identifier for the DDS sector.

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Byte 1

This byte shall be set to (0A) as the identifier for the DDS sector.

Byte 2

This byte shall specify the Track Number of the first track of the first group (logical track No. 0).

Byte 3

This byte shall be set to (02) indicating that the Secondary Defect List has been recorded and that the linear replacement algorithm has been used.

Byte 4, 5 (MSB, LSB)

These bytes shall specify the number g of groups, $g \leq 2048$.

Byte 6 to 9 (MSB, byte, byte, LSB)

These bytes shall specify the number n of user data sectors per group.

Byte 10 to 13 (MSB, byte, byte, LSB)

These bytes shall specify the number m of primary spare sectors per group.

Byte 14 to 21

These bytes shall be set to (FF).

Byte 22 to 25 (track no. (MSB, byte, byte, LSB))

These bytes shall specify the address of the start of the WDL area.

Byte 26 to 29 (MSB, byte, byte, LSB)

These bytes shall specify the number of sectors in the WDL area.

Byte 30 to 33 (track no. (MSB, byte, byte, LSB)

These bytes shall specify the address of the start of the secondary spare area.

Byte 34 to 37 (MSB, byte, byte, LSB)

These bytes shall specify the number of sectors in the secondary spare area.

Byte 38 to Z*

These bytes shall be set to (00).

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Table D.1 - Byte assignment of the DDS

Byte	Description
0	(0A) the identifier for the DDS sector
1	(0A) the identifier for the DDS sector
2	the Track Number of the first track of the first group (logical Track Number 0)
3	(02) indicating that the SDL has been recorded and that linear replacement algorithm has been used
4	the number g of groups (MSB)
5	the number g of groups (LSB)
6	the number n of user data sectors per group (MSB)
7	the number n of user data sectors per group
8	the number n of user data sectors per group
9	the number n of user data sectors per group (LSB)
10	the number m of the primary spare sectors per group (MSB)
11	the number m of the primary spare sectors per group
12	the number m of the primary spare sectors per group
13	the number m of the primary spare sectors per group (LSB)
14	this byte shall be set to (FF)
.	.
.	.
.	.
21	this byte shall be set to (FF)
22	the address of the start of the WDL area, Track Number (MSB)
23	the address of the start of the WDL area, Track Number
24	the address of the start of the WDL area, Track Number
25	the address of the start of the WDL area, Track Number (LSB)
26	the number of sectors in the WDL area (MSB)
27	the number of sectors in the WDL area
28	the number of sectors in the WDL area
29	the number of sectors in the WDL area (LSB)
30	the address of the start of the secondary spare area, Track Number (MSB)
31	the address of the start of the secondary spare area, Track Number
32	the address of the start of the secondary spare area, Track Number
33	the address of the start of the secondary spare area, Track Number (LSB)
34	the number of sectors in the secondary spare area (MSB)
35	the number of sectors in the secondary spare area
36	the number of sectors in the secondary spare area
37	the number of sectors in the secondary spare area (LSB)
38	this byte shall be set to (00)
.	.
.	.
.	.
Z*	this byte shall be set to (00)

* For 1024-byte sector, Z = 1023.
For 512-byte sector, Z = 511

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D.6 Secondary Defect List (SDL)

Each sector of the four Secondary Defect Lists shall have the layout as shown below. Each SDL sector shall have a header from byte 0 to 9, including a page number, byte 7. The first sector of the SDL has page number 1, consecutive sectors have consecutive page numbers. The addresses of the replaced sectors need not be listed in ascending order.

Byte 0

This byte shall be set to (00).

Byte 1

This byte shall be set to (02) as the defect list identifier for the SDL.

Byte 2

This byte shall be set to (00).

Byte 3

This byte shall be set to (00) indicating that the SDL has no sublist.

Byte 4, 5 (MSB, LSB)

These bytes shall specify the list length in number of bytes from byte 6 to byte Y*, where Y* is the number of the last byte of the sector containing information.

Byte 6

This byte shall be set to (00).

Byte 7

This byte shall specify the page number of the SDL which shall be a positive integer and shall start from 1.

Byte 8, 9

These bytes shall be set to (FF) for compatibility with Rewritable ODCs.

Byte 10 to Byte 13 (track No. (MSB, byte, LSB), sector No.)

These bytes shall specify the address of the defective sector.

Byte 14 to Byte 17 (track No. (MSB, byte, LSB), sector No.)

These bytes shall specify the address of the replacement sector.

Byte 18 to Byte Y*

The allocation of information to each following unit(s) of 8 bytes shall correspond to that of bytes 10 to 17, each unit identifying a defective sector and its replacement sector.

Byte Y* + 1 to Byte Z*

These bytes shall be set to (FF).

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Table D.2 - Byte assignment of the SDL

Byte	Description
0	(00)
1	(92) the defect list identifier for the SDL
2	(00)
3	(00) indicating that the SDL has no sublist
4	the list length in number of bytes from byte 6 to byte Y* (MSB)
5	the list length in number of bytes from byte 6 to byte Y* (LSB)
6	(00)
7	the page number of the SDL
8	(FF)
9	(FF)
10	the address of the defective sector, Track Number (MSB)
11	the address of the defective sector, Track Number
12	the address of the defective sector, Track Number (LSB)
13	the address of the defective sector, sector No.
14	the address of the replacement sector, Track Number (MSB)
15	the address of the replacement sector, Track Number
16	the address of the replacement sector, Track Number (LSB)
17	the address of the replacement sector, sector No.
18	each unit of 8 bytes shall correspond to byte 10 to 17
.	
.	
.	
Y*	
Y*+1	this byte shall be set to (FF)
.	. . . .
.	. . . .
.	. . . .
Z*	this byte shall be set to (FF)

* For 1024-byte sector, Y = 1027 and Z = 1023
For 512-byte sector, Y = 505 and Z = 511

D.7 Working Defect List (WDL)

The following defect list shall be used to record temporarily the link information of the replacement. Every WDL shall have a page number which shall be the page number of the newest SDL plus 1. If there is no SDL, the page number of the WDL shall be 1.

Byte 0

This byte shall be set to (00).

Byte 1

This byte shall be set to (03) as the defect list identifier for the WDL.

Byte 2

This byte shall be set to (00).

Byte 3

This byte shall be set to (00) indicating that the WDL has no sublist.

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Byte 4,5 (MSB, LSB)

These bytes shall specify the list length in number of bytes from byte 6 to byte X*, where X* is the last byte which has the newest link information of the replacement.

Byte 6

This byte shall be set to (00).

Byte 7

This byte shall specify the page number of the WDL.

Byte 8, 9

These bytes shall be set to (FF) for compatibility with Rewritable ODCs.

Byte 10 to Byte 13 (track No. (MSB, byte, LSB), sector No.)

These bytes shall specify the address of the defective sector.

Byte 14 to Byte 17 (track No. (MSB, byte, LSB), sector No.)

These bytes shall specify the address of the replacement sector.

Byte 18 to Byte Y*

The allocation of information to each unit of 8 bytes shall correspond to that of bytes 10 to 17. All bytes which have no link information of the replacement shall be set to (FF).

Byte Y* + 1 to Z*

These bytes shall be set to (FF).

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Table D.3 - Byte assignment of the WDL

Byte	Description
0	(00)
1	(03) the defect list identifier for the WDL
2	(00)
3	(00) indicating that the WDL has no sublist
4	the list length in number of bytes from byte 6 to byte X* (MSB)
5	the list length in number of bytes from byte 6 to byte X* (LSB)
6	(00)
7	the page number of the WDL
8	(FF)
9	(FF)
10	the address of the defective sector, Track Number (MSB)
11	the address of the defective sector, Track Number
12	the address of the defective sector, Track Number (LSB)
13	the address of the defective sector, sector No.
14	the address of the replacement sector, Track Number (MSB)
15	the address of the replacement sector, Track Number
16	the address of the replacement sector, Track Number (LSB)
17	the address of the replacement sector, sector No.
18	each unit of 8 bytes shall correspond to byte 10 to 17
.	
.	
.	
Y*	
Y*+1	this byte shall be set to (FF)
.	. . . .
.	. . . .
.	. . . .
Z*	this byte shall be set to (FF)

* For 1024-byte sector, Y = 1017 and Z = 1023.
For 512-byte sector, Y = 505 and Z = 511.
X is the last byte which has the newest link information of the replacement.

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