STANDARD ECMA-120

DATA INTERCHANGE ON 12.7 mm
18-TRACK MAGNETIC TAPE CARTRIDGES

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BRIEF HISTORY

In 1985 ECMA decided to produce an ECMA Standard for a 12,7 mm, 18-Track Magnetic Tape Cartridge. Considerable work was invested in this project so that an urgently needed standard would be produced rapidly.

Three areas in particular have received close attention in order to effect an improvement on earlier standards for magnetic tapes for digital data interchange.

i) The requirements for magnetic properties have previously been defined by relating the performance of the tape under test to that of a Standard Reference Material (SRM). It is desirable that such SRMs are established and maintained by a national laboratory and the industry is indebted to National Bureau of Standards in Washington for those for magnetic tapes. The establishment of such an SRM is protracted and the cost cannot be recouped by the sales of Secondary Standard Reference Tapes. In this Standard the need for an SRM has been removed by the incorporation of new and more fundamental tests to measure the performance of the tape in basic units (5.14, 5.15, 5.16 and 5.18).

ii) The signal-to-noise ratio and the amplitudes of the signals from a tape recorded for interchange have previously been measured by comparison with the Standard Reference Amplitude (SRA) read from the SRM. Here more fundamental measurements are specified (7.9).

iii) The timing errors of the interchanged tape have previously been measured using a read head and read amplifier of defined characteristics. Here the performance of the read chain has largely been eliminated by assessing the performance of the write chain via the recorded signals (7.7).

Extensive work is still proceeding in several laboratories to confirm the effectiveness of these new tests in defining the requirements for a tape and a write chain to satisfy the needs of the system. It has been decided to publish the Standard in its present form in order to meet the needs of users and industry; it is intended that these aspects shall be reviewed for the next edition of the Standard.

Upon request of ISO/TC97/SC11 this ECMA Standard has been contributed to ISO for further processing as an international standard under the ISO fast-track procedure.

Adopted as an ECMA Standard by the General Assembly of ECMA on Dec. 11, 1986.
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1. SCOPE AND CONFORMANCE

1.1 Scope
This ECMA Standard specifies the physical and magnetic characteristics of a 12.7 mm wide, 18-track magnetic tape cartridge, to enable interchangeability of such cartridges. It also provides a format and recording method, thus allowing, together with Standard ECMA-13 for Magnetic Tape Labelling, full data interchange by means of such magnetic tape cartridges.

1.2 Conformance
A magnetic tape cartridge conforms to this Standard if it satisfies all the requirements of Sections II to IV.

2. REFERENCES
ECMA-6 : 7-bit Input/Output Coded Character Set
ECMA-35 : Code Extension Techniques
ISO 1302 : Method of indicating surface structure on technical drawings
ISO 683/XIII: Wrought stainless steels

3. DEFINITIONS
For the purpose of this Standard, the following definitions apply.

3.1 Cartridge
A container holding a supply reel of magnetic tape with an attached leader block.

3.2 Data Density
The number of 8-bit bytes stored per unit length of tape, expressed in bytes per millimetre.

3.3 Flux Transition Spacing
The distance between successive flux transitions.

3.4 Flux Transition Position
That point which exhibits maximum free-space flux density normal to the tape surface.

3.5 Magnetic Tape
A tape which will accept and retain the magnetic signals intended for input, output and storage purposes on computers and associated equipment.

3.6 Physical Recording Density
The number of recorded flux transitions per unit length of track, expressed in flux transitions per millimetre (ftpmm).
3.7 Track
A longitudinal area on the tape along which a series of magnetic signals may be recorded.

4. ENVIRONMENT AND SAFETY
Unless otherwise stated, the conditions specified below refer to the ambient conditions in the test or computer room and not to those within the tape equipment.

4.1 Cartridge/Tape Testing Environment
Tests and measurements made on the tape to check requirements of this Standard shall be carried out under the following conditions:
- Temperature: 23 °C ± 2 °C
- Relative Humidity: 40% to 60%
- Conditioning before testing: 24 hours.

4.2 Cartridge Operating Environment
Cartridges used for data interchange shall be operated under the following conditions:
- Temperature: 16 °C to 32 °C
- Relative Humidity: 20% to 80%
- Maximum Wet Bulb: 25.6 °C
- The temperature of the air immediately surrounding the tape shall not exceed 40.5 °C.
- Conditioning before operating: if a cartridge has been exposed during storage and/or transportation to conditions outside the above values, it shall be conditioned for a period of at least 24 hours.

4.3 Cartridge Storage Environment
Cartridges used for data interchange shall be stored under the following conditions.
- Temperature: 5 °C to 32 °C
- Relative Humidity: 5% to 80%
- Maximum Wet Bulb: 27 °C

4.4 Safety Requirements

4.4.1 Safeness
The cartridge and its components shall not constitute a safety or health hazard when used in its intended manner or in any foreseeable misuse in an information processing system.

4.4.2 Flammability
The cartridge and its components shall be made from materials which, if ignited from a match flame, and when so ign-
SECTION II

CHARACTERISTICS OF THE TAPE
5. CHARACTERISTICS OF THE TAPE

5.1 Material
The tape shall consist of a base material (oriented polyethylene terephthalate film or its equivalent) coated on one side with a strong yet flexible layer of ferromagnetic material dispersed in a suitable binder. The back surface of the tape may also be coated with a ferromagnetic or non-ferromagnetic material.

5.2 Tape Length
The length of the tape shall not be less than 165 m.

5.3 Tape Width
The width of the tape shall be 12,650 mm ± 0,025 mm. The width shall be measured across the tape from edge-to-edge when the tape is under a tension of less than 0,28 N.

5.4 Tape Discontinuity
There shall be no discontinuities in the tape such as those produced by tape splicing or perforations.

5.5 Total Thickness of Tape
The total thickness of the tape at any point shall be between 0,0259 mm and 0,0337 mm.

5.6 Base Material Thickness
The thickness of the base material shall be 0,0234 mm nominal.

5.7 Longitudinal Curvature
The radius of curvature of the edge of the tape shall not be less than 33 m.

Procedure
Allow a 1 m length of tape to unroll and assume its natural curvature on a flat smooth surface. Measure the deviation from a 1 m chord. The deviation shall not be greater than 3,8 mm. This deviation corresponds to the minimum radius of curvature of 33 m if measured over an arc of circle.

5.8 Out-of-Plane Distortions
All visual evidence of out-of-plane distortion shall be removed when the tape is subjected to a uniform tension of 0,6 N. Out-of-plane distortions are local deformations which cause portions of the tape to deviate from the plane of the surface of the tape. Out-of-plane distortions are most readily observed when the tape is lying on a flat surface under no tension.

5.9 Cupping
The departure across the width of tape from a flat surface shall not exceed 0,3 mm.
Procedure
Cut a 1.0 m ± 0.1 m length of tape. Condition it for a minimum of 3 hours in the test environment by hanging it so that the coated surface is freely exposed to the test environment. From the centre portion of the conditioned tape cut a sample of 25 mm length. Stand the sample on its end in a cylinder which is at least 25 mm high with an inside diameter of 13.0 mm ± 0.2 mm. With the cylinder standing on an optical comparator measure the cupping by aligning the edges of the sample to the reticle and determining the distance from the aligned edges to the corresponding surface of the sample at its centre.

5.10 Dynamic Frictional Characteristics
In the tests of 5.10.1 and 5.10.2 the specified forces of 1.0 N and 1.50 N, respectively, comprise both the force component of the dynamic friction and the force of 0.64 N applied to the sample of tape.

5.10.1 Frictional Drag Between the Recording Surface and the Tape Back Surface
The force required to move the recording surface in relation to the back surface shall not be less than 1.0 N.

Procedure
i) Wrap a sample of tape around a 25.4 mm diameter circular mandrel with the back surface of the sample facing outward.
ii) Place a second sample of tape, with the recording surface facing inward, around the first sample for a total wrap angle of 90°.
iii) Apply a force of 0.64 N to one end of the outer sample of tape. Secure its other end to a force gauge which is mounted on a motorized linear slide.
iv) Drive the slide at a speed of 1 mm/s.

5.10.2 Frictional Drag Between the Tape Recording Surface and Ferrite after Environmental Cycling
The force required to move the tape at a point 1.34 m from the leader block of the cartridge shall not be greater than 1.50 N. The force required at a point 4.3 m from the junction of the tape with the cartridge hub shall not exceed the first force by more than a factor of 2.

Procedure
i) Wind a tape on to a spool hub of diameter 50 mm to an outside diameter of 97 mm with a winding tension of 2.2 N nominal.
ii) Repeat the following two steps five times:
   a) Store for 48 hours at a temperature of 50 °C and a relative humidity of 10% to 20%.
   b) Acclimatize in the testing environment for two hours and rewind with a tension of 2.2 N nominal.
   iii) Acclimatize the tape for 48 hours at a temperature of 30.5 °C and a relative humidity of 85%. The tape shall remain in this environment for steps iv) and v).
   iv) Apply a force of 0.64 N to one end of a sample taken 1.34 m from the leader block. Pass the sample over a ferrite rod of diameter 25.4 mm with the recording surface in contact with the rod.
   The rod shall be made from the ferrite specified in Appendix C. It shall be polished to a roughness value Rₐ of 0.05 μm (roughness grade N2, ISO 1302). Pull the other end of the sample horizontally at 1 mm/s.
   v) Repeat step iv) for a sample taken 4.3 m from the junction of the tape with the cartridge hub.

5.11 Coating Adhesion
The force required to peel any part of the coating from the tape base material shall not be less than 1.5 N.

Procedure
i) Take a sample of the tape approximately 300 mm long and scribe a line through the recording coating across the width of the tape 125 mm from one end.
ii) Using a double-sided pressure sensitive tape, attach the sample to a smooth metal plate, with the recording surface facing the plate, as shown in the figure below.
iii) Fold the sample over 180°, attach the metal plate and the free end of the sample to the jaws of a universal testing machine and set the speed of the jaw separation to 254 mm per min.
iv) Note the force at which any part of the coating first separates from the base material. If this is less than 1.5 N, the test has failed. If the sample peels away from the double-sided pressure sensitive tape before the force exceeds 1.5 N, an alternative type of double-sided pressure sensitive tape shall be used.
v) If the back surface of the tape is coated, repeat i) to iv) for the back coating.
5.12 Flexural Rigidity

The flexural rigidity of the tape in the longitudinal direction shall be between 0.06 N.mm² and 0.16 N.mm².

Procedure

Clamp a 180 mm sample of tape in a universal testing machine, allowing a 100 mm separation between the machine jaws. Set the jaw separation speed at 5 mm per minute. Plot force against distance. Calculate the flexural rigidity using the slope of the curve between 2.2 N and 6.7 N. The calculation is:

\[ E = \frac{\Delta F/\Delta T}{3L/L} \]

\[ I = WT^2/12 \]

Flexural rigidity = EI = \(\frac{\Delta F^2}{12\Delta L/L}\)

Where:

\(\Delta F\) = change in force in N
\(T\) = measured thickness in mm
\(W\) = measured width in mm
\(\Delta L/L\) = change in sample length between the jaws divided by original length between the jaws.

5.13 Electrical Resistance of the Recording Surface

The electrical resistance of any square area of the magnetic surface shall be within the range:

10⁵ Ohm to 5.10⁸ Ohm

Procedure

Condition a sample of tape to the test environment for 24 hours. Position the sample over two 24-carat gold-plated, semi-circular electrodes having a radius R = 25.4 mm and a finish of at least N4, so that the recording surface is in contact with each electrode. These electrodes shall be placed parallel to the ground and parallel to each other at a distance d = 12.7 mm between their centres. Apply a force F of 1,62 N to each end of the sample. Apply a DC voltage of 500 V ± 10 V across the electrodes and measure the resulting current flow. From this value, determine the electrical resistance.

5.14 Magnetic Coercivity

The coercive force of the recording coating shall be 41.4 kA/m ± 2.4 kA/m when measured in the longitudinal direction.

Procedure

This test shall be performed using an EG&G Princeton Applied Research Model 155 Vibrating Sample Magnetometer or equivalent. The magnetometer must be operated in accordance to the manufacturer's operating procedures and calibrated. The following instructions shall be complied with.

1) Cut a sample disk of diameter 10 mm to 12 mm from the parent tape. If the tape has a ferro-magnetic back coating, this shall be removed.
Mount the sample in the magnetometer so that it will be horizontal to the magnetic field, with the direction parallel to the edge of the parent tape (i.e. the longitudinal direction of the sample) parallel to the magnetic field.

ii) Make the time constant of the lock-in amplifier compatible with the cycle time required by iii).

iii) Cycle the sample 0, +350 kA/m, 0, -350 kA/m, 0 for four cycles, with a period of 10 minutes per cycle.

iv) Continue iii) to +350 kA/m, reduce to 0, then, over a period of 2.5 minutes, increase the magnetizing force \( H \) in the negative direction until the magnetization is reduced to 0.

v) Note the value of this negative field strength. This is the magnetic coercivity.

5.15 Magnetic Particle Orientation

The squareness is the ratio of the residual flux density to the saturation density. The magnetic particle orientation is the ratio of the squareness in the longitudinal direction of the parent tape divided by the squareness in the direction perpendicular to the edge of the parent tape.

The magnetic particle orientation shall not be less than 2,0 and the squareness in the longitudinal direction shall be greater than 0,80.

The test shall be performed using the sample, the equipment and the procedure specified in 5.14.

5.16 Remanence

The remanence is the magnetic flux density of the tape after removal of a magnetizing force.

After subjecting the tape to a magnetizing force of 350 kA/m as in 5.14 and 5.15 during production, the value of the remanence is a maximum.

Before recording as in 7 and before carrying out the tests in 5.19, it is necessary to ensure that the remanence of the tape does not exceed 20% of the maximum value.

**Procedure**

The remanence shall be measured using a Vibrating Sample Magnetometer (see 5.14).

i) Cut a sample disk of diameter 10 mm to 12 mm from the parent tape. Mount the sample in the magnetometer so that it will be horizontal to the magnetic field, with the direction parallel to the edge of the parent tape (i.e. the longitudinal direction of the sample) parallel to the magnetic field.

ii) Centre the sample between the poles of the magnetometer in accordance with the instructions of the manufacturer of the VSM. The sample shall not be exposed to any stray or ambient magnetic field during preparation or mounting.

iii) Note the remanence of the sample.

iv) Rotate the sample through 180° and repeat steps ii) and iii).

v) Cycle the sample 0, +350 kA/m, 0, -350 kA/m, 0 for four cycles.

vi) Note the positive and negative values of the maximum remanence.

vii) Calculate the ratio of the peak excursion between iii) and iv) to the peak excursion in vi).

5.17 Tape Abrasivity

Tape abrasivity is the tendency of the tape to wear the tape transport. The length of the wear pattern on a wear bar shall not exceed 56 um when measured as specified in Appendix C.

5.18 Magnetic Recording Characteristics

The magnetic recording characteristics shall be as follows.

5.18.1 Effective magnetic separation

The EMS is a measure of the density response after read-gap-loss correction.

The EMS of the tape shall not be greater than 0,41 um.

**Procedure**

**Test conditions**
- The tape shall be initially AC erased.
- The tape speed shall be 0,76 m/s.
- The width of the write track shall not be less than that of the read track.
- The length of the write gap shall be 1,0 um ± 0,2 um.
- The resonant frequency of the read-head shall not be less than 4 MHz.
- The tape tension shall be 2,2 N ± 0,2 N.
- The read-gap loss function shall be known.
- The write current shall be that producing the maximum read signal amplitude at 1944 fTppm.

Using a spectrum analyser, measure the signal amplitude at 1944 fTppm and at 972 fTppm over the same length of tape and compensate for the gap loss effect.
Compute the EMS as follows:

$$EMS = \frac{10^3 \ln \frac{E_1}{E_2}}{972 \pi}$$

where:

- $E_1$ is the average signal amplitude at 972 ft/mm compensated for gap loss.
- $E_2$ is the average signal amplitude at 1944 ft/mm compensated for gap loss.

5.18.2 Narrow band signal-to-noise ratio (NB-SNR)

The ratio of the average signal amplitude power to the average integrated (side band) noise power shall not be less than 27 dB.

Procedure

Test conditions
- The tape shall be initially AC erased.
- The tape speed shall be 0.76 m/s.
- The width of the read track shall be 410 um.
- The width of the write track shall be less than that of the read track.
- The length of the write gap shall be 1.0 um ± 0.2 um.
- The resonant frequency of the read head shall not be less than 4 MHz.
- The tape tension shall be 2.2 N ± 0.2 N.
- The write current shall be that producing the maximum read signal amplitude at 972 ft/mm.
- The spectrum analyzer shall have a resolution bandwidth of 1 kHz and a video bandwidth of 10 Hz.

i) Measure the read-signal amplitude at 972 ft/mm of at least 150 samples over a 46 m length of the tape, using the spectrum analyzer.

ii) Measure the noise power at least ten times over the same 46 m of tape and integrate it over the range from 37 kHz to 330 kHz.

iii) The read-signal amplitude shall not be compensated for gap loss.

5.18.3 Broad band signal-to-noise ratio (BB-SNR)

The ratio of the average signal amplitude power to the average integrated broad band floor noise power shall not be less than 36 dB when normalized to a track width of 410 um.

Procedure

Test conditions
- The tape shall be initially AC erased.
- The tape speed shall be 0.76 m/s.
- The width of the write track shall be less than that of the read track.
- The length of the read gap shall not exceed 0.5 um.
- The length of the write gap shall be 1.0 um ± 0.1 um.
- The resonant frequency of the read head shall not be less than 4 MHz.
- The tape tension shall not exceed 2.4 N.
- The write current shall be that producing the maximum read signal amplitude at 972 ft/mm.
- The spectrum analyzer shall have a resolution bandwidth of 3 kHz and a video bandwidth of 30 Hz.

i) Measure the read-signal amplitude at 972 ft/mm of at least 150 samples over a 46 m length of the tape, using the spectrum analyzer.

ii) Measure the noise power at least ten times over the same 46 m of tape and integrate it over the range from 37 kHz to 330 kHz.

iii) The read-signal amplitude shall not be compensated for gap loss.

5.19 Tape Quality

The conditions for the following tests shall be:
- The tape speed shall be 2 m/s.
- The physical recording density shall be 972 ft/mm.
- The length of the write gap shall be 1.0 um ± 0.2 um.
- The write current shall be the current that produces the maximum read signal amplitude at 972 ft/mm.
- The track layout shall be as specified in 8.
- The width of the read track shall be 410 um.

5.19.1 Missing pulses

A missing pulse is a loss of read-back signal amplitude. A missing pulse exists when the read-back signal amplitude is less than 25% of the average read-back signal amplitude measured over the preceding consecutive 25000 flux transitions, exclusive of missing pulses.

5.19.2 Missing pulse zones

A missing pulse zone begins with a missing pulse and ends when 64 consecutive flux transitions are detected or a length of 1 mm of tape has been measured.
i) The missing pulse zone rate shall be less than one in $8 \times 10^6$ flux transitions recorded.

ii) The total length of all zones shall not exceed 50 mm on each track.

5.19.3 Coincident missing pulse zones

There are two 9-track groups in the 18-track format. One group comprises the odd-numbered tracks, the other group comprises the even-numbered tracks. A simultaneous missing pulse zone condition on two or more tracks of a 9-track group is a coincident missing pulse zone.

If a coincident missing pulse zone occurs at the same time in both groups of tracks, it shall be considered as a single coincident missing pulse zone. Its length shall begin with the start of the earliest coincident missing pulse zone and terminate with the end of the latest coincident missing pulse zone.

There shall not be more than 10 coincident missing pulse zones per cartridge.

No coincident missing pulse zone shall exceed 50 mm.
6. DIMENSIONAL AND MECHANICAL CHARACTERISTICS OF THE CARTRIDGE

The cartridge shall consist of the following elements:

- a case,
- a reel for the magnetic tape,
- a magnetic tape wound on the hub of the reel,
- a locking mechanism for the reel,
- a write-inhibit mechanism,
- a leader block,
- a latching mechanism for the leader block.

Dimensional characteristics are specified for those parameters deemed mandatory for interchange and compatible use of the cartridge. Where there is freedom of design, only the functional characteristics of the elements described are indicated. In the enclosed drawings a typical implementation is represented in third angle projection.

Where they are purely descriptive the dimensions are referred to three Reference Surfaces A, B and C forming a geometrical trihedral (see Fig. 1). Where the dimensions are related to the position of the cartridge in the drive, they may be referred to another surface of the cartridge. Fig. 2 to 8 show the dimensions of the empty case.

Fig. 1 is a general view of the whole cartridge.
Fig. 2 shows the front side of the case which lies on Reference Surface A,
Fig. 3 shows the top side of the case,
Fig. 4 shows the rear side of the case,
Fig. 5 shows the bottom side of the case which lies in Reference Surface C,
Fig. 6 shows the side of the case which lies in Reference Surface B,
Fig. 7 shows an enlarged view of a part of Fig. 2,
Fig. 8 shows an enlarged cross-section of a location notch,
Fig. 9 shows an enlarged cross-section of a detail of the opening of the case,
Fig. 10 shows an enlarged partial cross-section of the cartridge in hand,
Fig. 11 shows the same cross-section as Fig. 9 but of the cartridge in the drive,
Fig. 12 shows schematically the teeth of the toothed rim,
Fig. 13 shows two views and an enlarged cross-section of the leader block,
Fig. 14 shows the fixation of the tape to the leader block, and Fig. 15 shows the leader block inserted in the case.

6.1 Overall Dimensions (Fig. 2-4)
The overall dimensions of the case shall be
\[ L_1 = 125,00 \text{ mm} \pm 0,32 \text{ mm} \]
\[ L_2 = 109,00 \text{ mm} \pm 0,32 \text{ mm} \]
\[ + 0,50 \text{ mm} \]
\[ L_3 = 24,50 \text{ mm} \]
\[ - 0,32 \text{ mm} \]

The corners of the case shall be rounded off as specified by
\[ R_1 = 3,00 \text{ max.} \]
\[ R_2 = 4,00 \text{ max.} \]
\[ R_3 = 3,00 \text{ min.} \]

6.2 Write-inhibit Mechanism (Fig. 2, 3)
The write-inhibit mechanism shall have a flat surface identified by a visual mark, e.g. a white spot, when in the position in which writing is inhibited. This Standard does not prescribe the actual implementation of the write-inhibit mechanism. For example, it can be a rotatable or a slidable element.

The front side of the case shall have a window specified by
\[ L_6 = 11,80 \text{ mm} \pm 0,25 \text{ mm} \]
\[ L_7 = 15,60 \text{ mm} \pm 0,25 \text{ mm} \]
\[ L_8 = 7,40 \text{ mm} \pm 0,25 \text{ mm} \]
\[ L_9 = 12,00 \text{ mm} \pm 0,25 \text{ mm} \]

In the write-inhibit position the flat surface of the write-inhibit mechanism shall be behind this window at a distance
\[ L_9 = 2,55 \text{ mm} \text{ min.} \]
from the front side of the case.

In the write-enable position this surface shall be within 0,25 mm of the front side of the case.
The force required for the operation of the write-inhibit mechanism shall be in the range
\[ 2 \text{ N} \text{ to } 9 \text{ N} \]
when applied tangentially to the surface of the case.

6.3 Label Area of the Rear Side (Fig. 3-4)
On the rear side of the case there shall be a label area specified by
\[ L_9 = 7,00 \text{ mm} \pm 0,25 \text{ mm} \]

\[ L_{10} = 80,00 \text{ mm} \]
\[ + 0,30 \text{ mm} \]
\[ - 0,16 \text{ mm} \]

\[ L_{11} = 12,30 \text{ mm} \pm 0,25 \text{ mm} \]
\[ L_{12} = 0,50 \text{ mm} \pm 0,25 \text{ mm} \]
\[ R_{a} = 1,00 \text{ max.} \]

6.4 Label Area of the Top Side (Fig. 3)
On the top side of the case there shall be a label area specified by \[ L_9, L_{10}, L_{12} \] and in addition by
\[ L_{13} = 31,00 \text{ mm} \pm 0,25 \text{ mm} \]
\[ + 0,30 \text{ mm} \]
\[ - 0,16 \text{ mm} \]
\[ L_{14} = 75,00 \text{ mm} \]

6.5 Opening of Case (Fig. 2, 3, 5 and 7)
The case shall have an opening for the tape in which the leader block can be inserted (see also Fig. 14). This opening shall be specified by
\[ L_{15} = 4,70 \text{ mm} \pm 0,25 \text{ mm} \]
\[ L_{16} = 14,90 \text{ mm} \pm 0,32 \text{ mm} \]
\[ L_{17} = 7,50 \text{ mm} \pm 0,25 \text{ mm} \]
\[ L_{18} = 87,10 \text{ mm} \pm 0,25 \text{ mm} \]
\[ L_{19} = 4,00 \text{ mm} \pm 0,25 \text{ mm} \]
\[ R_{a} = 4,00 \text{ mm} \pm '1,25 \text{ mm} \]
\[ \alpha = 50^\circ \pm 1^\circ \]

Moreover, Fig. 7 shows at a larger scale the details of the configuration of the case opening as seen at the right-hand side of Fig. 2.
\[ L_{61} = 3,40 \text{ mm} \pm 0,50 \text{ mm} \]
\[ L_{62} = 17,70 \text{ mm} \pm 0,50 \text{ mm} \]
\[ L_{63} = 3,00 \text{ mm} \pm 0,50 \text{ mm} \]
\[ \omega_1 = 1^\circ \pm 30' \]
\[ \omega_2 = 20^\circ \pm 2^\circ \]

6.6 Locating Notches (Fig. 5, 6 and 8)
There shall be two locating notches open toward the bottom side. These location notches shall be specified by
\[ L_{20} = 106,00 \text{ mm} \pm 0,25 \text{ mm} \]
\[ L_{21} = 5,00 \text{ mm} \pm 0,25 \text{ mm} \]
\[ L_{22} = 7,00 \text{ mm} \pm 0,25 \text{ mm} \]
\[ L_{23} = 104,00 \text{ mm} \pm 0,25 \text{ mm} \]
\[ L_{2a} = 2.50 \text{ mm} \pm 0.25 \text{ mm} \]
\[ \beta = 1^\circ 30' \pm 30' \]
\[ \gamma = 2^\circ \pm 30' \]

6.7 Locating Areas (Fig. 5)
The bottom side of the case shall have three circular locating areas \( a_1', a_3, \) and \( a_5 \) which shall lie in the same horizontal plane within 0.25 mm. Areas \( a_1 \) and \( a_5 \) shall have a diameter of 10.00 mm \( \pm 0.25 \) mm. The position of their centre shall be specified by:
\[ L_{35} = 108.50 \text{ mm} \pm 0.25 \text{ mm} \]
\[ L_{36} = 3.50 \text{ mm} \pm 0.25 \text{ mm} \]
\[ L_{37} = 105.00 \text{ mm} \pm 0.25 \text{ mm} \]
Area \( a_5 \) shall have a diameter of 14.00 mm \( \pm 0.25 \) mm. The position of its centre shall be specified by:
\[ L_{38} = 31.25 \text{ mm} \pm 0.25 \text{ mm} \]
\[ L_{39} = 54.50 \text{ mm} \pm 0.25 \text{ mm} \]

6.8 Inside Configuration of the Case around the Case Opening (Fig. 5 and 9)
Fig. 5 and 9 show the inside configuration of the case around the opening of the case. This configuration shall be defined as follows (see also 6.10):
\[ L_{40} = 3.30 \text{ mm} \pm 0.25 \text{ mm} \]
\[ L_{41} = 18.40 \text{ mm} \pm 0.25 \text{ mm} \]
\[ R_{6} = 1.50 \text{ mm} \pm 0.25 \text{ mm} \]
\[ R_{7} = 1.50 \text{ mm} \pm 0.25 \text{ mm} \]
The oblique edge of the case shall be tangential to the arc of circle defined by \( R_6 \) at an angle
\[ A = 40^\circ \pm 30' \]

6.9 Other External Dimensions of the Case (Fig. 6)
The external form of the case shall be further specified by:
\[ L_{32} = 113.20 \text{ mm} \pm 0.30 \text{ mm} \]
\[ L_{33} = 26.00 \text{ mm} \pm 0.25 \text{ mm} \]
\[ R_{8} = 145.50 \text{ mm} \pm 0.25 \text{ mm} \]
\[ R_{9} = 145.50 \text{ mm} \pm 0.25 \text{ mm} \]
\[ \delta = 30^\circ \pm 30' \]

6.10 Central Window (Fig. 5)
The bottom side of the case shall have a central window. The location of its centre shall be specified by \( L_{39} \) and
\[ L_{34} = 61.00 \text{ mm} \pm 0.25 \text{ mm} \]

Its diameter shall be
\[ d_4 = 43.50 \text{ mm} \pm 2.00 \text{ mm} \]
The angle with its apex at the centre of this window and formed by the two lines tangential to the parts shown in Fig. 5 in cross-section shall be
\[ \theta = 16^\circ \pm 30' \]

6.11 Stacking Ribs
The bottom side of the case shall have two parallel stacking ribs. Their dimensions shall be:
\[ L_{35} = 5.00 \text{ mm} \pm 0.25 \text{ mm} \]
\[ L_{36} = 1.00 \text{ mm} \pm 0.16 \text{ mm} \]
\[ L_{37} = 74.50 \text{ mm} \pm 0.25 \text{ mm} \]
Their locations shall be:
\[ L_{38} = 31.00 \text{ mm} \pm 0.25 \text{ mm} \]
\[ L_{39} = 7.50 \text{ mm} \pm 0.32 \text{ mm} \]
\[ L_{40} = 79.50 \text{ mm} \pm 0.25 \text{ mm} \]

6.12 Tape Reel (Fig. 10 and 11)
Fig. 10 and 11 show the tape reel mounted within the case. Fig. 9 specifies the different dimensions of the reel when the cartridge is in hand, Fig. 11 when it is within the drive. For the sake of clarity of the drawing the stacking ribs are not shown in Fig. 10 and 11.

6.12.1 Locking mechanism (Fig. 11)
This Standard does not specify the actual implementation of the locking mechanism. It only specifies the material and the position of its button. This button shall be made of nylon 6/6 with 2% ± 1% molybdenum disulphide.

Its dimensions shall be:
\[ d_9 = 2.00 \text{ mm} \pm 0.50 \text{ mm} \]
\[ d_{10} = 10.00 \text{ mm} \pm 0.20 \text{ mm} \]
\[ \rho = 15^\circ \pm 2^\circ \]

6.12.2 Axis of rotation of the reel
The axis of rotation of the reel shall be perpendicular to Plane P (see 6.12.7) and pass through the centre of the central window as specified by \( L_{29} \) and \( L_{34} \).

6.12.3 Metallic insert
The reel shall have a metallic insert made of stainless steel (ISO 683/XIII, type 10 or 16). It shall withstand a pull out force of 300 N min. Its dimensions shall be
6.12.4 Toothed rim
Furthermore, the reel shall have a toothed rim accessible through the central window, and having the dimensions

\[ \begin{align*}
  d_2 &= 35,00 \text{ mm} + 0.20 \text{ mm} \\
  d_3 &= 11,15 \text{ mm} \pm 0.05 \text{ mm} \\
  e_1 &= 1.50 \text{ mm} \pm 0.10 \text{ mm}
\end{align*} \]

Its central opening (diameter d_1) shall be concentric with the axis of rotation of the reel within 0.15 mm.

6.12.5 Hub of the reel
The hub of the reel shall have a diameter

\[ \begin{align*}
  d_h &= 50,00 \text{ mm} + 0.00 \text{ mm} \\
  - 0.20 \text{ mm}
\end{align*} \]

Further dimensions of the hub shall be

\[ \begin{align*}
  L_{h1} &= 13.05 \text{ mm} + 0.20 \text{ mm} \\
  - 0.10 \text{ mm}
\end{align*} \]

when measured at the hub surface, and

\[ R_{10} = 0.08 \text{ mm max.} \]

The hub shall meet the following requirements:
- the straightness of the hub surface shall be within 0.04 mm,
- the perpendicularity to the plane P through the pitch line of the teeth of the rim (see 6.12.7) shall be within 0.07 mm,
- the ratio of the difference in the diameters d_6 of any two sections (perpendicular to the axis) to the distance between these sections shall not exceed 0.0038,
- the rate of change across the width of the hub surface shall not exceed 0.025 mm per mm,
- the total runout of the hub related to the cylinder perpendicular to the circular pitch line (see 6.12.7) of the teeth of the toothed rim shall not exceed 0.2 mm total indicator reading (TIR).

6.12.6 Relative positions
6.12.6.1 With the cartridge in hand (Fig. 10):
- the distance of the tip of the button of the locking mechanism to Reference Surface C shall be
  \[ L_{a2} = 1.90 \text{ mm} + 1.40 \text{ mm} \]
  \[ - 0.90 \text{ mm} \]
- the distance from the bottom surface of the metallic insert to Reference Surface C shall be
  \[ L_{a3} = 0.40 \text{ mm} + 1.00 \text{ mm} \]
  \[ - 0.50 \text{ mm} \]

6.12.6.2 Whether the cartridge is in hand or in the drive (Fig. 10 and 11):
- the distance from the bottom surface of the metallic insert to plane P shall be
  \[ L_{a4} = 2.27 \text{ mm} + 0.12 \text{ mm} \]
- the distance of the inside of the lower flange of the reel to plane P shall be
  \[ L_{a5} = 0.65 \text{ mm} \pm 0.09 \text{ mm} \]

6.12.6.3 With the cartridge in the drive (Fig. 11):
- the distance from the tip of the button of the locking mechanism to Reference Surface C shall be
  \[ L_{a6} = 8.10 \text{ mm} \pm 0.16 \text{ mm} \]
- the force required to move the button into this position shall not exceed 12.25 N,
- the distance from the centreline of the tape to Reference Surface C shall be
  \[ L_{a7} = 12.25 \text{ mm} \text{ nominal} \]
- the distance from the Reference Surface C to Plane P (see 6.12.7) shall be:
  \[ L_{a8} = 6.00 \text{ mm} \pm 0.16 \text{ mm} \]

6.12.7 Characteristics of the toothed rim
The toothed rim shall comprise 60 teeth spaced at an angle of

\[ 6\text{°} \pm 5\text{°} \text{ non-cumulative} \]

The teeth are specified at the pitch diameter d_6 by

\[ L_{a8} = 4 \text{ mm} \text{ nominal} \]
\[ L_{n0} = 2 \text{ mm nominal} \]
\[ \varphi = 30^\circ \text{ nominal} \]

The pitch line is the circumference of the teeth taken at the distance \( L_{n0} \). The plane in which it lies is the plane \( P \) mentioned above.

The blend radius at the bottom of the teeth shall be
\[ R_{11} = 0,25 \text{ mm max.} \]

The blend radius at the tip of the teeth shall be
\[ 0,10 \text{ mm} \leq R_{12} \leq 0,30 \text{ mm} \]

6.13 Leader Block (Fig. 13)
The leader block shall have the following dimensions.
\[ L_{30} = 31,80 \text{ mm} \pm 0,04 \text{ mm} \]
\[ L_{51} = 6,80 \text{ mm} \pm 0,10 \text{ mm} \]
\[ L_{52} = 21,80 \text{ mm} \pm 0,20 \text{ mm} \]
\[ L_{53} = 10,93 \text{ mm} \pm 0,06 \text{ mm} \]
\[ L_{54} = 5,46 \text{ mm} \pm 0,10 \text{ mm} \]
\[ L_{55} = 6,00 \text{ mm} \pm 0,25 \text{ mm} \]
\[ L_{56} = 16,50 \text{ mm} \pm 0,00 \text{ mm} \]
\[ L_{57} = 5,20 \text{ mm} \pm 0,20 \text{ mm} \]
\[ R_{13} = 25,00 \text{ mm} \pm 0,25 \text{ mm} \]
\[ R_{26} = 1,40 \text{ mm} \pm 0,20 \text{ mm} \]
\[ d_7 = 7,00 \text{ mm} \pm 0,20 \text{ mm} \]
\[ d_8 = 4,00 \text{ mm} \pm 0,20 \text{ mm} \]
\[ \mu_1 = 90^\circ \pm 2^\circ \]
\[ \mu_2 = 8^\circ \pm 0^\circ \]
\[ \mu_3 = 44^\circ \pm 3^\circ \]

6.14 Fixation of the Tape to the Leader Block (Fig. 14)
There shall be a cylindrical insert for fixing the tape to the leader block. It shall cover the full width of the tape and not protrude beyond the surfaces of the leader block.

In zone \( Z \) the bottom edge of the tape (as seen in Fig. 14) shall be parallel to the edge of the leader block within 0,12 mm and shall be at a distance
\[ L_{58} = 1,90 \text{ mm} \pm 0,26 \text{ mm} \]

from it, when measured while the tape is under tension.

When fixed to the leader block the end of the tape shall not protrude above the surface of the leader block by more than
\[ L_{59} = 2,50 \text{ mm} \]

The leader block shall remain attached to the tape when a force of 10 N is applied at an angle
\[ \mu_4 = 38^\circ \pm 2^\circ \]
as shown in Fig. 14.

6.15 Latching Mechanism (Fig. 15)
This Standard does not specify the actual implementation of the latching mechanism for the leader block. It specifies only the forces required to pull out and to insert the leader block.

The pull-out force, i.e. the force required to pull the leader block and the tape attached to it out of the cartridge shall satisfy both following conditions:
- to be in the range 3,0 N to 7,5 N, and
- the product of the maximum value of the pull-out force and the displacement distance shall be less than 13 Nmm.

The insertion force shall be measured at the same angle and jaw separation speed as the pull-out force.

Procedure
Clamp the cartridge in a universal testing machine that can extract the leader block at the angle \( \mu_5 \) starting at the pickup point (see Fig. 14). The leader-block pickup point is located by the intersection of the centre lines positioned by dimensions \( L_{37}, L_{38} \). Set the jaw separation speed to 10 mm/min, pull the leader Block allowing it to pivot on the pulling pin as it exits the cartridge. Measure the distance between the point where the force first exceeds 0,5 N and the point where the maximum pull-out force is observed. The force shall be measured with a pin that fits into diameters \( d_7 \) and \( d_8 \) (see Fig. 12).

The insertion force, i.e. the force required to push the leader block into latched position in the cartridge shall not be greater than 12 N when measured at an angle
\[ \mu_5 = 48^\circ \pm 3^\circ \].

6.16 Tape Wind
When the cartridge is viewed from the top, the tape shall be wound counter-clockwise and with the recording surface toward the hub.
6.17 Wind Tension
The tape shall be wound with a tension of:
2.2 N ± 0.2 N

6.18 Diameter of the Tape Reel
When the tape is wound around the reel hub at the winding tension specified in 6.17, the reel shall have a diameter between 89 mm and 98 mm.

6.19 Reel Moment of Inertia
The moment of inertia of the empty reel shall be
0.03300 gm² ± 0.00363 gm².
The moment of inertia of the reel loaded with tape shall be within
0.166 gm² to 0.216 gm².

Procedure
Tortionally oscillate the reel on an inertial dynamics unit. The oscillation period shall be measured electronically with a universal counter. The oscillation time shall then be converted to its rotational inertial value.
SECTION IV

RECORDING METHOD
DATA FORMAT
LAYOUT OF THE TAPE
7. **Method of Recording**

The method of recording shall be Inverted Frequency Modulation (IFM) defined as follows:

- a ONE is represented by a flux transition at the beginning of a bit cell,
- a ZERO is represented by flux transition at the beginning of a bit cell followed by a flux transition at the centre of the bit cell.

7.1 **Physical Recording Density**

The physical recording density shall be:
- for all ZEROs: 1944 ftpmm
- for all ONEs: 972 ftpmm

7.2 **Bit Cell Length**

The resulting nominal bit cell length is 1,029 μm.

7.3 **Average Bit Cell Length**

The average bit cell length shall be the sum of n bit cell lengths divided by n.

7.4 **Long-Term Average Bit Cell Length**

The long-term average bit cell length shall be the average bit cell length taken over a minimum of 972 000 bit cells. The long-term average bit cell length shall be within ± 4% of the nominal bit cell length.

7.5 **Short-Term Average Bit Cell Length**

The short-term average bit cell length (STA) shall be the average taken over 16 bit cells. The short-term average bit cell length shall be within ± 7% of the nominal bit cell length.

7.6 **Rate of Change**

The rate of change of the short-term average bit cell length shall not exceed 1.6%.

\[
\text{Rate of Change} = \frac{\left| \text{STA}_{n} - \text{STA}_{n+1} \right|}{\text{STA}_n} \times 100 \% \leq 1.6 \%
\]
7.7 Write Phase
The intercept of the write phase curve shall be between -9° and -29°. The error between the data and the fitted curve shall not exceed 4° over the 3rd, 5th, 7th, 9th and 11th harmonics. See Appendix E for the test procedure and curve definition.

7.8 Total Character Skew
No bit belonging to the same written transverse column shall be displaced by more than 19 bit cell lengths when measured in a direction parallel to the Reference Edge (8.2) of the tape.

7.9 Signal-To-Noise Ratio
The broad-band signal-to-noise ratio at 972 ft/min normalized to a read-track width of 410 μm shall be in the range 34 dB to 46 dB.

Procedure
Test conditions:
- The tape speed shall be 0.76 m/s.
- The resonant frequency of the read head shall not be less than 4 MHz.
- The tape tension shall be 2.2 N ± 0.2 N.
- The spectrum analyzer shall have a resolution bandwidth of 3 kHz and a video bandwidth of 30 Hz.

i) Measure the read-signal amplitude at 972 ft/min of at least 150 samples over a 46 m length of the tape, using the spectrum analyzer.

ii) Measure the noise power at least 10 times over the same 46 m of tape and integrate it over the range 37 kHz to 330 kHz.

iii) The read-signal amplitude shall not be compensated for gap loss.

8. TRACK FORMAT

8.1 Number of Tracks
There shall be 18 tracks.

8.2 Reference Edge
The Reference Edge of the tape is its bottom edge when viewing the recording surface of the tape with the hub end of the tape to the observer's right (see 10.8.2).

8.3 Track Positions
The distance from the centrelines of the tracks to the Reference Edge shall be:
Track 1 : 11.68 mm
Track 2 : 11.05 mm

8.4 Track Width
The width of a written track shall be 0,540 mm ± 0,017 mm.

8.5 Azimuth
On any track the angle that a flux transition across the track makes with a line perpendicular to the Reference Edge shall not be greater than 3 minutes of arc.

Note 1:
At the time of writing the tape, the azimuth should be less than 1 minute of arc. The remaining 2 minutes of arc is the allowance for tape distortion caused by environmental conditions and aging.

9. DATA FORMAT
Prior to recording, the data shall be arranged in groups completed with computed check characters. These data groups shall be in turn arranged in a given sequence together with additional groups of bytes having a prescribed bit pattern. The so arranged data bytes and additional bytes shall then be recorded on the tape according to a specific coding scheme.

9.1 Types of Bytes
The format specified by this Standard distinguishes three types of bytes:
- data bytes,
- pad bytes,
- Block-ID bytes.

9.1.1 Data bytes
Data Bytes are 8-bit bytes available for the recording of the information to be interchanged and/or stored.
9.1.1.1 Coded Representation of characters in data bytes

Characters shall be represented by means of the 7-bit Coded Character Set (Standard ECMA-6) and, where required, by its 7-bit or 8-bit extensions (Standard ECMA-35) or by means of the 8-bit Code (Standard ECMA-43).

i) Recording of 7-bit Coded Characters

Each 7-bit coded character shall be recorded in bit positions $b_1$ to $b_6$ of a byte; bit-position $b_7$ shall be recorded with ZERO. The relationship shall be as follows:

<table>
<thead>
<tr>
<th>Binary weight</th>
<th>64 32 16 8 4 2 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bit designation</td>
<td>$b_7$ $b_6$ $b_5$ $b_4$ $b_3$ $b_2$ $b_1$</td>
</tr>
<tr>
<td>Bit-positions in the byte</td>
<td>$B_8$ $B_7$ $B_6$ $B_5$ $B_4$ $B_3$ $B_2$ $B_1$</td>
</tr>
</tbody>
</table>

ii) Recording of 8-bit Coded Characters

Each 8-bit coded character shall be recorded in bit positions $b_1$ to $B_8$ of a byte. The relationship shall be as follows:

<table>
<thead>
<tr>
<th>Binary Weight</th>
<th>128 64 32 16 8 4 2 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bit designation</td>
<td>$B_8$ $B_7$ $B_6$ $B_5$ $B_4$ $B_3$ $B_2$ $B_1$</td>
</tr>
</tbody>
</table>

Note 1:
If each character has a coded representation consisting of one single 7-bit or 8-bit byte, the number of characters is equal to the number of data bytes. Code extension techniques allow multiple-byte representation. In this case the number of characters is equal to the number of data bytes divided by the number of bytes of the coded representation of a single character.

9.1.1.2 Representation of binary data in data bytes

When the coding method requires it, the coded representations to be recorded in data bytes shall be regarded as an ordered sequence of bit positions, each containing a bit, which can be either a ZERO or a ONE.

The binary weights, bit designations and bit positions shall be as given in 9.1.1.1 ii).

9.1.2 Pad bytes

Pad bytes are 8-bit bytes having a bit pattern consisting of eight ZEROS.

9.1.3 Block-ID bytes

There shall be four 8-bit bytes for the representation of the Block-ID. These four bytes shall follow the last data byte. The 32 bits are numbered from 1 (most significant) to 32 (least significant). These bits shall have the following values:

- Bit 1 shall be ZERO.
- Bits 2 to 8 shall express in binary notation the value of a Physical Position Indicator. This value shall be the largest positive integer satisfying the condition:

$$1 \leq \frac{62,5 \sqrt{625 + R^2 - R_0^2}}{R} \leq 91$$

Where:
- $R_0$ is the initial radius of the fully loaded reel of tape,
- $R$ is the current radius of the reel of tape.

Note 1:
The purpose of the physical position indicator is to provide a coarse, fast indication of the location of the data without having to read the data or all Block-ID bytes.

- Bits 9 to 12 shall be ZEROS.
- Bits 13 to 32 shall express in binary notation a Count which is increased by 1 for each Data Block (see 9.3) and each Tape Mark (see 10.5). The Count is set to 0 for the first Recorded Data Block (see 9.6) or Tape Mark following the Initial Interblock Gap (see 10.1). These 32 bits shall be assigned to the following positions.

<table>
<thead>
<tr>
<th>Byte sequence</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bits</td>
<td>1 to 8</td>
<td>9 to 16</td>
<td>17 to 24</td>
<td>25 to 32</td>
</tr>
<tr>
<td>Bit position</td>
<td>8 to 1</td>
<td>8 to 1</td>
<td>8 to 1</td>
<td>8 to 1</td>
</tr>
</tbody>
</table>

9.2 Frame

A frame shall be a logical section across all 18 tracks containing logically related 8-bit bytes. Each byte in a frame is recorded along a track.
9.3 Data Block

A Data Block shall comprise at least 1 and at most 32768 data bytes.

It shall have the following structure:
- First 2 frames:
  - Prefix
- Further frames up to 2340 frames grouped in clusters:
  - Data Frames
- Next frames, up to 2 frames:
  - Residual Frames 1 and/or Residual Frame 2
- Last 2 frames:
  - Suffix.

9.3.1 Prefix

The prefix shall consist of two frames containing pad bytes in each track.

9.3.2 Data Frames

Each Data Frame shall consist of:
- the first 7 data bytes recorded in odd tracks 1 to 13,
- the next 7 data bytes recorded in even tracks 2 to 14,
- a Diagonal Redundancy Character (DRC-A) recorded in track 15 (see 9.4.1),
- a Vertical Redundancy Character (VRC-A) recorded in track 17 (see 9.4.2),
- a Diagonal Redundancy Character (DRC-B) recorded in track 16 (see 9.4.1),
- a Vertical Redundancy Character (VRC-B) recorded in track 18 (see 9.4.2).

The Data Frames are grouped in clusters as follows:
- the first cluster shall comprise up to 69 frames of data bytes,
- the next clusters, if provided, shall each comprise 71 frames of data bytes,
- the last cluster shall comprise up to 71 frames of data bytes.
9.3.3 Residual Frame 1

If after the last Data Frame of the last Data cluster 8 or 9 data bytes remain to be recorded, there shall be a Residual Frame 1. If the number of remaining data bytes is less than 8 there shall be no Residual Frame 1.

The structure of the Residual Frame 1 shall be:
- 8 or 9 data bytes,
- four Block-ID bytes,
- 1 or 2 pad bytes, depending on the number of remaining data bytes,
- in Tracks 15 and 17 the DRC-A and the VRC-A, respectively,
- in Tracks 16 and 18 the DRC-B and the VRC-B, respectively.

```
1 7 data bytes
  15 DRC - A
  17 VRC - A
  2 1 data byte
  4 1 data or BlockID
  8 3 Block ID bytes
  12 BlockID or pad
  14 1 pad byte
  16 DRC - B
  18 VRC - B
```

9.3.4 Residual Frame 2

If there is no Residual Frame 1, i.e. if there are 7 or less remaining data bytes, these data bytes followed by the 4 Block-ID Bytes followed by pad bytes shall be recorded in odd tracks 1 to 13 and even tracks 2 to 8. If there are no remaining data bytes, the 4 Block-ID bytes shall be recorded in odd tracks 1 to 7, followed by pad bytes in odd tracks 9 to 13 and even tracks 2 to 8.

If there is a Residual Frame 1, odd tracks 1 to 13 and even tracks 2 to 8 shall be recorded with pad bytes.

In either case:
- Track 10 shall be recorded with the Residual Byte (see 9.3.4.1)
- Track 12 and 14 with the CRC Byte 1 and the CRC Byte 2, respectively (see 9.3.4.2)
- Tracks 15 and 17 with the DRC-A and the VRC-A, respectively (see 9.4.1 and 9.4.2)
- Tracks 16 and 18 with the DRC-B and the VRC-B respectively (see 9.4.1 and 9.4.2).

```
1 up to 7 data bytes or
  7 up to 4 BlockID or
  11 up to 7 pad bytes
  15 DRC - A
  17 VRC - A
  2 up to 4
  4 Block ID or
  6 pad bytes
  8 Residual Byte
  10 2 CRC bytes
  12 DRC - B
  14 VRC - B
```

9.3.4.1 Residual Byte

The Residual Byte shall be recorded in track 10 of the Residual Frame 2. Its bits are numbered from 1 (most significant) to 8 (least significant).

Bits 1 and 2 shall be unspecified, they can be a ONE or a ZERO.

Bits 3 and 4 shall be ONES.

Bits 5 to 8 shall express in binary notation the total number of pad bytes in the Residual Frame(s).

The allocation of bits to the bit positions in the Residual Byte shall be:

<table>
<thead>
<tr>
<th>Bit position</th>
<th>Bits 1 to 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>8 to 1</td>
</tr>
</tbody>
</table>
9.3.4.2 CRC Bytes
The 16-bit Cyclic Redundancy Check Character (CRC) shall be represented by two bytes recorded in tracks 12 and 14 of the Residual Frame 2. The CRC character shall be computed from the generator polynomial.
\[ x^{16} + x^{15} + x^2 + x + 1 \]
The CRC is computed over the data, the Block-ID and the pad bytes. It does not include the ECC bytes.
The bits of the bytes of the CRC shall be processed starting with bit 1, i.e. the least-significant bit and ending with bit 8, i.e. the most significant bit.

Note: At this polynomial is symmetrical it yields the same value when read in either direction.
The allocations of bits to bit positions in the two CRC bytes is:

<table>
<thead>
<tr>
<th>Bits</th>
<th>CRC Byte 1</th>
<th>CRC Byte 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>9 to 16</td>
<td>1 to 8</td>
<td></td>
</tr>
<tr>
<td>8 to 1</td>
<td>8 to 1</td>
<td></td>
</tr>
</tbody>
</table>

9.3.5 Suffix
The suffix shall consist of two frames containing:
- in odd track 1 to 13: pad bytes
- in track 15: DRC-A (see 9.4.1)
- in track 17: VRC-A (see 9.4.2)
- in even track 2 to 14: pad bytes
- in track 16: DRC-B (see 9.4.1)
- in track 18: VRC-B (see 9.4.2)

9.4 Error Correcting Code
The error correcting code yields two check characters:
- the Diagonal Redundancy Check (DRC)
- the Vertical Redundancy Check (VRC).

Computation of the DRCs and VRCs starts with the Prefix and ends with the Suffix.
In 9.4.1 and 9.4.2 the following notation is used:
\[ T_m = \text{the } m\text{-th bit of the } n\text{-th track} \]

9.4.1 Diagonal Redundancy Check (DRC)
The two DRCs shall be recorded in tracks 15 and 16, respectively. The bits in each of these tracks shall be computed from the bits in all other tracks, except tracks 17 and 18. The m-th bit in each of these tracks is specified by:
\[ m\text{-th bit of track } 15 = \left\{ \sum_{n=0}^{6} T(2n+1)_{m-n-1} + \sum_{n=1}^{8} T(2n)_{m-n-7} \right\} \pmod{2} \]
\[ m\text{-th bit of track } 16 = \left\{ \sum_{n=9}^{i=7} T(2n+1)_{m-n-2i} + T15_{m-15} + \sum_{n=7}^{i=7} T(2n)_{m-n-8} \right\} \pmod{2} \]

9.4.2 Vertical Redundancy Check (VRC)
The two VRCs shall be recorded in tracks 17 and 18, respectively. The bits in each of these tracks shall be computed from the bits of the eight other tracks having the same index parity. The m-th bit in each of these tracks is specified by:
\[ m\text{-th bit of track } 17 = \left\{ \sum_{n=0}^{7} T(2n+1)_{m} \right\} \pmod{2} \]
\[ m\text{-th bit of track } 18 = \left\{ \sum_{n=1}^{8} T(2n)_{m} \right\} \pmod{2} \]

9.4.3 ECC Format
In each frame eight bits of the DRCs and the VRCs shall be considered as an 8-bit byte.
9.4.4 Summary of ECC

9.5 Recording of 8-bit bytes on the tape
Each 8-bit byte in the Prefix, in the Data Frames, in the Residual Frame(s) and in the Suffix shall be represented by a 9-bit pattern on the tape.

Appendix F specifies the 9-bit pattern representing each 8-bit byte. The bit of the 9-bit pattern in the lowest bit position shall be recorded first.

9.6 Recorded Data Block
When recorded in the tape each Data Block shall have the following structure and be called a Recorded Data Block.

9.6.1 Preamble
The Preamble shall consist of 9 to 13 frames recorded with the 9-bit pattern 111111111 in all tracks.

9.6.2 Beginning of Data Mark (BDM)
The BDM shall consist of two frames recorded with the 9-bit pattern 100010001 in all tracks.

9.6.3 Resync Control Frame
A Resync Control Frame shall have the 9-bit pattern 100010001 in all tracks. A Resync Control Frame shall be recorded after each Data Cluster, but not after the last one.

9.6.4 End of Data Mark (EDM)
The EDM shall consist of two frames recorded with the 9-bit pattern 100010001 in all tracks.

BIBLIOGRAPHY
For a complete description of this ECC scheme, see A.M. PATEL: Adaptive cross parity (ACP) code for a high-density magnetic tape subsystem, in IBM Journal of Research and Development, Vol. 29, Number 6 of November 1985.
9.6.5 Postamble
The Postamble shall consist of 9 to 13 frames recorded with
the 9-bit pattern 111111111 in all tracks.

9.7 Data Density
Due to the EEC bytes, the 8-bit to 9-bit conversion and to the
Resync Control Frames the maximum density of user bytes is:
\[
14 \times 972 \times \frac{1}{8} \times \frac{8}{9} = 1491 \text{ user bytes per mm}
\]
where:
14 : the number of bytes per frame,
972 : the number of flux transitions per mm for the all ONEs
density,
1/8 : the inverse value of the number of bits per byte,
8/9 : corresponds to the GCR mode,
71/72 : corresponds to the RESYNC Control Frames.

10. TAPE FORMAT
The format of the tape is defined by the following control
blocks separating and/or qualifying the Recorded Data Blocks.
- the Density Identification Burst,
- the ID Separator Burst,
- Interblock Gaps,
- Erase Gaps,
- Tape Marks.
The five control blocks have the following recording character-
istics.
1) The 18 tracks are divided in six zones:
   - zone A : Tracks 1, 7, 13
   - zone B : Tracks 2, 8, 14
   - zone C : Tracks 3, 9, 15
   - zone D : Tracks 4, 10, 16
   - zone E : Tracks 5, 11, 17
   - zone F : Tracks 6, 12, 18

ii) The tracks of each zone are recorded either with the all
    ONEs pattern or with the repeated 6-bit pattern 100000
called tone.

10.1 Density Identification Burst
The Density Identification Burst shall be characterized by:
- all ONEs in zones A, C, F
- tone in zones B, D, E
Its length shall be:
Nominal : 2375 mm
Minimum : 2250 mm
Maximum : 3060 mm
The Density Identification Burst shall be the first recording
on the tape.

10.2 ID Separator Burst
The ID Separator Burst shall be characterized by:
- all ONEs in all zones.
Its length shall be:
Nominal : 2,0 mm
Minimum : 1,9 mm
Maximum : 2,1 mm

10.3 Interblock Gaps
The Interblock Gaps shall be characterized by:
- all ONEs in zones A, D, F
- tone in zones B, C, E.
The length of each Interblock Gaps shall be:
Nominal : 2,0 mm
Minimum : 1,6 mm
Maximum : 3,0 mm
Any discontinuity across all tracks in an Interblock Gap (e.g. due to start/stop mode) shall not be greater than 0,03 mm. Such discontinuity shall not occur less than 0,5 mm before the Preamble of a Recorded Data Block or within 0,5 mm after the Postamble of such a block.
An Interblock Gap shall be recorded immediately after the ID Separator Burst. These shall be an Interblock Gap recorded before and after each Recorded Data Block, each Erase Gap (see 10.4) and each Tape Mark (see 10.5), except after the last Tape Mark on the tape (see 10.7).

10.4 Erase Gaps
Erase Gaps shall be characterized by:
- all ONEs in zones B, C, F
- tone in zones A, D, E.
Erase Gaps shall be recorded over a length of tape where an unsuccessful write operation occurred or upon an erase instruction.

10.4.1 Normal Erase Gaps
The length of a Normal Erase Gap shall be:
Nominal : 7,8 mm
Minimum : 7,4 mm
Maximum : 8,2 mm
Up to 20 successive Normal Erase Gaps, separated by Interblock Gaps, are permitted to be written to cover a defect area.

10.4.2 Elongated Erase Gaps
The length of an Elongated Erase Gap shall be:
Maximum : 200 mm
Elongates Gap shall be recorded in the case that a Normal Erase Gap and/or the following Interblock Gap are not recognized as such. Within an Elongated Erase Gap partial Interblock Gaps of not more than 1 mm are permitted to appear.

10.5 Tape Marks
Tape Marks are control blocks characterized by:
- all ONEs in zones B, D, E
- tone in zones A, C, F.
The length of each Tape Mark shall be:
Nominal : 1,0 mm
Minimum : 0,7 mm
Maximum : 1,3 mm
10.8 Summary of the Tape Format

10.8.1 Characteristics of Recording other than Recorded Data Blocks

10.8.2 Arrangement of Recording on the Tape
APPENDIX A

RECOMMENDATIONS FOR TRANSPORTATION

A.1 ENVIRONMENT

It is recommended that during transportation the cartridges are kept within the following conditions:

A.1.1 Unrecorded Cartridges

Temperature : -23 °C to 48 °C
Relative Humidity : 5% to 100%
Wet Bulb Temperature : 27 °C
Duration : 10 days max.

There shall be no condensation in or on the cartridge.

A.1.2 Recorded Cartridges

Temperature : 5 °C to 32 °C
Relative Humidity : 5% to 80%
Wet Bulb Temperature : 27 °C
Duration : 10 days max.

There shall be no condensation in or on the cartridge.

A.2 HAZARDS

Transportation of recorded cartridges involves three basic potential hazards.

A.2.1 Impact Loads and Vibration

The following recommendations should minimize damage during transportation.

i) Avoid mechanical loads that would distort the cartridge shape.

ii) Avoid dropping the cartridge more than 1 m.

iii) Cartridges should be fitted into a rigid box containing adequate shock-absorbant material.

iv) The final box must have a clean interior and a construction that provides sealing to prevent the ingress of dirt and water.

v) The orientation of the cartridges within the final box should be such that their axes are horizontal.

vi) The final box should be clearly marked to indicate its correct orientation.
A.2.2 **Extremes of Temperature and Humidity**

1) Extreme changes in temperature and humidity should be avoided whenever possible.

2) Whenever a cartridge is received it should be conditioned in the operating environment for a period of at least 24 hours.

A.2.3 **Effects of Stray Magnetic Fields**

A nominal spacing of not less than 80 mm should exist between the cartridge and the outer surface of the shipping container. This should minimize the risk of corruption.

---

**APPENDIX B**

**INHIBITOR TAPE**

Any tape that reduces the performance of the tape drive or other tapes is called an inhibitor tape. Certain tape characteristics can contribute to poor tape drive performance. These characteristics include: high abrasiveness, high static friction to tape path components, poor edge conditions, excessive tape wear debris, interlayer slippage, transfer of oxide coating to the back of the next tape layer, separation of tape constituents causing deposits that may lead to tape sticking or poor performance of other tapes. Tapes that have these characteristics may not give satisfactory performance and can result in excessive errors.

Tapes to be used in this cartridge should not be inhibitor tapes.
APPENDIX C

TAPE ABRASIVITY MEASUREMENT PROCEDURE

Tape abrasivity is the tendency of the tape to wear the tape transport.

Wind a minimum of 520 m of new and unused tape onto a supply reel. Install a clean ferrite wear bar made as shown in Fig. C1 on a holding fixture similar to that shown in Fig. C2. The test edge facing upward shall be unworn and free of chips or voids greater than 1 um in size. The radius of the test edge must not be greater than 13 um.

The material of the ferrite bar shall be single-phase polycrystalline ferrite. It shall have the following weight percentages:

- ZnO 22%
- NiO 11%
- Fe₂O₃ 67%

Its average grain size shall be 7.2 um ± 2 um. Its density shall not be less than 5,32 g/cm³.

Note:

Such material should be available as "Sumitomo HA/R3" from Sumitomo Special Metals Div. in Torrance (California), USA.

The surface finish on all four sides of the bar shall be at least of roughness grade N2 (ISO 1302).

Install the test fixture on a tape transport so that the wrap angle of the tape over the bar is 8° on each side for 16° of total wrap.

Set the tape tension at the bar at 1.4 N.

With a tape speed of 1 m/s, make one pass of the tape over the wear bar. The length of tape passing over the wear bar shall be 520 m ± 2.5 m.

Remove the holding fixture from the transport and measure the length of the flat worn on the wear bar. This measurement is most easily made using a microscope of known magnification, a camera, and a reference reticule. Magnification of 300 times or higher is recommended.

Measurements should be taken across the 1/4, 1/2 and 3/4 points of the 12.65 mm width of the wear pattern. The three readings are averaged and the average length is used. Fig. C3 shows a typical wear pattern and the points of measurements.

![Fig. C1 - Ferrite Wear Bar](image-url)
APPENDIX D

RECOMMENDATIONS ON TAPE DURABILITY

When delivered from the supplier the tape of a new cartridge should meet the following requirements.

Testing and measurements performed on the cartridge using an appropriate drive are described below. The test must be performed in operating environment (see 4.2) for the tape and the tape drive.

D.1 SHORT-LENGTH DURABILITY/RELIABILITY

D.1.1 The short-length durability/reliability is the ability of the tape to withstand the wearing action encountered during repeated accesses to a short file of data.

D.1.2 No permanent read errors are permitted for a minimum of 40000 read forward passes. In addition, no more than one permanent read error is permitted on the average for each 80000 read forward passes.

D.1.3 Procedure

Ensure the tape drive is clean before starting this test. As a test sample, use a minimum of four cartridges, written in the area of the tape free of coincident missing pulse zones, to be cycled during the test. The area to be tested on each cartridge should be approximately 500 data blocks of 25000 bytes each past the tape load point. The test area should consist of 50 such data blocks.

Each test cycle consists of starting at the beginning of the test area and accessing each data block in the test area before returning, using backspace file, to the beginning of the test area. For a complete test, 80000 cycles should be made on each cartridge. Ten attempts to read forward should be made for each error before a permanent error is logged.

Tape path cleaning between passes is not permitted for this test.

D.2 LONG-LENGTH DURABILITY/RELIABILITY

D.2.1 The long-length durability/reliability is the ability of the tape to resist the wearing action encountered while cycling full-length passes on a tape drive. This is not a test for end of life for the tape.

D.2.2 The cartridges should meet the following requirements.

i) The coincident missing pulse zones for the first 200 full length passes should not be more than 10 write errors per cartridge.

ii) There should not be more than 16 coincident missing pulse zones on any single pass and no permanent errors.
D.2.3 Procedure
Clean the tape drive before starting this test. The data written should consist of data blocks of at least 16000 bytes.
Tape path cleaning between passes is not permitted for this test.

APPENDIX E
WRITE-PHASE MEASUREMENTS
A specification of the write transfer function is required to complete the set of constraints for an interchange tape. The phase of this transfer function, together with the minimum SNR, constitute a sufficient set of nominal signal constraints for interchange. The following procedure describes a method for measuring the write transfer function phase and a method for describing the shape of this phase.

E.1 PROCEDURE
The first step in obtaining the write transfer function phase consists of taking amplitude samples of the 26-bit sequence (10001000101100101101100101) that appears in every track at the beginning of each recorded block. The sequence starts with the first bit of the frame of the BDM (9.6.2) and ends with the 8th bit of the second frame of the Prefix (9.3.1). This sequence will always be preceded and succeeded by ONES. For purposes of later references the waveform that would be generated by NRZI encoding (that is, a single transition at ONES and no transition at ZEROS) of this sequence is called the NRZI waveform. As described in 7, the actual flux changes written on the tape are obtained using a write waveform that is generated by Inverted Frequency Modulation.

18-bit sequence

| 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 1 |

Equivalent NRZI pattern

Ideal write waveform

In order to separate the phase of the read and write transfer functions, the recorded sequence is read using both forward and backward direction tape motion. In each case the resulting read-back signals are sampled in the time domain using a minimum of four samples per bit and a total number of samples which spans exactly 26 bits. All succeeding phase calculations are then performed numerically. At least 100 repetitions of the sampled 26-bit period are time-averaged to obtain smoothed estimates of the output waveform. A forward transfer function is computed by dividing the Fourier series for the averaged forward read waveform by the Fourier series for the ideal write waveform, where both transforms are computed over exactly one 26-bit period. Because the phase of the transfer function is of interest, the time reference position of the output waveform must be selected to be nearly coincident with that of the write waveform in order to avoid problems associated with "phase wrapping." The latter occurs because the arc tangent function is evaluated in
the range \(-180^\circ\) to \(+180^\circ\). Time misalignment introduces a linear phase term which then "wrap" into the range of the arc tangent function. Time coincidence can readily be accomplished by comparing the NRZI waveform with the observed output. Similarities during long period portions of the waveforms serve as useful indicators for this purpose. Although exact alignment is not required, sufficient care should be taken to ensure that the time references coincide within one bit period.

Transfer-function calculations are carried out using harmonics 7 to 16 for a total of ten frequency points. The Fourier series coefficients for the 26-bit ideal write waveform are:

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<th>Harmonic Number</th>
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<td>-0.0678</td>
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<tr>
<td>16</td>
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</table>

Once the forward-transfer function has been computed in this manner, it is further normalized for time delay by adding a linear-phase term, which forces the 13th harmonic (corresponding to the all-ONES frequency) to \(90^\circ\). The phase of this transfer function then consists of the sum of the write and read phases.

An analogous procedure is employed to compute the backward transfer function by dividing the transform of the averaged waveform obtained through reading the backward direction by the Fourier series for the time-reversed write waveform (i.e., the complex conjugate of the series used in the forward transfer function calculation). Because the read occurred in a direction opposite to that used to write the pattern, the phase of the resulting backward transfer function consists of the difference between the write phase and the read phase. Because the read transfer function is identical for both the forward and backward read measurements, the write phase can be extracted by taking one half of the difference between the forward and backward transfer function phases.

E.2 WRITE-PHASE CURVE DEFINITION

The phase of the write transfer function obtained using the procedure in E.1 is denoted by \(\theta(n)\), where \(n\) is the harmonic number (7 to 16). This measurement is approximated by the linear func-

\[
\theta(n) = a_0 + a_1 \cdot n
\]

where \(a_0\) and \(a_1\) are constants chosen to minimize the sum-squares error \(e^2\),

\[
e^2 = \sum (\phi(n) - \theta(n))^2
\]

where the sum \(\sum\) is taken over \(n = 7, 8, \ldots, 16\).

The intercept \(a_0\) of this function at \(n = 0\), is used to specify acceptable write-phase performance, as described in 7.7.
APPENDIX F

REPRESENTATION OF 8-BIT BYTES BY 9-BIT PATTERNS

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**Bit position** | 8 | 1 | 9 | 1