INTERNATIONAL STANDARD

ISO/IEC 8441-1

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Information technology — High density digital recording (HDDR) —

Part 1:
Unrecorded magnetic tape for (HDDR) applications

Technologies de l'information — Enregistrement numérique à haute densité (HDDR) —

Partie 1: Bande magnétique vierge pour les applications HDDR

Reference number
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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 8441-1 was prepared by Joint Technical Committee ISO/IEC JTC 1, *Information technology*.

ISO/IEC 8441 consists of the following parts, under the general title *Information technology — High density digital recording (HDDR)*:

— *Part 1: Unrecorded magnetic tape for (HDDR) applications*

— *Part 2: Guide for interchange practice*

Annexes A, B, C, D, E, F and G of this part of ISO/IEC 8441 are for information only.

Introduction

This part of ISO/IEC 8441 gives guidance on the performance levels of unrecorded tape suitable for high density digital recording for interchange purposes. It should be noted that the performance levels specified may differ from those attained at the time of purchase of the tape.

Information technology — High density digital recording (HDDR) —

Part 1:
Unrecorded magnetic tape for (HDDR) applications

1 Scope

This part of ISO/IEC 8441 specifies requirements for unrecorded magnetic tape designed for high density digital recording (HDDR) having the following characteristics:

a) nominal thickness 25,4 µm (0,001 in);

b) longitudinal magnetic orientation;

c) coercivity 72 kA/m (900 Oe) max.

These tapes are suitable for interchange in accordance with ISO/IEC 8441-2.

Requirements for packaging are also included.

NOTE 1 Tapes of coercivity above 32 kA/m (400 Oe) are usually classified as high energy tapes and users should establish compatibility with equipment used for driving them.

Annex A gives guidance on glass and metal-flanged reels. Annex B gives information on the wear of recording heads. Different categories of environmental conditions and their effects on tape are dealt with in annex C. Severe operating conditions are considered in annex D. Surface electrical resistance testing is dealt with in annex E. A tape abrasivity testing technique is described in annex F. A list of bibliographical references is given in annex G.

NOTES

2 It is recognized that archival interchange tapes, or those produced by systems in use prior to the publication of this part of ISO/IEC 8441, may not comply with the requirements and/or recommendations herein.

3 Various tests and procedures herein refer to recording with a.c. HF bias. In practice, certain HDDR systems do not use bias. The use of bias in this part of ISO/IEC 8441 does not imply that the tape so tested is in any way unsuitable for a biasless system.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of ISO/IEC 8441. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this part of ISO/IEC 8441 are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 1184:1983, *Plastics — Determination of tensile properties of films.*

ISO 1860:1986, *Information processing — Precision reels for magnetic tape used in interchange instrumentation applications.*

3 Definitions

For the purpose of this part of ISO/IEC 8441, the following definitions apply.

NOTE 4 Tape speed is taken to be 3 048 m/s (120 in/s), unless otherwise stated.

3.1 abrasivity: The propensity of a magnetic tape to cause wear of a recording head, by the passage of the tape over the head.

NOTES

5 It may be expressed as micrometres of head wear per metre of tape passed (microinches per inch), or as a value relative to a given reference tape.

6 The actual wear produced in the recording head will also depend on the tape speed and tension (see annex B).

3.2 durability: The ability of a tape to maintain its output uniformity and dropout characteristics after a given number of passes on the reference test recorder.

3.3 ease of erasure: The ability of a specified erasing field to effect a specified reduction in the level of a signal recorded on a tape.

3.4 electrical surface resistance: The surface resistance, in ohms per square, of the magnetic coating or the back surface of a tape, as appropriate.

NOTE 7 The SI unit of surface resistivity is the ohm, although ohms per square is used in practice.

3.5 elongation under stress: The increase in the distance between reference lines on the test piece due to a tensile load, expressed as a percentage of the initial distance between the reference lines.

3.6 E value: The radial distance by which the reel flanges extend beyond the outermost layer of tape wound on a reel under a tensile force of 0,109 N/mm ± 0,033 N/mm of tape width (10 ozf/in ± 3 ozf/in of tape width).

NOTE 8 0,109 N/mm ± 0,033 N/mm is equivalent to 282 gf/in ± 85 gf/in.

3.7 instantaneous nonuniformities (dropouts): A tape defect which causes a reduction in the reproduced signal amplitude sufficient to jeopardize or impair data recovery.

For the purpose of this part of ISO/IEC 8441, the onset of a dropout event is denoted by a 12 dB reduction in the output level from a 0,635 mm (0,025 in) wide track of a 1,524 µm (60 µin) wavelength test signal recorded as a square wave slightly above saturation level (see 8.5.1). The end of a dropout event is denoted by recovery of the signal to within 9 dB of the average level.

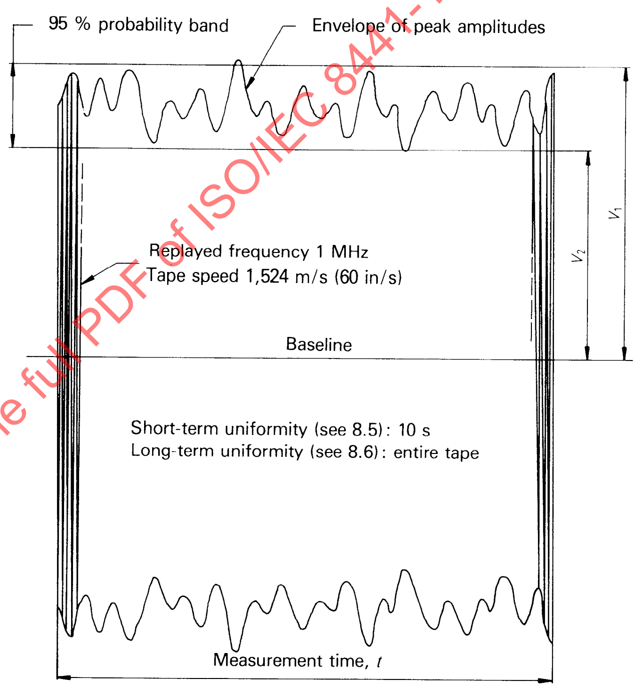
NOTES

9 The dropout count associated with each dropout event is the duration of the event expressed as one-half of the number of test signal periods occurring during the dropout event.

10 For a tape speed of 3 048 m/s (120 in/s) the test signal period is 0,5 µs. Hence, the dropout count is equal to the duration, in microseconds, for a tape speed of 3 048 m/s (120 in/s) (for a general definition, see ISO/IEC 8441-2).

3.8 operating bias current: That bias current through the recording head which gives a 2 dB fall-off (overbias peak) of the peak output from the reference tape when a 2,0 MHz signal is recorded at reference level (see 3.13), at a tape speed of 3 048 m/s (120 in/s).

3.9 output level uniformity (long term): The difference between the maximum and minimum peak output levels, the peak value in either case being the value that contains 95 % of the peaks (see figure 1 and 8.4).



Deviation from uniformity $= 20 \log_{10} \frac{V_1}{V_2}$ dB

Figure 1 — Replayed waveform for output uniformity test

3.10 reference tape: An unrecorded length of tape used as a reference.

NOTE 11 The reference tape should be one adopted by agreement between the interchange parties. When absolute quantitative performance levels and an international source of standard reference tapes have been established, such agreements may be replaced by reference to standard reference tapes.

3.11 reference head: A head used in conjunction with the reference tape.

NOTE 12 The reference head should be agreed on between the interchange parties.

3.12 reference output level: The reproduce level of a 200 kHz signal recorded on the reference tape at 6 dB below standard record level 3 048 m/s (120 in/s) and with operating bias current.

3.13 reference record level

3.13.1 with a.c. bias: The input level of a 200 kHz signal recorded on the reference tape at 3 048 m/s (120 in/s), with operating bias current such that on play back, the output signal has 1 % third-harmonic distortion as measured with a wave analyser.

3.13.2 without a.c. bias: The record head reference current level without a.c. bias (generally expressed in milliamperes peak-to-peak) is established in accordance with ISO/IEC 8441-2. The same current level (in milliamperes) established at the record head to 200 kHz and for tape speed 3 084 m/s (120 in/s) is defined as the reference record level.

3.14 secondary reference tape: An unrecorded length of tape, the magnetic characteristics (i.e. sensitivity, wavelength response, bias characteristic, distortion characteristics), of which have been calibrated against the reference tape.

3.15 sensitivity: The output of the tape sample under test compared to that from the reference tape expressed as a ratio, normally quoted in decibels, the frequency being 200 kHz in both cases.

3.16 signal-to-noise ratio: The ratio of the reproduced signal power from a tape and the wideband noise power (tape and equipment) measured over the system bandwidth.

3.17 wavelength response: The output voltage frequency characteristic of the tape when normalized to a specific wavelength compared to the response of the reference tape.

4 General

4.1 Materials

The tape shall consist of a uniform layer of ferromagnetic material held in a flexible binder medium on a suitable continuous and splice-free, flexible base material with a conductive back coating.

4.2 Tape reels

The tape shall be wound on reels in accordance with ISO 1860.

NOTE 13 Glass-flanged reels are preferable to reels with metal flanges, with or without window slots (see annex A), particularly for recorders in performance categories B and C (see ISO 8441-2, annex A) because they are known to give improved performance and greater protection against dropouts, especially if combined with protecting collars.

4.3 Tape wind

The tape shall be wound with the magnetic coated surface innermost.

NOTE 14 This is sometimes called "A" wind.

4.4 Packaging

Each reel shall be enclosed by an individual wrapper (e.g. polyethylene) packaged in an appropriate container which provides support of the enclosed reel at the hub. If windowless flanges with wraparound bands are used, the wrapper may not be necessary.

5 Test conditions

5.1 General

For all procedures described in this part of ISO/IEC 8441, conditioning shall be as specified in 5.2, and in the test environment as specified in 5.3.

5.2 Conditioning

Conditioning shall be carried out in the test environment (see 5.3). The tape may be tissue cleaned. It shall be wound and rewound with a tensile force of 0,109 N/mm ± 0,33 N/mm of tape width (10 ozf/in ± 3 ozf/in of tape width). The tape shall then be stored, unwrapped, for a minimum of 24 h to allow it to stabilize.

NOTE 15 0,109 N/mm ± 0,033 N/mm is equivalent to 282 gf/in ± 85 gf/in.

5.3 Test environment

The test environment shall be as follows:

a) Temperature: + 23 °C ± 3 °C (+ 73 °F ± 5 °F)

b) Relative humidity: 45 % to 55 %

6 Dimensions

6.1 Tape width

The tape width shall be one of those given in table 1.

NOTE 16 The metric and imperial dimensions are not exact conversions.

In case of doubt or dispute, the imperial values shall be used to determine compliance with this part of ISO/IEC 8441.

Table 1 — Tape widths

Millimetres	Inches
12,65 ± 0,025	0,498 ± 0,001
25,35 ± 0,025	0,998 ± 0,001
50,75 ± 0,025	1,998 ± 0,001

6.2 Tape length

The tape length shall be as given in table 2 for the appropriate reel diameter.

6.3 Tape thickness

The tape thickness is controlled by, and specified in terms of, the "E" value (see 3.6). The nominal thickness of the magnetic coating is 5 µm (200 µin), and the nominal tape thickness is 25 µm (0,001 in). The "E" value shall be at least 2,54 mm (0,1 in) for reels having a diameter up to and including 203 mm (8 in), and shall be at least 3,18 mm (0,125 in) for reels having a diameter greater than 203 mm (8 in).

Table 2 — Tape lengths

Nominal reel diameter		m	ft
203 mm (8 in)	Minimum length[1)]	670 674	2 210
267 mm (10,5 in)	Minimum length[1)]	1 400 1 410	4 625
318 mm (12,5 in)	Minimum length[1)]	2 200 2 204	7 230
356 mm (14 in)	Minimum length[1)]	2 800 2 815	9 235
381 mm (15 in)	Minimum length[1)]	3 290 3 303	10 795
406 mm (16 in)	Minimum length[1)]	3 800 3 822	12 440

1) The minimum lengths are specified on the basis of tapes with a nominal thickness of 25 µm (0,001 in), and the "E" values given in 6.3. "E" values less than those given in 6.3 will result in longer tapes.

7 Physical properties

7.1 Yield strength

7.1.1 Procedure

Test five samples in accordance with ISO 1184, except that

a) the minimum tape length is 200 mm (8 in);

b) the initial jaw separation is 100 mm (4 in);

c) the rate of jaw separation is 0,8 mm/s (2 in/min).

7.1.2 Requirement

The tensile load at the 1 % offset yield point (as defined in ISO 1184) shall not be less than 2,10 N/mm (12 lbf/in) of tape width, even if the tape breaks prior to reaching the 1 % offset yield point.

NOTE 17 2,10 N/mm is equivalent to 5,44 kgf/in.

7.2 Elongation under stress

7.2.1 Procedure

Test at least five sample lengths of each type of tape. Select sample lengths of 600 mm (24 in) minimum. Clamp each sample at one end and make a transverse length reference mark approximately 500 mm (20 in) from the point of clamping. Allow the samples to hang freely in the test environment (see 5.3) for at least 24 h.

Attach a 50 g (2 oz) weight to the free end of each sample. Measure the distance between the clamping point and the reference mark with an accuracy of ± 0,25 mm (0,010 in), taking care that the tape is tensioned only by the 50 g (2 oz) weight. Note this length for each sample. This is the pre-stress length measurement.

Remove the 50 g (2 oz) weight and attach a weight corresponding to a tension of 1,75 N/mm (10 lbf/in) of tape width to each sample below the reference mark. Note the time of attachment to each sample. Allow the stressed samples to hang undisturbed for 180 min ± 3 min. Attach a 50 g (2 oz) weight to each sample and measure the distance between the clamping point and the reference mark with an accuracy of ± 0,25 mm (0,010 in), noting the length for each sample as before. This is the post-stress length measurement.

NOTE 18 1,75 N/mm is equivalent to 4,53 kgf/in.

7.2.2 Requirement

The difference between the pre-stress and post-stress lengths for each sample shall not exceed 0,5 %.

7.2.3 Full reel moment of inertia

The maximum moments of inertia for full reels of tape are given in table 3.

8 Performance

8.1 Reference test system

8.1.1 System components

The reference test system shall consist of a reference tape and reference head mounted on a recorder/reproducer, referred to as the reference recorder, which shall have a wideband 2,0 MHz capability at 3,048 m/s (120 in/s) tape speed as defined in ISO 8441-2, and preferably a facility to clean the tape during recording and playback.

8.1.2 Preparation of recorder for testing

The reference recorder shall be set up as follows:

a) Thoroughly clean and demagnetize the recorder and adjust the heads for correct azimuth (see ISO 8441-2).

   NOTE 19 Cleanliness is particularly critical in drop-out assessment (see 3.7).

b) Set the tape tension of 0,109 N/mm ± 0,033 N/mm of tape width (10 ozf/in ± 3 ozf/in of tape width).

   NOTE 20 0,0109 N/mm ± 0,033 N/mm is equivalent to 282 gf/in ± 85 gf/in.

c) Ensure that the record and reproduce head segments and the head configuration comply with the dimensions given in table 2 or table 4 of ISO 8441-2 [14 tracks on 12,7 mm (0,5 in), or 28 tracks on 25,4 mm (1,0 in), using head segments with a track of 0,635 mm ± 0,025 mm (0,025 in ± 0,001 in)].

d) Perform the measurements at a tape speed of 3 048 m/s (120 in/s), except where another speed is specified.

e) Ensure that the recorder electronics are properly terminated.

f) Specify all test signals.

8.2 Sensitivity

8.2.1 Procedure

For each type of tape to be tested, establish the applicable reference output level to calibrate the reference recorder for the sensitivity measurement.

A 200 kHz signal shall be recorded at 6 dB below reference record level (see 3.13). Note the equalization settings and the reproduce amplifier gain settings when establishing the reference output level. Reproduce the tape and measure the recorder output.

8.2.2 Requirement

The output from a test sample, excluding the first and last 2 % of its length, shall not vary throughout its length from the reference output level by more than ± 2 dB.

8.3 Wavelength response

(See 3.17.)

8.3.1 Procedure

Repeat the procedure described in 8.2.1 at each frequency given in table 4 for each type of tape being tested, avoiding the use of edge tracks, and ignoring the first and last 2 % of the tape length.

Table 3 — Maximum moments of inertia for full reels

Nominal tape width	Nominal reel diameter											
	203 mm (8,0 in)		266 mm (10,5 in)		318 mm (12,5 in)		355 mm (14,0 in)		381 mm (15,0 in)		406 mm (16,0 in)	
	g·m²	lb·ft²	g·m²	lb·ft²	g·m²	lb·ft²	g·m²	lb·ft²	g·m²	lb·ft²	g·m²	lb·ft²
6,30 mm (0,25 in)	2,78	0,066	10,16	0,241	19,72	0,468	29,81	0,707	41,75	0,989	54,27	1,29
12,70 mm (0,50 in)	3,77	0,089	14,57	0,345	28,14	0,667	43,21	1,02	59,78	1,42	77,79	1,84
25,40 mm (1,00 in)	5,73	0,136	23,37	0,554	44,97	1,07	69,99	1,66	95,82	2,27	124,8	2,96
50,80 mm (2,00 in)	9,66	0,229	40,97	0,971	78,63	1,86	123,55	2,93	167,92	3,98	218,86	5,19

8.3.2 Requirement

The output at each frequency, when normalized to the output at 15 µm (600 µin) and compared to the response of the reference tape, shall be within the limits given in table 4.

Table 4 — Wavelength response

Test frequency at tape speed of 3,048 m/s (120 in/s)	Recorded wavelength	Requirement variation from reference tape
kHz	µm (in·10^{-3})	dB
0,8	3 810 (150)	± 2
12	254 (10)	± 2
120	25,4 (1,00)	± 2
480	6,35 (0,250)	± 2
960	3,18 (0,125)	± 2,5
1 200	2,54 (0,100)	± 2,5
1 500	2,03 (0,080)	± 3
2 000	1,52 (0,060)	± 3

8.4 Output level uniformity (long term)

(See 3.9.)

8.4.1 Procedure

For each type of tape, perform measurements on the following tracks:

a) 12,7 mm (0,5 in) tape tracks 1, 7, 8, 14 (see table 2 of ISO 8441-2);

b) 25,4 mm (1 in) tape tracks 1, 15, 16, 28 (see table 4 of ISO 8441-2).

At a tape speed of 3 048 m/s (120 in/s) record the 1 MHz test frequency at reference record level (see 3.13), with the bias current adjusted as recommended by the recorder manufacturer as optimum for the tape on test. Record this signal along the entire tape length.

Determine the tape output uniformity as defined in 3.9.

NOTE 21 The results obtained from this test shall specify whether or not a.c. bias was used.

8.4.2 Requirement

The value, expressed in decibels, shall not exceed ± 2 dB. The performance of the first and last 2 % of the tape length shall be ignored.

8.5 Instantaneous nonuniformity (dropouts)

8.5.1 Procedure

On at least every other track (seven tracks) of either the odd or the even head of a 28 track assembly, record either a 2 MHz square wave signal at 3 048 m/s (120 in/s), or a 1 MHz squarewave signal at 1,52 m/s (60 in/s) throughout the entire tape length. Set the reference record level (see 3.13). For play back, use a reproduce amplifier (with no AGC device) and a threshold detector with hysteresis able to monitor the output signal and detect any amplitude loss and recovery to the limit stated in 3.7. The signal-to-noise ratio of the test signal at the input to the threshold detector should be at least 25 dB. The reference level for dropout detection shall be established by averaging the test signal output amplitude over 10 m (33 ft) tape length in the vicinity of any dropout.

For each of the seven tracks tested, note the accumulated dropout count, where the count for each dropout corresponds to one-half the number of periods of the test frequency affected (see 3.7).

NOTE 22 Results obtained from this test shall state whether or not a.c. bias was used.

8.5.2 Requirement

The accumulated dropout count on any tested track shall be less than 1 per 10 m (1 per 32,8 ft) of tape length averaged along the entire length of the tape. The performance of the first and last 2 % of the tape length shall be ignored.

NOTE 23 A different dropout requirement may be agreed on between interchange parties to suit particular system requirements.

8.6 Signal-to-noise ratio

(See 3.16.)

8.6.1 Procedure

The appropriate centreline or reference tape shall be optimized to the reference recorder for the particular tape to be tested. A 200 kHz signal shall be recorded at reference record level. The reproduced signal output shall be noted. The tape shall be externally erased in a bulk degausser. The tape shall be re-recorded with no input signal but with the recorder inputs terminated with their proper impedance. The reproduced signal output noise shall be noted.

The instrument used for these measurements shall have no more than 3 dB attenuation at the reference recorder band-edge frequency for the record speed specified, and an 18 dB per octave roll-off characteristic. The signal-to-noise ratio of this tape is the value, in decibels, of the reproduced signal output minus the reproduced signal noise. The tape to be evaluated shall be tested in the same manner, except that no re-adjustment of the reference recorder shall be made.

8.6.2 Requirement

The difference between the signal-to-noise ratio of the centreline or reference tape, and the tape being tested shall not exceed 4 dB.

8.7 Ease of erasure

(See 3.3.)

8.7.1 Procedure

The tape shall be externally erased in a bulk degausser. A signal of 1 kHz shall be recorded at standard record level (see 3.13) at 15 in/s. The reproduce gain and equalization shall be set for tape optimization. The input signal level shall be measured and noted. The input signal level shall be increased by 10 dB and this signal level recorded. The tape shall be rewound, and placed in a chamber at 66 °C ± 3 °C (150 °F ± 5 °F), (20 ± 5) % relative humidity for 4 h. The tape shall be played back and the output measured through a properly terminated 1 kHz filter with a passband of 10 Hz. The tape shall be externally erased in a bulk degausser producing a 50 Hz or 60 Hz a.c. field of 30 kA/m (1 000 Oe) (peak value). The tape shall be played back and the output measured again through the filter network.

8.7.2 Requirement

The difference between the recorded signal level and the residual signal level shall be 60 dB min.

8.8 Electrical surface resistance

8.8.1 Definition

8.8.1.1 electrical surface resistance: The surface resistance, in ohms, of the magnetic coating of the tape as measured between opposite sides of a square area.

8.8.2 Requirement

The surface electrical resistance of the magnetic coating shall not exceed the value specified in table 5.

8.8.3 Procedure

8.8.3.1 Apparatus. The apparatus for this test shall consist of a temperature and humidity chamber and the apparatus as specified in annex E, or equivalent.

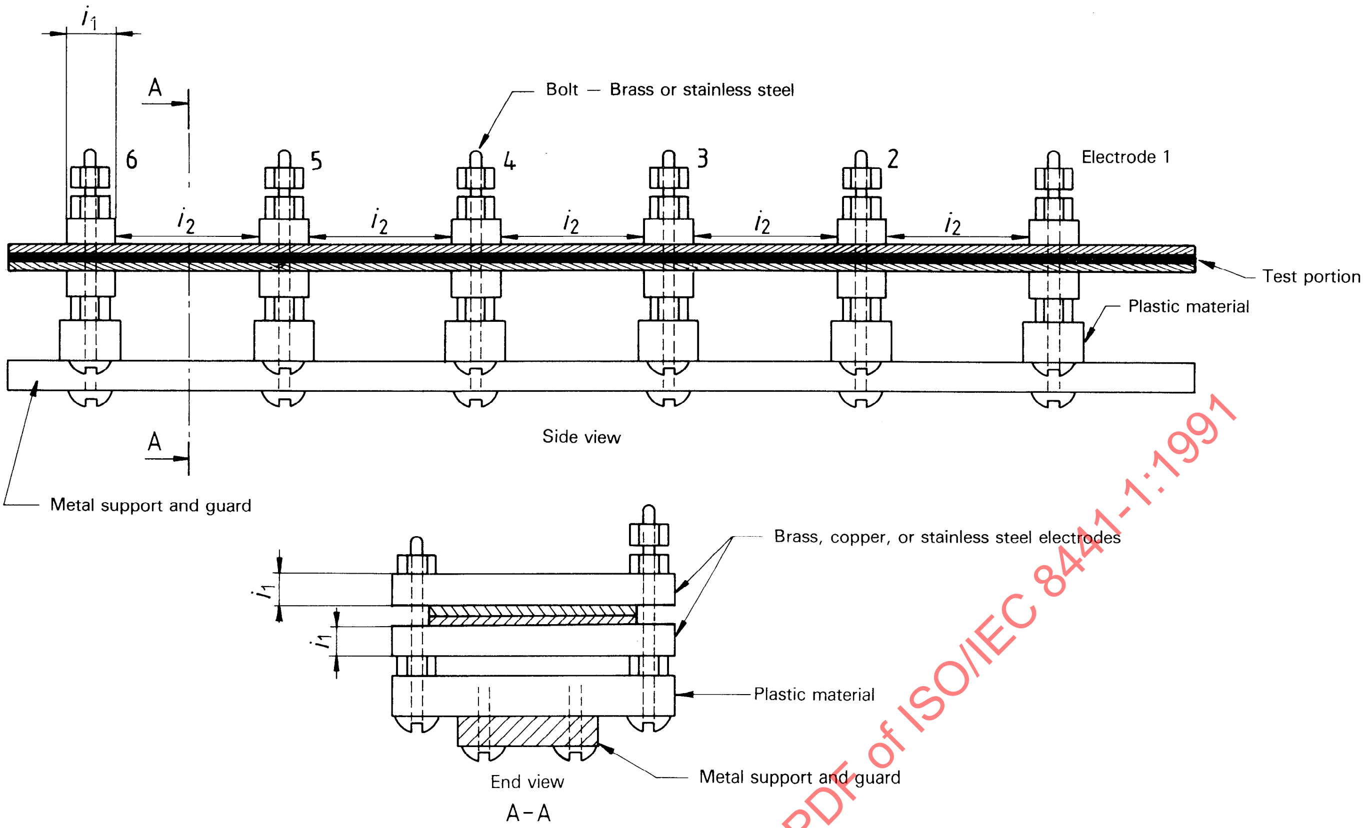
8.8.3.2 Preparation of samples. Samples of tape shall be prepared as specified under preliminary conditioning (see 5.2). Lengths of tape sufficient for this test shall be unwound from the reels and placed in a standard test environment (see 5.2) without kinks or bends and allowed to remain for at least 24 h before test. A minimum of two samples shall be taken from each reel of tape being tested.

8.8.3.3 Procedure. Following pre-conditioning (see 8.8.3.2) two 12,7 mm (0,5 in) wide layers of the sample tape shall be placed back-to-back between the strip electrodes, as shown in figure 2 and figure 3, so that the recording surfaces are in contact with all the electrodes. In mounting the test portion for measurement it is important that no conduction paths exist between the electrodes except those through the test portion. To ensure that the length of tape held between each pair of strip electrodes is the same, the test portion shall be placed under 2,2 N ± 0,5 N (0,5 lbf ± 0,1 lbf) tension as it is being clamped.

The width of the test portion shall be 12,7 mm (0,5 in). If the sample tape is less than 12,7 mm (0,5 in) wide [e.g. 6,3 mm (0,25 in) wide], two or more sample tapes shall be placed side-by-side to make up a 12,7 mm (0,5 in) test portion. If the tape is 25,4 mm (1,0 in) wide, it may be folded longitudinally with the recording surface outermost to make a 12,7 mm (0,5 in) back-to-back test portion for measurement. Test portions obtained from wider tapes must be cut down to 12,7 mm or 25,4 mm (0,5 in or 1,0 in) width and mounted as described above.

NOTE 24 Neither the test portion nor the insulating surfaces should be handled with the bare fingers. The use of clean lint-free gloves is recommended.

Measurement shall be made between each pair of adjacent electrodes. This will produce a total of five readings per test portion. The resistance of the coating shall be determined by means of a guarded circuit, as shown in figure 3, using 500 V ± 10 V potential.



Dimension	Inches	Millimetres
i_1 (× 24)	0,250	6,35
i_2 (× 5)	1,000	25,40

Figure 2 — Tape resistance measurement electrodes

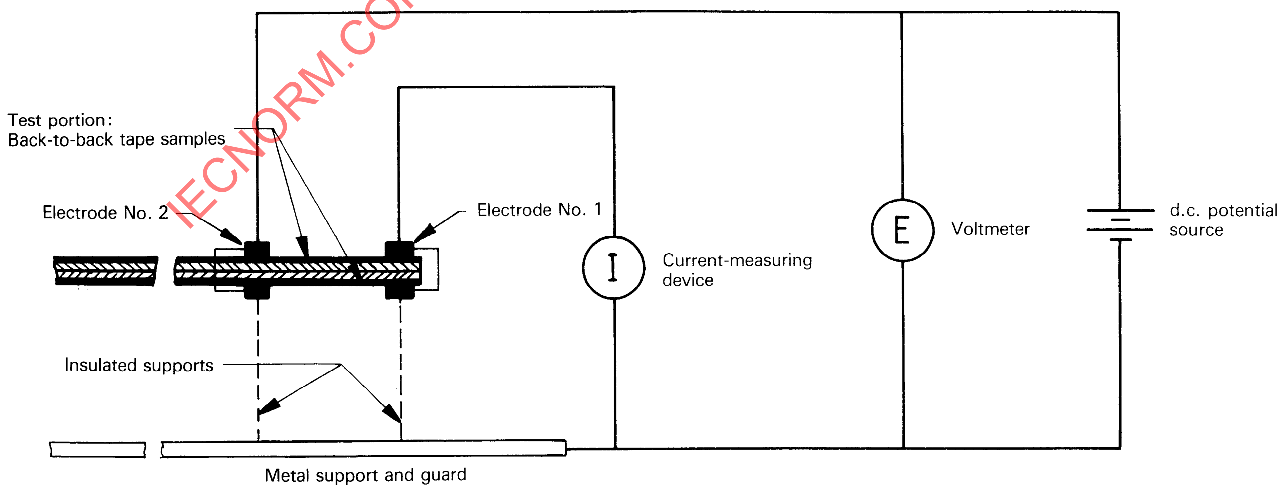


Figure 3 — Tape resistance measurement circuit

The average value of the five surface resistance measurements shall not exceed the limit shown in table 5.

8.9 Environmental performance

8.9.1 Procedure

Record the tape under the conditions described in 8.4.1. Subject the tape to a temperature of 55 °C ± 3 °C (131 °F ± 5 °F), and a relative humidity of 90 % min. to 95 % max. for a period of 24 h. Upon removal from this environment, rewind the tape once, and keep in the test environment specified in 5.3 for a minimum of 24 h. Test the tape for output uniformity (see 8.4) to determine compliance with 8.4.2. Following these tests, subject the tape to a temperature of −12 °C ± 3 °C (10 °F ± 5 °F) and a relative humidity of less than 10 % for a period of 24 h. Upon removal from this environment, rewind the tape once, and keep in the test environment specified in 5.3 for a minimum of 24 h. Again test the tape for output uniformity to determine compliance with 8.4.2 .

8.9.2 Requirement

The tape shall comply with the output uniformity requirements in 8.4.2, when subjected to the specified temperature and humidity conditions.

8.10 Durability

8.10.1 Procedure

Subject a section of tape at least 1 000 m (3 280 ft) long, to 50 forward/reverse cycles at a speed of 1,524 m/s (60 in/s). After reconditioning the tape in accordance with 5.2, perform the long-term uniformity and dropout tests in accordance with 8.4 and 8.5.

8.10.2 Requirement

After 50 forward/reverse passes (without tape lifters), the tape shall meet the output level uniformity and dropout rate requirements of 8.4.2 and 8.5.2, undegraded.

8.11 Abrasivity

Abrasivity measurements may be made in several ways. The method of measurement should be selected by agreement between the tape manufacturer and the interchange parties.

Table 5 — Performance requirements

Characteristic	Limit		Units
Sensitivity [1]	0 ± 2		Decibel
Wavelength response [1]	See 8.3.2		
Output level uniformity	Class E1	Class E2	
Short term — edge tracks	3,0	2,5 max.	Decibel
Short term — centre tracks	2,5	2,5 max.	Decibel
Long term — edge tracks	3,0	2,5 max.	Decibel
Long term — centre tracks	2,5	2,5 max.	Decibel
Instantaneous non-uniformity (dropouts)			
Centre tracks	49 (15)	33 (10) max.	Dropout per 100 m (Dropout per 100 ft)
Edge tracks	131 (40)	49 (15) max.	Dropout per 100 m (Dropout per 100 ft)
Harmonic distortion [1]	2,0 max.		Percent
Signal-to-noise ratio [1]	4 (see 8.6)		Decibel
Layer-to-layer signal transfer	40		Decibel
Ease of erasure	60 min.		Decibel
Electrical resistance	200 max.		Megohm
Environmental extremes	See 8.9.2		

1) Indicates items calibrated using the reference tape.

Annex A
(informative)

Glass- and metal-flanged tape reels

It has been reported that tapes spooled on conventional metal-flanged reels, with "windows" in the flanges, suffer an increase in dropout levels following temperature cycling or bulk erasure. The proposed explanation for this phenomenon is that the presence of the windows in the metal flanges introduces variations in the tape wind tension around each layer, according to whether that part of the layer is exposed in a window or enclosed by the metal flange. Subsequent temperature cycling or bulk erasure then promotes interlayer tape slip to even out the local tension differences. This slippage generates coating wear debris and a consequent increase in the tape dropout level.

It has been found that tapes spooled on windowless metal reels or glass-flanged reels do not suffer from this increase in dropouts following bulk erasure. This supports the above explanation.

The windows in metal flanges allow the evenness of the tape pack to be inspected and clearly show how much tape is on a reel. Glass-flanged reels also offer these advantages and obviate the window problem described above. Where data integrity is of great importance, glass-flanged reels are recommended as a standard product which avoids the possible adverse effect of windows.

Annex B
(informative)

Wear of recording heads

Wear of recording heads depends on a number of factors, including tape speed, relative humidity, tape tension, and abrasivity, and is measured as the volume of material removed.

High tape speeds tend to lift the tape off the head aerodynamically, thus reducing the pressure at the contact point and reducing head wear. The higher the tape speed, the greater the length of tape that passes over a head in unit time, so despite aerodynamic effects, the head wear in unit time may increase with increasing tape speed. Again, the amount of head wear will be directly proportional to the tape tension, as an increase in tension will increase the pressure at the contact point.

Abrasivity is a property of the tape itself, and is neither speed nor tension dependent. It can be thought of as the average number of potential cutting or scratching edges per unit length of tape.

The wear of the recording head will also depend on the head material (mu-metal, Al/Fe/Si, Cr/Cu, ferrite, etc.). In general, however, the relative tendencies for magnetic tapes to abrade or wear recording heads will be in the same ranking (i.e. tapes causing greater amount of wear for mu-metal heads will also cause relatively greater wear for other types of heads).

The abrasivity of a magnetic tape can be assessed using the Fulmer Thin Film Wear Sensor (see annex F). This is a thin, electrically resistive metal film deposited on a ceramic substrate over which the tape is run. The passage of the tape wears the film, causing an increase in its electrical resistance. The rate of change of the resistance of the film is continuously monitored by the Fulmer Tape Abrasivity Meter. This meter provides a constant current input through the thin film, and the voltage across the sensor is monitored by a voltage-to-frequency converter. This frequency is measured using a Rockwell 6502 microprocessor every 0,5 s. The processor is programmed to convert the values of 40 consecutive frequency readings into a measurement of the rate of change of resistance, from which the tape abrasivity is calculated.

NOTE 25 See annex G [3], for further information on measuring the abrasivity of magnetic tape.

Annex C
(informative)

Environmental conditions

C.1 General

The following information gives guidance on storage and operating conditions for HDDR tape.

C.2 Normal operating conditions

Temperature range[1]	10 °C to 40 °C (50 °F to 104 °F)
Relative humidity range[2]	40 % to 60 %
Barometric pressure	50 kPa to 106 kPa

C.3 Extended operating conditions[3]

Temperature range[1]	0 °C to 55 °C (32 °F to 131 °F)
Relative humidity range[2]	25 % to 95 %
Barometric pressure	5 kPa to 106 kPa

C.4 Severe operating conditions[3]

Annex D provides guidelines for instrumentation tapes for use in severe conditions (for example, airborne recording).

C.5 Shipping and short-term storage

Temperature range	10 °C to 40 °C (50 °F to 104 °F)
Relative humidity range[2]	10 % to 40 %
Barometric pressure	5 kPa to 106 kPa

C.6 Extended shipping and short-term storage[4]

Temperature range	− 60 °C to + 60 °C (− 76 °F to + 140 °F)
Relative humidity range[4]	0 % to 95 %
Barometric pressure	5 kPa to 106 kPa

C.7 Recommended long-term storage

Temperature range	15 °C to 25 °C (59 °F to 77 °F)
Relative humidity range[2]	10 % to 20 %
Barometric pressure	50 kPa to 106 kPa

C.8 Deterioration of tape arising from exposure to adverse environmental conditions

Environmental deterioration of tape from exposure to atmospheric conditions of relative humidity and temperature occurs principally through chemical breakdown of the polymeric polyester urethane oxide binder. The mechanism of deterioration of the binder results from chemical reaction with atmospheric moisture (hydrolysis).

The nature of this reaction is such that there are levels of relative humidity and temperature (represented by the boundary between zones 2 and 3 in figure C.1) above which deterioration from this chemical reaction results in a level of binder breakdown which may give rise to tape problems such as layer-to-layer adhesion, tape squeal, increased tape drag and friction and liberation of gummy and stricky head deposits.

1) These temperatures apply to the air in the immediate vicinity of the tape within the tape transport.

2) Relative humidity values should be maintained under noncondensing conditions.

3) The purchaser and supplier should liaise on performance under severe operating conditions. Extended environments may require component qualification for tape and transport.

4) The deterioration of tape under adverse conditions is progressive (see clause C.8). Tapes subjected to such conditions for long periods may need additional restrictions (see recommended long-term storage conditions in clause C.7).

For environmental conditions within zone 3, the rates of binder breakdown from hydrolysis are related to the initial chemical condition of the binder, and the levels of temperature and relative humidity. The rate of breakdown is such that incipient tape problems can manifest themselves following a cumulative exposure of tapes to atmospheric moisture for 24 h. The deterioration can be slowed or stopped by limiting the exposure of tapes to, or isolating tapes from, atmospheric moisture. On the other hand, the environmental conditions within zone 1 of figure C.1 are benign, and the "Recommended storage and operation" area is recommended for both general tape use and long-term storage. It is also recommended that tapes be periodically taken from storage, conditioned for 24 h in a benign environment, such as specified in 5.3, and rewound in that environment before returning to storage. When transporting a tape from storage environment to operating environment, the tape must be stabilized at operating environment for a minimum of 24 h.

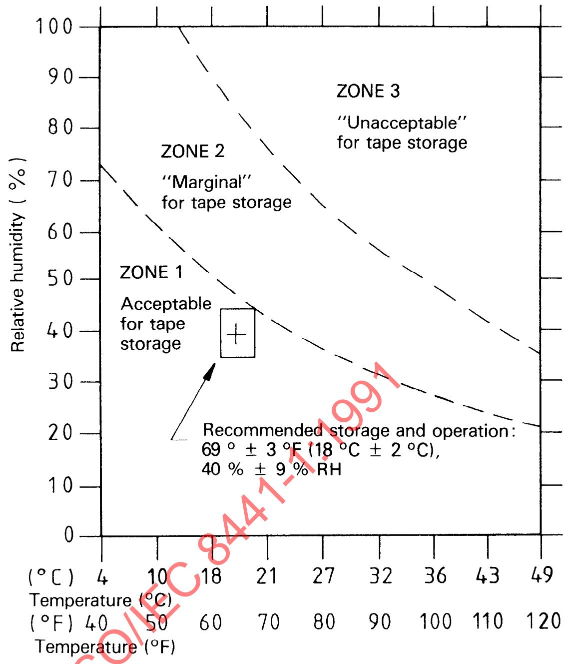


Figure C.1 — Contours of constant long-term storage environment

Annex D
(informative)

Severe operating conditions

(This annex is based on ISO 6371:1988, annex C.)

D.1 Application

This annex defines additional tests which are recommended as guidelines for instrumentation tape used in applications involving limited-duration recording (but not playback) under severe environmental conditions (for example, airborne recording). For the purpose of this annex, these conditions are defined as follows:

a) Temperature: – 20 °C to + 77 °C (– 4 °F to + 170 °F)

b) Relative humidity: 25 % to 95 %

c) Barometric pressure: 5 kPa to 105 kPa

d) Maximum duration of use: 2 h in extreme conditions

Ideally, the tape temperature should not fall below 0 °C because of the possibility of tape lubricant exudation. If the tape has been subjected to temperatures below 0 °C, it may be advantageous to tissue clean it prior to recovering the data to obviate any chance of tape/head separation due to build-up of tape lubricant deposits on the heads.

D.2 Conditions

The set-up conditions defined in 8.1 of this part of ISO/IEC 8441 apply, except that the operating bias current should correspond to a 2 dB fall-off (over bias peak) of the peak output from the reference tape when a 1,0 MHz signal is recorded at the reference record level (see 3.13), at a tape speed of 1,524 m/s (60 in/s).

NOTES

26 This test is applicable to tapes used in either 1,5 MHz or 2,0 MHz wideband or DR equipment.

27 The tape tension of the recording transport may require reduction to accommodate the reduced strength of the tape base film at elevated temperatures as shown in figure D.1.

D.3 Environmental performance tests for limited duration recording under severe conditions

D.3.1 Definition of severe conditions

For the purpose of this annex, severe conditions are those extremes of temperature, humidity, and barometric pressure which, when applied for a limited duration, do not cause any unacceptable degradation in tape performance in the recording mode.

D.3.2 Requirement

When subjected to the specified environmental conditions during recording, the tape shall meet the requirements agreed on between the interchange parties for the intended application, with respect to output level uniformity (long-term and short-term), wavelength response, sensitivity, and signal-to-noise ratio when played back in the test environment specified in 5.3.

WARNING — It may be necessary to adopt requirements more relaxed than those in clause 8.

D.3.3 Test procedure

D.3.3.1 Low temperature test

a) **Prerecording conditioning.** Condition the tape for 48 h under environmental conditions of – 20 °C, 20 % relative humidity, and 100 kPa ± 5 kPa barometric pressure.

b) **Recording.** Maintain the environmental conditions in accordance with D.3.3.1 a) in the recorder tape path, and carry out the recording procedures as specified in 8.2.1, 8.3.1, 8.4.1 and 8.5.1.

c) **Postrecording conditioning.** Condition the tape for 48 h in the test environment specified in 4.3.

d) **Playback.** Maintain the environment specified in 4.3 in the recorder tape path. Play back the tape and determine the extent of compliance as specified in 8.2.2, 8.3.2, 8.4.2 and 8.5.2.

D.3.3.2 High temperature test

a) **Prerecording conditioning.** Condition the tape for 16 h under environmental conditions of 77 °C, 95 % relative humidity, and 100 kPa ± 5 kPa barometric pressure.

b) **Recording.** Maintain the environmental conditions in accordance with D.3.3.2 a) in the recorder path, and carry out the recording procedures as specified in 8.2.1, 8.3.1, 8.4.1 and 8.5.1. The total recording duration should not exceed 90 min.

NOTE 28 Ferric oxide (Fe_2O_3) tape requires, on average, about 1 dB less record current at 77 °C. High energy tape can require about 3 dB (30 %) less current than normal for optimum recording at high temperatures. Users should establish the optimum current for themselves.

c) **Postrecording conditioning.** As defined in D.3.3.1 c).

d) **Playback.** As defined in D.3.3.1 d).

D.3.3.3 Low pressure test

a) **Prerecording conditioning.** Condition the tape for 48 h on a tape transport under environmental conditions of 23 °C, 50 % relative humidity, and 5 kPa ± 0,5 kPa barometric pressure. Execute a high-speed, full-length forward and rewind pass every 2 h.

b) **Recording.** Maintain the relative humidity and pressure specified in D.3.3.3 a), but establish a temperature of 77 °C in the tape path. Carry out the recording procedures as specified in 8.2.1, 8.3.1, 8.4.1 and 8.5.1.

c) **Postrecording conditioning.** As defined in D.3.3.1 c).

d) **Playback.** As defined in D.3.3.1 d).

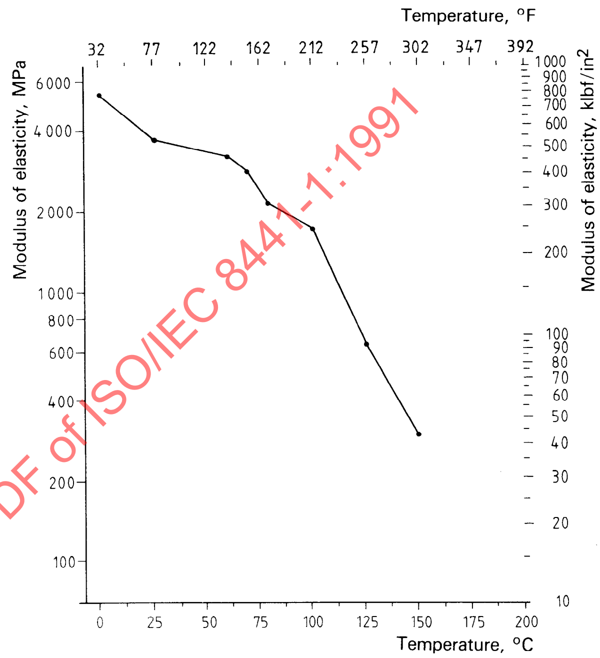


Figure D.1 — Temperature dependence of elastic modulus of polyester-base film

Annex E
(informative)

Surface electrical resistance testing

E.1 Scope

These methods are designed for use in determining insulation and volume resistance and approximate surface resistance of electrical insulating materials together with means of converting the latter two into terms of volume and surface resistivities.

E.2 Test specimens

Dimensions for solid insulating materials: for insulation resistance measurements, the specimen may have any practical form but is usually in the form of a sheet, a bar, a tape, a rod, or a tube. For volume and surface resistance measurements, the test specimen shall be in the form of a flat plate or a tube, having dimensions in accordance with the specifications.

E.3 Apparatus

The apparatus shall consist of suitable electrodes, a source of direct-current potential, a suitable current indicating amplifier, and a voltmeter. The latter role may be filled by a galvanometer with suitable shunts and a calibrating resistance, or a megohm bridge, together with suitable switches and keys.

E.3.1 Electrodes for testing insulation resistance

It is important that good and complete contact be made between the electrodes and the surface of the material on test. For repeated tests at high relative humidities it is essential that the electrode metal(s) be protected against tarnishing. For insulation resistance determinations the electrode arrangements most commonly used for solid materials are shown in figure E.1 (binding posts), figure E.2 (bar, thin sheets and tapes), and figure E.3 (tapered pins).

E.3.2 Electrodes for testing volume and surface resistance

When both the volume and surface resistances are to be measured, there shall be applied to each solid specimen three electrodes designated, respectively, as electrode No. 1, electrode No. 2, and electrode No. 3 (see figure E.4). In the case of a flat specimen, electrode No. 2 shall be in the form of a ring surrounding electrode No. 1 as shown in figure E.4. In the case of tubular specimens, the electrodes shall be applied as shown in figure E.5. For liquid materials the cell should have a guard electrode. However, a two-terminal cell may be used, provided it is established that the insulation resistance of the insulation between the electrodes is at least 100 times the resistance through the liquid.

E.3.3 Electrode materials

The electrode materials shall be corrosion-resistant under the conditions of test.

E.3.3.1 Contact or specimen electrode material

Specimen electrodes as shown in figure E.4 to figure E.7 may be made of silver conductive paint (provided its solvent does not attack the material under test), sprayed metal (provided satisfactory adhesion can be obtained), evaporated metal, metal foil applied with a thin film of petrolatum silicone grease, or silicone oil (provided the gap can be properly cleaned without disturbing the edges of the adjacent electrodes when surface resistance is to be measured), colloidal graphite (provided it will adhere to the specimen, the specimen does not absorb water readily, and the test is to be made in a dry atmosphere), conductive rubber or mercury (provided care can be taken to eliminate possible toxic effects).

NOTE 29 Conductive paint for specimen electrodes has desirable characteristics, such as giving intimate surface contact with the test surface, and often being sufficiently porous to moisture to permit conditioning. Each application must be considered for proper choice of material. There should be no adverse interaction between the material and its vehicle, that is, solvent attack, etc. The film must adhere properly to the test surface to give good electrical contact.

E.3.3.2 Backing or cell electrode material

The electrode material shall be free of insulating and semi-conducting oxide films. Gold- or silver-plated brass, preferably with a surface flash of rhodium, is highly satisfactory. Nickel is usually satisfactory, but chromium should be avoided. Stainless steel electrodes, above 304 in the type 300 series, are satisfactory.

E.3.4 Direct-current potential

The direct current potential source may be a dry or storage battery or a rectified alternating-current voltage supply. When the alternating-current voltage supply is employed, precautions must be observed to maintain a sufficiently constant direct-current voltage with negligible ripple. Unless otherwise specified, the potential shall be 100 V ± 10 V.

E.3.5 Measuring equipment

E.3.5.1 Voltmeter and current indicating amplifier, electrometer, or microammeter

The voltmeter shall have a reading error less than ± 2 % of full scale and have a range such that the test voltage reading is greater than one-third of full scale. If possible, the current indicating amplifier, electrometer, or microammeter shall have a sensitivity and ranges such that the reading during measurement shall be greater than one-third full scale. The most sensitive current indicating amplifiers or electrometers have full scale deflection for 10^{-18}. Thus a resistance as high as 5 times 10^{15} Ω can be measured with an accuracy of 10 % using 100 V. Careful static shielding will be required when using an instrument of this sensitivity. For lower resistance a calibrated galvanometer or microammeter can be used to measure the current.

E.3.5.2 Galvanometer and calibrated resistance

A galvanometer with proper shunts can be used to compare an unknown resistance with a calibrated resistance. The galvanometer shall have as high a sensitivity as is consistent with reasonable stability of zero. A sensitivity of 10^{-10} A/mrad (1 mm at 1 m scale distance) is sufficient to measure resistance as high as 10^{11} with an accuracy of ± 10 %. It should be well damped. The most convenient shunt is the type known as a universal or Ayrton shunt whereby that fraction of the total current which passes through the galvanometer may be changed without changing the galvanometer damping. The calibrated resistance shall be at least 100 000 Ω. A resistance of 1 MΩ is preferred. An insulated guarded switch is needed for shorting the specimen.

E.3.5.3 Bridge

A bridge method of measuring insulation resistances up to 10^{11} Ω may be used if a high-resistance balance detector, such as a vacuum tube voltmeter, is employed, and the necessary guarding requirements are observed.

E.3.6 Switches and keys

All switches and keys shall be suitably insulated and guarded.

E.4 Procedure

E.4.1 Conditioning of specimens

Determinations of insulation resistance of solid dielectrics shall be made only on specimens which have been kept for a specified time in air at a specified humidity and temperature. These conditions shall be in accordance with the specifications. The specimen shall be kept in the same conditions during the determination. The measurements shall be made without opening the humidity chamber. Where electrode leads pass through the walls of the chamber, care shall be taken to ensure against current leakage at these points by suitable guarding or by passing leads through bushings of wax or other nonwetting materials.

NOTE 30 Coaxial cables such as Uniradio RG-6A/u (up to 85 °C) or RG-143 (up to 250 °C) may be used for all leads, the braids to be properly terminated at the instrument ground to minimize errors arising from stray capacities to ground, operator, and equipment.

E.4.2 Precautions in mounting specimens

In mounting the specimens for measurement, it is important that there shall be no conductive paths between the electrodes except those through the specimen. For example, the specimens shown in figure E.1, figure E.2, figure E.3 and figure E.4 shall be held by one or both edges so that none of the electrodes touches the supports.

E.4.3 Method of measuring resistance

E.4.3.1 Voltmeter-ammeter method

The test potential is applied to the specimen and current measuring instrument (current indicating amplifier, electrometer, or microammeter) in series. The potential is measured with a suitable voltmeter (see E.3.5.1) and the current flowing at the end of a specified electrification time is measured by the current measuring instrument. The value of the resistance, (R), is obtained from the equation

$$R = \frac{E}{I}$$

where

E is the value of the potential applied to the specimen;

I is the current flow through the specimen at the specified electrification time.

E.4.3.2 Comparison method

E.4.3.2.1 Galvanometer with calibrated resistance. The test potential is applied to the specimen, the calibrated resistance and the galvanometer, all connected in series. The shunt is adjusted to give an adequate deflection of the galvanometer and this deflection and the shunt ratio are noted. After setting the shunt ratio to the proper value, the switch across the specimen is closed, leaving only the calibrated resistance in the circuit. The galvanometer deflection and the shunt ratio are then noted. The value of the resistance, (R), is computed from the equation

$$R = M \cdot \frac{D}{d} \cdot \frac{s}{S} - M$$

where

M is the value of the calibrated resistance;

D is the deflection of the galvanometer when the calibrated resistance only is in the circuit;

d is the deflection of the galvanometer when the calibrated resistance and the specimen are in the circuit;

S is the shunt ratio when the calibrated resistance only is in the circuit;

s is the shunt ratio when the calibrated resistance and the specimen are in the circuit.

Or, if the shunt setting is given in multiplying factors, the formula becomes

$$R = M \cdot \frac{D}{d} \cdot \frac{F}{f} - M$$

where

F is the shunt multiplying factor for the calibrating resistance;

f is the shunt multiplying factor for the specimen.

If the calibrating resistance is so small that the potential source will give too large a deflection of the galvanometer with the smallest shunt ratio (or largest multiplying factor), it is then necessary to calibrate by means of a low potential source. The same measurements shall be made as in the previous cases, but it is now necessary to know the voltage of the calibrating potential, E, and of the measuring potential, e. Then

$$R = M \cdot \frac{D}{d} \cdot \frac{s}{S} \cdot \frac{e}{E} - M$$

or

$$R = M \cdot \frac{D}{d} \cdot \frac{F}{f} \cdot \frac{e}{E} - M$$

E.4.3.2.2 Bridge. The specimen is connected to the measuring terminals of the bridge and the proper potential is applied. The bridge shall be continuously adjusted so that it is in balance at the end of the specified electrification time. The reading of the bridge is then the resistance of the specimen.

E.4.3.3 Precautions in measuring high resistances

In measuring very high resistances it is important that all apparatus between the guard electrode and the terminal of the current measuring instrument be guarded and adequately insulated from guard and ground. The resistance to ground of all connections and apparatus between the current measuring instrument and the guarded electrode, including the surface resistance between the guarded electrode and the guard electrode, must be high enough not to form an appreciable shunt on the current measuring instrument. This means it should be more than 100 times the input resistance of the instrument. For the most sensitive indicating amplifiers or electrometers this input resistance may be 10^{13} Ω to 10^{14} Ω. For a galvanometer it may be only 1 MΩ. For a bridge it should be 100 times the value of the ratio resistance. These values include the resistance from the guarded electrode to the guard electrode when volume and surface resistances are being measured.

NOTE 31 The insulating supports with assembled cables should be periodically measured for leakage between the measuring electrode and ground. This may be conveniently done by temporarily disconnecting the cable shield and guard electrode from ground and measuring the current flow through the apparatus when the high voltage is connected to the measuring electrode. If the leakage resistance obtained is not beyond the range of the apparatus, the reason for the low value should be determined and corrected.

If it is necessary that one side of the specimens be grounded, then either the potential source or the current measuring instrument must be well insulated from ground. In either case the resistance to ground must be more than 100 times the resistance to be measured.

E.4.3.4 Electrification time

Unless otherwise specified, the electrification time (the elapsed time between the application of the potential and the measurement of the current or resistance) shall be 60 s.

E.4.4 Insulation resistance determination

E.4.4.1 Method

The insulation resistance shall be determined as follows: Connect the measuring leads to adjacent terminals on the specimen and measure the resistance at the specified electrification time. If needed, short the specimen for at least 2 min, reverse the polarity of the potential source and remeasure the resistance.

E.4.4.2 Measurements for insulation resistance

The following measurements shall be made when insulation resistance is to be determined:

E.4.4.2.1 Dimensions of the electrodes (figure E.1, figure E.2 and figure E.3).

E.4.4.2.2 Distance between or spacing of the electrodes.

E.4.4.2.3 The insulation resistance between the electrodes.

E.4.4.2.4 The temperature of the material under test.

E.4.4.2.5 The relative humidity of the atmosphere surrounding the material under test.

E.4.4.2.6 Voltage used in measuring.

E.4.4.3 Calculations for insulation resistance

The insulation resistance is the resistance as measured between any two adjacent binding posts of figure E.1, between any two adjacent metal strips of figure E.2, or between the tapered pins of figure E.3. This value should be expressed merely as "insulation resistance". In the case of the metal strips the surface resistance per square may be calculated by the following formula:

$$\sigma = \frac{R'b}{L}$$

where

- R' is twice the surface resistance as measured;
- b is the average length of electrodes;
- L is the distance between the electrodes.

E.4.5 Volume and surface resistance determination

E.4.5.1 Method

The volume resistance shall be measured using a completely guarded circuit. Electrode No. 1 shall be used as the guarded electrode and shall be connected to the current measuring instrument, electrode No. 2 shall be used as the guard electrode and shall be connected to the junction between the current measuring instrument and the potential source, the electrode No. 3 shall be used as the unguarded electrode and shall be connected to the other terminal of the potential source. If a bridge is used, electrodes Nos. 1 and 3 shall be connected to the measuring terminals and electrode No. 2 connected to the guard terminal.

E.4.5.2 Precautions in measuring volume resistance

In measuring the volume resistance it is important that the current flow between the guarded electrode and the guard electrode shall be negligible. The current through the specimen divides between this path and that through the current measuring instrument, and only the flow through the current measuring instrument is measured. In order that the error resulting from this source shall be less than 1 %, the insulation resistance between the guarded electrode and the guard electrode shall be more than 100 times the resistance of the current measuring instrument. For the most sensitive indicating amplifiers a resistance of 10^{14} Ω may be required between the guard and the guarded electrodes.

E.4.5.3 Measurements for volume resistivity

The following measurements shall be made when volume resistivity is to be determined by means of the specimen shown in figure E.4 to figure E.7.

E.4.5.3.1 Areas of guarded electrodes corrected with sufficient accuracy for gap width between the guard and guarded electrodes for the following electrode system are shown in figure E.4 to figure E.7.

E.4.5.3.1.1 For flat circular electrodes (figure E.4 or figure E.5) the effective area is

$$A_{\text{effective}} = \frac{\pi}{4}(d_{\text{effective}})^2$$

$$d_{\text{effective}} = D_1 + g \text{ (if } g \leqslant 1{,}66t\text{) or}$$

$$= D_1 + 1{,}66t \text{ (if } g \geqslant 1{,}66t\text{)}$$

where

- $A_{effective}$ is the effective area of the measuring electrode No. 1;
- $d_{effective}$ is the effective diameter of the measuring electrode No. 1;
- g is the gap or linear separation between measuring and guard electrodes (between Nos. 1 and 2);
- t is the thickness of the specimen;
- D_1 is the outside diameter of measuring electrode No. 1.

E.4.5.3.1.2 For flat rectangular electrodes (figure E.4 or figure E.5) the effective area is

$A_{effective} = (L + g)(W + g)$ (if $g \leqslant 1{,}66t$) or

$= (L + 1{,}66t)(W + 1{,}66t)$ (if $g > 1{,}66t$)

where

- L is the length of measuring electrode No. 1;
- W is the width of measuring electrode No. 1.

E.4.5.3.1.3 For tubular electrodes (figure E.6 and figure E.7) the width becomes the effective circumference of the tube (figure E.6):

$A_{effective} = (L + g)(\pi D_0)$ (if $g \leqslant 1{,}66t$) or

$= (L + 1{,}66t)(\pi D_0)$ (if $g > 1{,}66t$)

D_0 = effective diameter of the tube

where

- D_0 is equal to $\frac{D_1 + D_2}{2}$;
- D_1 is the average inside diameter of the tube;
- D_2 is the average outside diameter of the tube.

E.4.5.3.2 Thickness of the specimen.

E.4.5.3.3 Conditioning treatment to which the specimen was exposed.

E.4.5.3.4 Applied voltage.

E.4.5.3.5 Volume resistance.

E.4.5.3.6 Temperature of the material under test.

E.4.5.3.7 Relative humidity of the air surrounding the material under test.

E.4.5.3.8 Volume resistivity, ρ, which shall be calculated from the volume resistance and reported in terms of ohms per centimetre as follows:

$$\rho = \frac{A_{R_v}}{t}$$

where

- t is the average thickness of the specimen;
- R_v is the volume resistance as measured by the instrument;
- A is the effective area, calculated as shown for the electrode system.

E.4.6 Surface resistance determination

E.4.6.1 Method

The surface resistance shall be measured using the completely guarded circuit. Electrode No. 1 shall be used as the guarded electrode and connected to the current measuring instrument; electrode No. 3 shall be used as the guard electrode and connected to the junction between the current measuring instrument and the potential source; electrode No. 2 shall be used as the unguarded electrode and connected to the other terminal of the potential source. If a bridge is used, electrodes No. 1 and 2 shall be connected to the measuring terminals and electrode No. 3 shall be connected to the guard terminal.

E.4.6.2 Precautions in measuring surface resistance

The precautions needed for measuring surface resistance are the same as for measuring volume resistance (see E.4.5.2).

E.4.6.3 Measurements for surface resistivity

The following measurement shall be made when surface resistivity is to be determined by means of the specimens shown in figure E.4 to figure E.7.

E.4.6.3.1 Surface resistance. The effective perimeter and gap are given with sufficient accuracy for the following electrode systems by

E.4.6.3.1.1 Flat circular electrodes (figure E.4 or figure E.5):

$P = \pi D_0$

where

- P is the effective diameter of the electrode system;
- D_0 is the effective diameter of electrode No. 1 $= \frac{D_1 + D_2}{2} = D_1 + g$;

D_1 is the outside diameter of electrode No. 1;

D_2 is the inside diameter of electrode No. 2;

g is the gap or linear distance between electrodes No. 1 and No. 2 (twice the specimen thickness but not exceeding 1/4 in).

E.4.6.3.1.2 Flat rectangular electrodes (figure E.4 or figure E.5):

$$P = 2(L + g) + 2(W + g)$$

where L and W are the length and width, respectively, of the measuring electrode No. 1.

E.4.6.3.1.3 Tubular electrodes (figure E.6 or figure E.7):

$$P = 2\pi D_2$$

where

D_2 is the average outside diameter of the tube;

g is the gap or linear distance between electrodes No. 1 and No. 2 twice the specimen thickness but not exceeding 1/6 in.

NOTE 32 When the tube is tapered, the perimeters shall be calculated separately for each gap, and the values added to give the total perimeter P.

E.4.6.3.2 Distance between electrodes No. 1 and No. 2.

E.4.6.3.3 Average perimeter.

E.4.6.3.4 Conditioning treatment to which the specimen was exposed.

E.4.6.3.5 Temperature of the material under test.

E.4.6.3.6 Relative humidity of air surrounding the material under test.

E.4.6.3.7 Applied voltage.

E.4.6.3.8 Surface resistivity, σ, which shall be calculated from the surface resistance and supported in ohms, as follows:

$$\sigma = \frac{P}{g} R_s$$

where

P is the effective perimeter, calculated as shown for the electrode system;

g is the gap;

R_s is the surface resistance as measured by the instrument.

E.5 Report

The report shall include the data specified in E.4.6, and the following:

a) the measured resistance, in ohms;

b) the type and dimensions of the electrodes with their spacing if determined;

c) the volume resistivity, in ohms per centimetre units, if determined;

d) the surface resistivity, in ohms, if determined;

e) the duration and type of conditioning (temperature and relative humidity) to which the specimen was subjected prior to measurement;

f) the temperature of the specimen at the time of test;

g) the relative humidity of the air surrounding the specimen at the time of measurement;

h) the voltage used.

Dimensions in decimetres

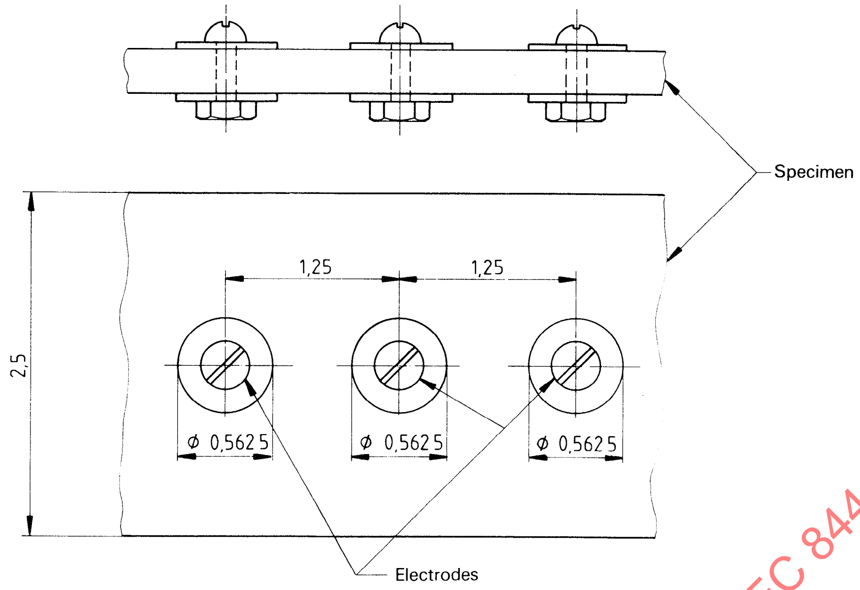
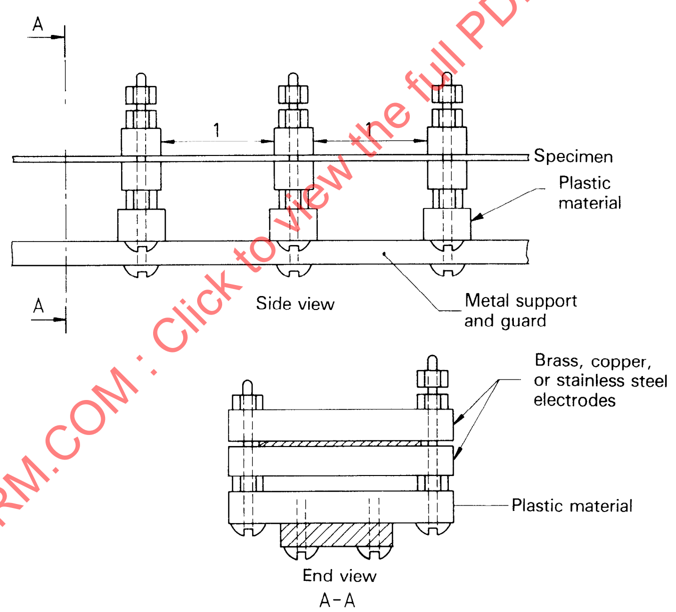


Figure E.1 — Application of binding-post electrodes to flat, solid specimens



NOTE — For rigid specimens, the metal support and accompanying methyl methacrylate insulators may be eliminated and the specimen supported by its leads. The bars shall have tinfoil wrapped around them and, after the bars have been clamped on to the specimen, tinfoil shall be pressed down with a thin tool along the edge of the bar to ensure intimate contact with the insulation.

Figure E.2 — Application of strip electrodes to flexible tapes and flat solid surfaces