BS EN 60811-401:2012

BSI Standards Publication

Electric and optical fibre cables — Test methods for non-metallic materials

Part 401: Miscellaneous tests — Thermal ageing methods — Ageing in an air oven

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National foreword

This British Standard is the UK implementation of EN 60811-401:2012. It is identical to IEC 60811-401:2012.

In the UK, the relationship between the supersessions of BS EN 60811 series can be summarized as follows.

BS EN 60811-100 together with	Supersedes -
-201, -202, -203, -501	BS EN 60811-1-1:1995
-301, -302, -411, -601, -602, -603, -604	BS EN 60811-5-1:2000
-401, -412	BS EN 60811-1-2:1995
-402, -502, -503, -606	BS EN 60811-1-3:1995
-403, -404, -507	BS EN 60811-2-1:1998
-405, -409	BS EN 60811-3-2:1995
-406, -511, -605, -607	BS EN 60811-4-1:2004
-407, -408, -410, -510, -512, -513	BS EN 60811-4-2:2004
-504, -505, -506	BS EN 60811-1-4:1995
-508, -509	BS EN 60811-3-1:1995

Superseded standards are withdrawn

The UK participation in its preparation was entrusted by Technical Committee GEL/20, Electric cables, to Subcommittee GEL/20/17, Electric Cables - Low voltage.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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EUROPEAN STANDARD

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June 2012

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English version

Electric and optical fibre cables - Test methods for non-metallic materials - Part 401: Miscellaneous tests - Thermal ageing methods - Ageing in an air oven

(IEC 60811-401:2012)

Câbles électriques et à fibres optiques - Méthodes d'essai pour les matériaux non-métalliques - Partie 401: Essais divers - Méthodes de vieillissement thermique - Vieillissement en étuve à air
(CEI 60811-401:2012)

Kabel, isolierte Leitungen und Glasfaserkabel - Prüfverfahren für nichtmetallene Werkstoffe - Teil 401: Sonstige Prüfungen - Thermische Alterungsverfahren - Alterung im Wärmeschrank
(IEC 60811-401:2012)

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European Committee for Electrotechnical Standardization
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Foreword

The text of document 20/1285/FDIS, future edition 1 of IEC 60811-401, prepared by IEC/TC 20 "Electric cables" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 60811-401:2012.

The following dates are fixed:

• latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2013-01-16
• latest date by which the national standards conflicting with the document have to be withdrawn	(dow)	2015-04-16

This document supersedes 8.1 and 8.4 of EN 60811-1-2:1995 + A2:2000 (partially). Full details of the replacements are shown in Annex A of EN 60811-100:2012.

There are no technical changes with respect to EN 60811-1-2:1995 + A2:2000, but see the Foreword to EN 60811-100:2012.

This standard is to be read in conjunction with EN 60811-100.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CENELEC [and/or CEN] shall not be held responsible for identifying any or all such patent rights.

This standard covers the Principle Elements of the Safety Objectives for Electrical Equipment Designed for Use within Certain Voltage Limits (LVD - 2006/95/EC)

Endorsement notice

The text of the International Standard IEC 60811-401:2012 was approved by CENELEC as a European Standard without any modification.

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Annex ZA
(normative)

Normative references to international publications with their corresponding European publications

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

NOTE When an international publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

Publication	Year	Title	EN/HD	Year
IEC 60228	-	Conductors of insulated cables	EN 60228	-
IEC 60811-100	2012	Electric and optical fibre cables - Test methods for non-metallic materials - Part 100: General	EN 60811-100	2012
IEC 60811-409	-	Electric and optical fibre cables - Test methods for non-metallic materials - Part 409: Miscellaneous tests - Loss of mass test for thermoplastic insulations and sheaths	EN 60811-409	-
IEC 60811-501	-	Electric and optical fibre cables - Test methods for non-metallic materials - Part 501: Mechanical tests - Tests for determining the mechanical properties of insulating and sheathing compounds	EN 60811-501	-
IEC 60811-504	-	Electric and optical fibre cables - Test methods for non-metallic materials - Part 504: Mechanical tests - Bending tests at low temperature for insulation and sheaths	EN 60811-504	-

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INTRODUCTION

The IEC 60811 series specifies the test methods to be used for testing non-metallic materials of all types of cables. These test methods are intended to be referenced in standards for cable construction and for cable materials.

NOTE 1 Non-metallic materials are typically used for insulating, sheathing, bedding, filling or taping within cables.

NOTE 2 These test methods are accepted as basic and fundamental and have been developed and used over many years principally for the materials in all energy cables. They have also been widely accepted and used for other cables, in particular optical fibre cables, communication and control cables and cables for ships and offshore applications.

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ELECTRIC AND OPTICAL FIBRE CABLES – TEST METHODS FOR NON-METALLIC MATERIALS –

Part 401: Miscellaneous tests – Thermal ageing methods – Ageing in an air oven

1 Scope

This Part 401 of IEC 60811 specifies the procedure for ageing in an air oven, which typically applies to crosslinked and thermoplastic compounds used for insulating and sheathing materials.

2 Normative references

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

IEC 60228, *Conductors of insulated cables*

IEC 60811-100:2012, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 100: General*

IEC 60811-409, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 409: Miscellaneous tests – Loss of mass test for thermoplastic insulations and sheaths*

IEC 60811-501, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 501: Mechanical tests – Tests for determining the mechanical properties of insulating and sheathing compounds*

IEC 60811-504, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 504: Mechanical tests – Bending tests at low temperature for insulation and sheaths*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60811-100 apply.

4 Test method

4.1 General

This part of IEC 60811 shall be used in conjunction with IEC 60811-100.

Unless otherwise specified, tests shall be carried out at room temperature.

An ageing treatment in an air oven may be required by the relevant cable standard:

a) for prepared test pieces of insulating or sheathing material only (see 4.2.3.2);
b) for prepared test pieces of cores (conductor and insulation) (see 4.2.3.2 and 4.2.3.3 if necessary);

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c) for test pieces of completed cable (see 4.2.3.4);

d) for the loss of mass test (see IEC 60811-409).

The ageing test a) or b) and the loss of mass test d) may be combined and carried out on the same test pieces when the aging time and aging temperature are the same.

In general, mechanical characteristics are measured after treatment, but in some cases, the conductor and the separator, if any, cannot be removed without damaging the insulation and a bending test is realized on the circular conductor up to and including 16 mm^2. Ageing followed by the bending test is considered the acceptance procedure in case of dispute.

4.2 Influence of the ageing treatment on the mechanical characteristics

4.2.1 Apparatus

The ageing treatment is realized in an oven with natural air flow or air flow by pressure. The air shall enter the oven in such a way that it flows over the surface of the test pieces and leaves near the top of the oven. The oven shall have not less than 8 and not more than 20 complete air changes per hour at the specified ageing temperature. Two test methods for measuring air flow through an oven are given in Annex A.

Unless otherwise specified in the relevant cable specification, a rotating fan inside the oven is allowed when testing rubber compounds. For all other compounds a fan shall not be used inside the oven, and in cases of dispute, rubber compounds shall also be tested in an oven which is designed to operate without a fan rotating inside it.

4.2.2 Sample and test pieces preparation

The sample of the cable, or sheath removed from the cable, or samples of core, cut into pieces which are sufficiently long, shall be taken, preferably from positions close to that from which the samples for the tensile tests without ageing are taken in accordance with IEC 60811-501.

Test pieces, dumb-bell or tubular, are prepared according to IEC 60811-501.

Test pieces can consist of samples of core, cut into pieces which are sufficiently long. If, after ageing, the conductor and the separator, if any, can be removed without damaging the insulation, preparation of test pieces shall be carried out according to Annex B (Clause B.2). For circular conductors up to and including 16 mm^2 and having plain or metal coated wires and also when a separator around the conductor is included, a bending test is carried out on the aged test pieces.

4.2.3 Ageing procedure

4.2.3.1 General

This test shall be carried out not less than 16 h after the extrusion or cross-linking, if any, of the insulating or sheathing compounds. It can be done on tubular or dumb-bell test pieces prepared according to IEC 60811-501 or insulated cores as described in the present standard.

4.2.3.2 Ageing procedure for test pieces prepared according to IEC 60811-501 and Clause B.1 and B.2.2 and Annex C of this standard

This procedure shall be used for

– test pieces of insulating material without conductor and of sheathing material, according to IEC 60811-501,

– test pieces of cores with the original conductor (see Clause B.1),

– tubular test pieces with a reduced conductor (see B.2.2),

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– complete cable (see Annex C).

Compounds of obviously different compositions shall not be tested at the same time in the same oven.

Five test pieces, as specified in IEC 60811-501 shall be suspended vertically and substantially in the middle of the oven so that each test piece is at least 20 mm from any other test pieces.

The test pieces shall not occupy more than 2 % of the volume of the oven.

The test pieces shall be kept in the oven at the temperature and for the time specified for the material in the relevant standard for the type of cable.

As soon as the ageing period is completed, the test pieces shall be removed from the oven and left at ambient temperature, avoiding direct sunlight, for at least 16 h.

4.2.3.3 Ageing procedure for test pieces prepared from conductors above 16 mm^2

The following procedure shall be used when the conductor and the separator, if any, cannot be removed without damaging the insulation after ageing.

The test pieces prepared as described in B.2.3.1 shall be placed substantially in the middle of the oven so that each test piece is at least 20 mm from any other test pieces. They shall be supported at both ends and the insulation shall not contact any object other than the binding wire. The test pieces shall not occupy more than 2 % of the volume of the oven, and they shall be kept in the oven at the temperature and for the time specified in the relevant standard for the type of cable.

As soon as the ageing period is completed, the test pieces shall be removed from the oven, left at ambient temperature avoiding direct sunlight, for at least 16 h, dumb-bell are prepared as described in B.2.3.2.

4.2.3.4 Ageing procedure for pieces of complete cable

The three test pieces of cable as described in Clause C.1 shall be suspended vertically and substantially in the middle of the oven at least 20 mm away from any other piece and shall not occupy more than 2 % of the volume of the oven.

The test pieces of cable shall be kept in the oven at the temperature and for the time specified in the relevant standard for the type of cable.

As soon as the specified heating period is completed, the test pieces of cable shall be removed from the oven and left at ambient temperature, avoiding direct sunlight, for at least 16 h.

4.2.4 Measurements

Determination of the mechanical properties on aged dumb-bell and/or tubular test pieces obtained directly after ageing or prepared after ageing, according to the case (see B.2.3 or Clause C.2) shall then be carried out in accordance of IEC 60811-501.

4.2.5 Expression of results

Calculate the tensile strength and the elongation at break, according to the definitions given in IEC 60811-501.

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If required by the standard for the material in the relevant standard for the type of cable, the values found for the aged test pieces shall be calculated, in terms of variation compared to the untreated test pieces according to the following formulae:

$$V_T = \frac{T_E - T_U}{T_U} \times 100 \quad (1)$$

$$V_E = \frac{E_E - E_U}{E_U} \times 100 \quad (2)$$

where

V_T variation of the tensile strength in per cent;

T_E tensile strength of aged test piece;

T_U tensile strength of untreated test piece;

V_E variation of the elongation at break in per cent;

E_E elongation at break of aged test piece in per cent;

E_U elongation at break of untreated test piece in per cent.

NOTE The untreated specimen is kept at room temperature.

4.2.6 Requirements

The value and the variation between the median value obtained of the test pieces aged and the median value of the values obtained for the untreated test pieces (see IEC 60811-501) expressed as a percentage of the latter shall not exceed the percentage specified in the standard for the material in the relevant standard for the type of cable.

4.2.7 Test report

The test report shall be in accordance with that given in IEC 60811-100.

4.3 Bending test on test pieces of core

4.3.1 Apparatus

Ageing is carried out in an oven as described in 4.2.1.

The bending test apparatus is described in IEC 60811-504.

4.3.2 Sample and test pieces preparation

Two samples of suitable length shall be taken from each core to be tested preferably from positions close to that from which the samples for the tensile tests without ageing are taken (see IEC 60811-504).

4.3.3 Procedure

Test pieces are aged according to the procedure described in 4.2.3.3.

As soon as the ageing period is completed, the test pieces shall be removed from the oven and left at room temperature, avoiding direct sunlight, for at least 16 h.

Each test piece shall then be bent at ambient temperature around a mandrel so as to form a close helix.

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The bending procedure shall be carried out uniformly at a rate of one turn in about 5 s.

The bending tests may be carried out with the apparatus described in IEC 60811-504.

The diameter of the mandrel shall be f times the diameter of the core. The values of f and also the number of turns are specified as follows.

Table 1 – Number of turns for bending test

Cross-sectional area of conductor mm^2	Factor f	Number of turns
Up to and including 2,5	1 ±0,1	7
4 and 6	2 ±0,1	6
10 and 16	4 ±0,1	5

4.3.4 Requirement

At the end of the bending procedure the test pieces shall be examined while still on the mandrel. The insulation of both test pieces shall not show any crack when examined with normal or corrected vision without magnification. Any cracks in the first or the last turn on the mandrel shall be disregarded.

4.3.5 Test report

The test report shall be in accordance with that given in IEC 60811-100.

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Annex A
(normative)

Methods of measuring air flow in ovens

A.1 Method 1 – Indirect or power consumption method

A.1.1 In this method, the additional power required to maintain the oven at a given temperature with its ports open, over that required to maintain the oven at the same temperature with its ports closed, is used as a measure of the quantity of air passing through the oven when the ports are open. The average power ($P1$ watts) required to maintain the oven temperature at the specified ageing temperature when the ports are open is determined over a period of 30 min or longer. The ventilation ports (and, if necessary, the thermometer aperture) are then closed and the average power ($P2$ watts) to maintain the same temperature over a similar period is determined. It is essential that the difference between the oven temperature and the room temperature should be the same for the two tests to within 0,2 °C. The room temperature should be measured at a point about 2 m from the oven, approximately level with its base, and at least 0,6 m from any solid objects.

A.1.2 The amount of air passing through the oven, when the ports are open, is given by the formulae:

$$m = \frac{P1 - P2}{C_p(t_2 - t_1)} \qquad (A.1)$$

$$V = \frac{3\,600\ \mathrm{m}}{d} \qquad (A.2)$$

where

C_p is the specific heat of air constant pressure ($J \times g^{-1} \times K^{-1}$);

t_1 is the room temperature, in degrees Celsius;

t_2 is the oven temperature, in degrees Celsius;

$P1 - P2$ is the difference in power consumption, as defined in A.1.1;

m is the mass of air, in grams per second;

V is the volume of air, in litres per hour;

d is the density of air in the laboratory at the time of test, in grams per litre.

NOTE The density of air at 101,3 kPa (760 mm Hg) and 20 °C is 1,205 g/l.

Hence: $V = \frac{3\,600\,(P1 - P2)}{1{,}003\,d\ (t_2 - t_1)}$ or $V = \frac{3\,590\,(P1 - P2)}{d\ (t_2 - t_1)}$

This formula assumes that, when the ports are closed, no air passes through the oven. Therefore, there should be no leakages; the air-tight door joint should be sealed with adhesive tape and all apertures, including the inlet port, should be effectively closed.

A.1.3 If the power consumption is measured with a wattmeter, the total length of time, in seconds, for which the oven heaters are “on” shall be measured with a stop-watch and the reading of the wattmeter shall be taken once during each "on" period.

The average of the wattage readings multiplied by the total time registered by the stop-watch and divided by the duration of the test, in seconds, is taken as the power, in watts, required to maintain a constant temperature.

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A.1.4 If a watt-hour or kilowatt-hour meter is used, the reading of the total energy consumption registered by the meter shall be divided by the duration of the test, measured as a fraction of an hour. If a household kilowatt-hour meter is used, the dial units are too large to enable a sufficient accuracy to be obtained over a reasonably short test, and the rotating disc with which these meters are provided shall be used therefore as the power consumption indicator. The meter shall be put into operation until the index mark on the disc is opposite the centre of the window; it shall then be disconnected until the start of the test.

To reduce the possible error, the period of test shall be long enough to permit 100 revolutions of the disc and the test shall preferably be ended when the mark on the disc is visible. If, however, the mark is out of sight at the end of the test, an estimated fraction of a revolution shall be added. The test shall be started and stopped at corresponding points on the "on-off" heating cycle (e.g., at the moment when the heaters are switched on by the thermostat).

A.2 Method 2 – Direct and continuous method

A.2.1 Description of the equipment

Starting from the high-pressure air source, i.e. from a pipe system or air cylinders:

A.2.1.1 Air pressure regulator

A device to reduce the air pressure from the many atmospheres of the supply mains to the quite low-pressure values needed for supplying the oven. It is equipped with an adjustable valve which permits a constant pressure downstream.

A.2.1.2 Flowmeter

An instrument with which the rate of air flow can be measured. It is illustrated by Figure A.1, and operates on a manometric principle, with:

a) A calibrated capillary tube, with an internal calibrated diameter of about 2 mm and a calibrated length of about 70 mm. Figure A.2 shows a typical calibration diagram which permits the control of air flow up to 500 l/h or 600 l/h.

b) A manometric tube with a double graduation of pressure difference ranging between 0 mm and ±300 mm of water. Distilled water is the manometric liquid.

A.2.1.3 Air oven

An air oven to be operated when carefully sealed, including sealing round the inlet tube, which should preferably enter the oven through the bottom. The outflow hole, which should be at the top of the oven, is the only port to be open.

NOTE The following two features facilitate the reliability of the method and the equipment:

– the flowmeter described above can be considered as fully reliable, easy to manufacture and to calibrate, as well as suitable for the range of air rates involved here;

– as shown by tests the adoption of a slightly “forced” ventilation does not alter, in practice, the uniformity of the temperature at the various points in the ovens.

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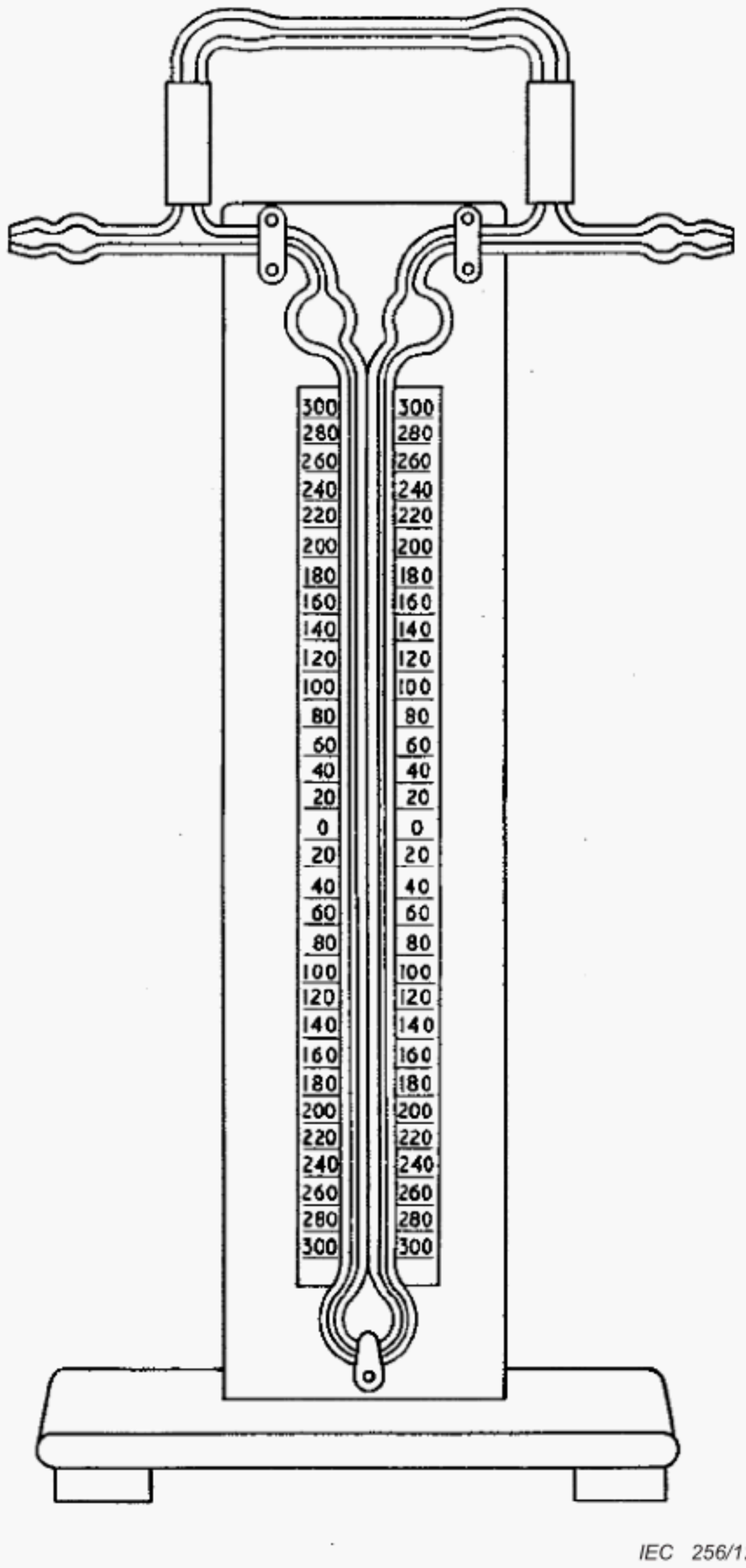

Figure A.1 – Flowmeter for air-flow control in air ovens for method 2

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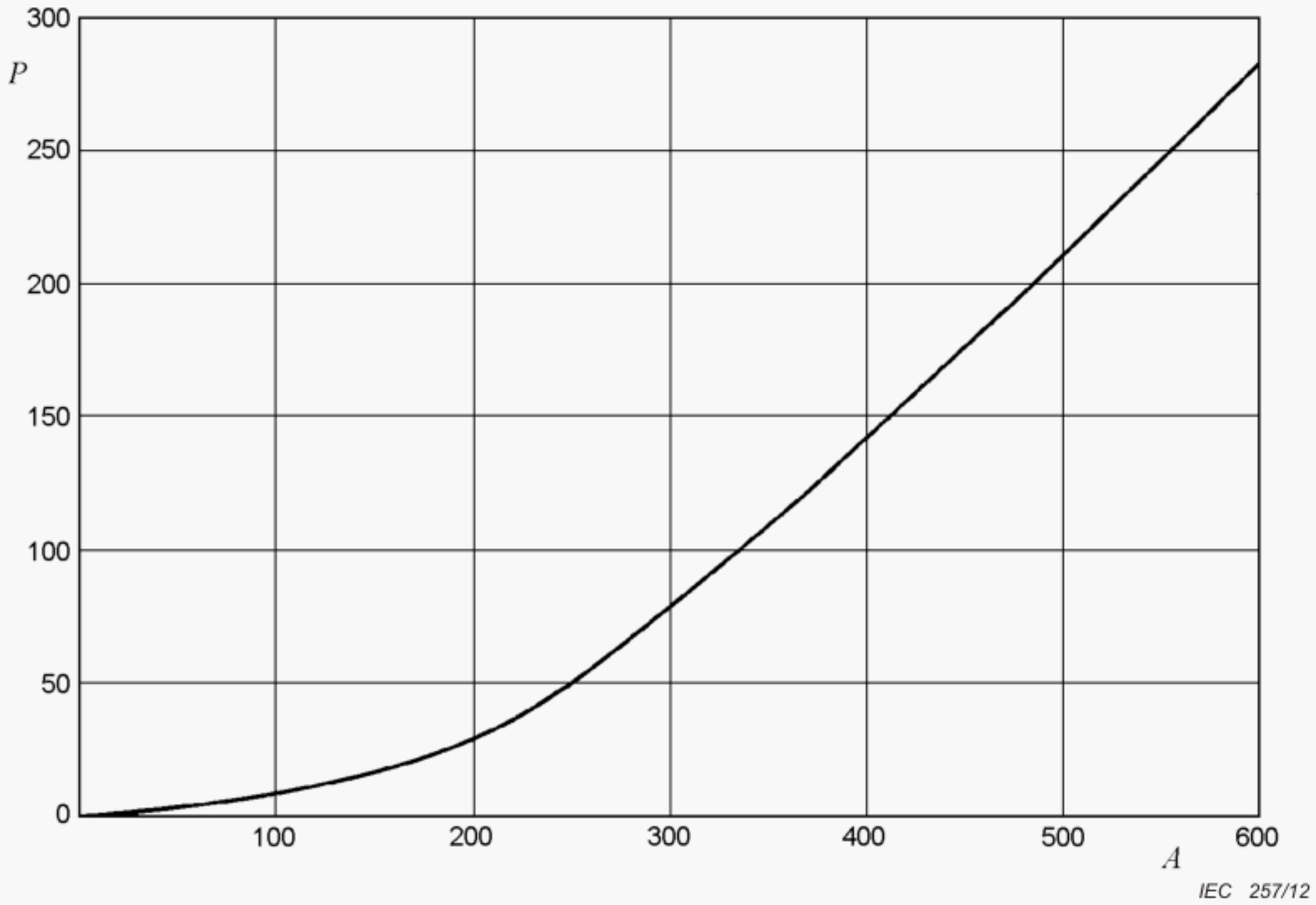

Key

P pressure differences, millimetres of water

A air flow in litres per hour

NOTE Capillary tube, diameter: d = 2 mm; length: l = 70 mm.

Figure A.2 – Calibration diagram of the capillary tube of the flowmeter for air-flow control in air ovens for method 2

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Annex B
(normative)

Test pieces preparation in presence of copper or metal coated copper conductor

B.1 Test pieces preparation of cores with the original conductor

When the conductor and the separator, if any, can be removed without damaging the insulation after ageing, the procedure shall be as follows: samples of core, cut into pieces which are sufficiently long, shall be taken, preferably from positions close to that from which the samples for the tensile tests without ageing are taken in accordance with IEC 60811-501. They shall then be aged as described in 4.2.3.2, after which the conductor shall be removed and the cross-sectional area of the test pieces shall be determined according to IEC 60811-501.

B.2 Test pieces preparation in case of adhesion of conductor insulation or separator after ageing

B.2.1 General

When it is not possible to remove the conductor or the separator, if any, after the ageing procedure without damaging the insulation, the appropriate preparation and test method shall be applied as given in Table B.1.

Table B.1 – Summary of ageing tests for insulated conductors in case of difficulties in preparing test pieces due to conductor insulation or separator adhesion during ageing

Class of copper conductor and conductor form acc. to IEC 60228	Test method
Class 1: plain copper	See B.2.2.1 or, if this method also gives rise to adhesion problems, see 4.3. Ageing followed by the bending test is considered the acceptance procedure in case of dispute
Class 1: metal coated or with a separator around the conductor	See 4.3
Class 2: circular conductors up to and including 16 mm^2 and having plain or metal coated wires and with or without separator as appropriate	See 4.3
Class 2: conductors above 16 mm^2, circular or shaped, and having plain or metal-coated wires	See 4.2.3.3
Classes 5 and 6: conductors up to and including 16 mm^2 having plain or metal-coated wires and with or without separator as appropriate	See B.2.2.2 or if this method also gives rise to adhesion problems see 4.3. Ageing followed by the bending test is considered the acceptance procedure in case of dispute
Classes 5 and 6: conductors above 16mm^2 having plain or metal-coated wires	See 4.2.3.3
NOTE In the case of the bending test (4.3), ageing conditions may be different from those requiring the determination of tensile properties (Clause B.1 and B.2.2); see the relevant cable standard.	

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B.2.2 Tubular test pieces preparation with a reduced conductor

B.2.2.1 Solid plain conductor with reduced diameter

After preparation of five tubular test pieces in accordance with IEC 60811-501 a piece of solid plain conductor, having a diameter reduced by up to 10 % shall be reinserted. This shall be achieved by stretching the original conductor or by using a conductor having the required smaller diameter.

These tubular test pieces shall then be aged as described in 4.2.3.2 after which the reduced conductor shall be removed and the cross-sectional area of the tubular test pieces shall be determined according to IEC 60811-501.

B.2.2.2 Class 5 and class 6 conductor with a reduced number of wires

The preparation of five tubular test pieces shall be carried out in accordance with IEC 60811-501. For this purpose, either approximately 30 % of the wires forming the conductor may be removed from the insulation or approximately 70 % of the wires may be reinserted into the tubular test piece.

These tubular test pieces shall then be aged as described in 4.2.3.2 after which the reduced conductor shall be removed and the cross-sectional area of the tubular test pieces shall be determined according to IEC 60811-501.

B.2.3 Test pieces preparation for conductors above 16 mm^2

B.2.3.1 Sampling and preparation of test pieces for ageing

Three test pieces each about 200 mm long shall be taken from each core to be tested, preferably from positions close to that from which the samples for the tensile tests without ageing are taken (see IEC 60811-501).

In the case of sector-shaped cores, a strip of not less than 10 mm width shall be cut out of the insulation at the sector back along the conductor axis and separated from the conductor. Subsequently, this strip shall be applied again in the same place and fastened with suitable wire in the middle of the test piece and at about 20 mm from each end in such a way that the strip is again well in contact with the conductor; see Figure B.1 below.

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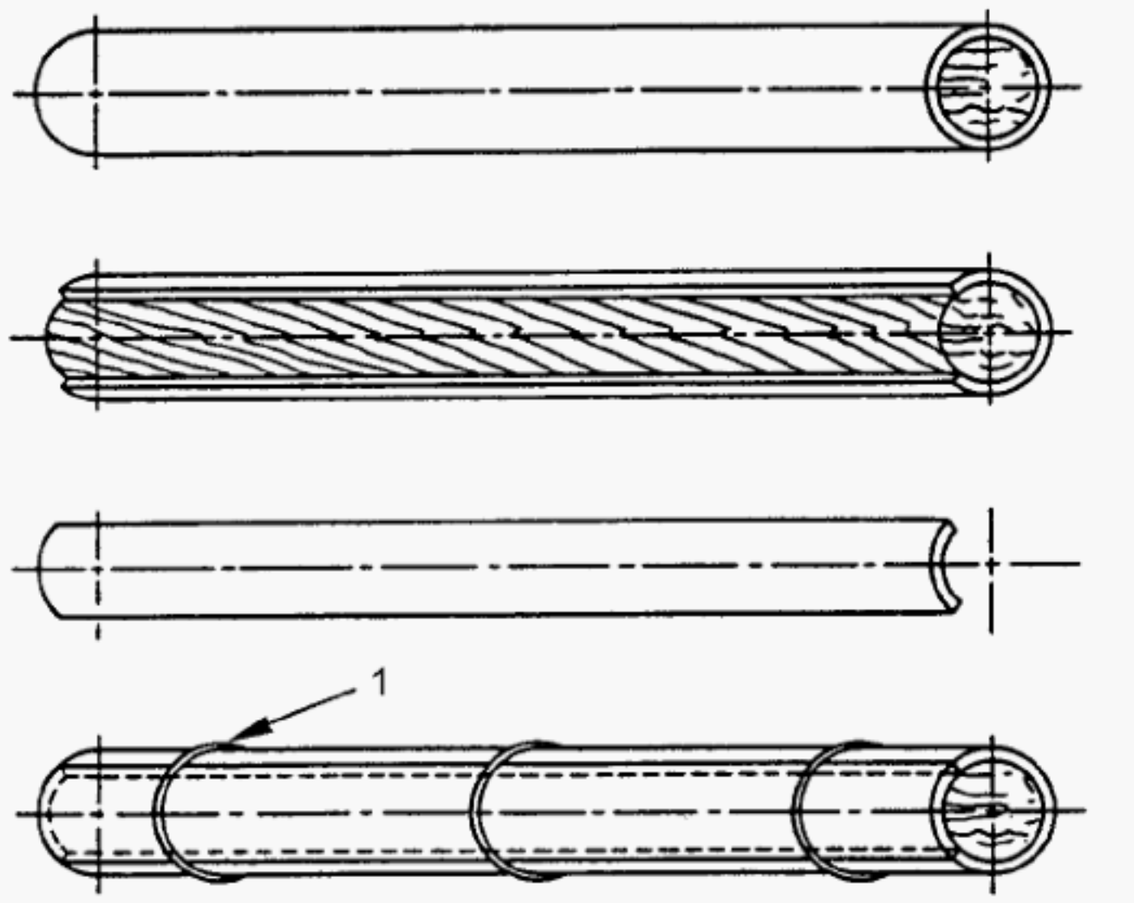

Key

1 binding wire (aluminium or zinc-coated steel)

Figure B.1 – Specially prepared test pieces

For cores with circular conductors, a similar procedure shall be applied, where, for smaller sizes (for example, 25 mm^2), up to half the insulation can be separated.

B.2.3.2 Dumb-bell tests pieces preparation after ageing

Aged test pieces are dismantled and dumb-bell test pieces, two from each test pieces, shall then be prepared in accordance with IEC 60811-501, the cross-sectional area being determined in accordance with IEC 60811-501, as shown in the Figure B.2 below.

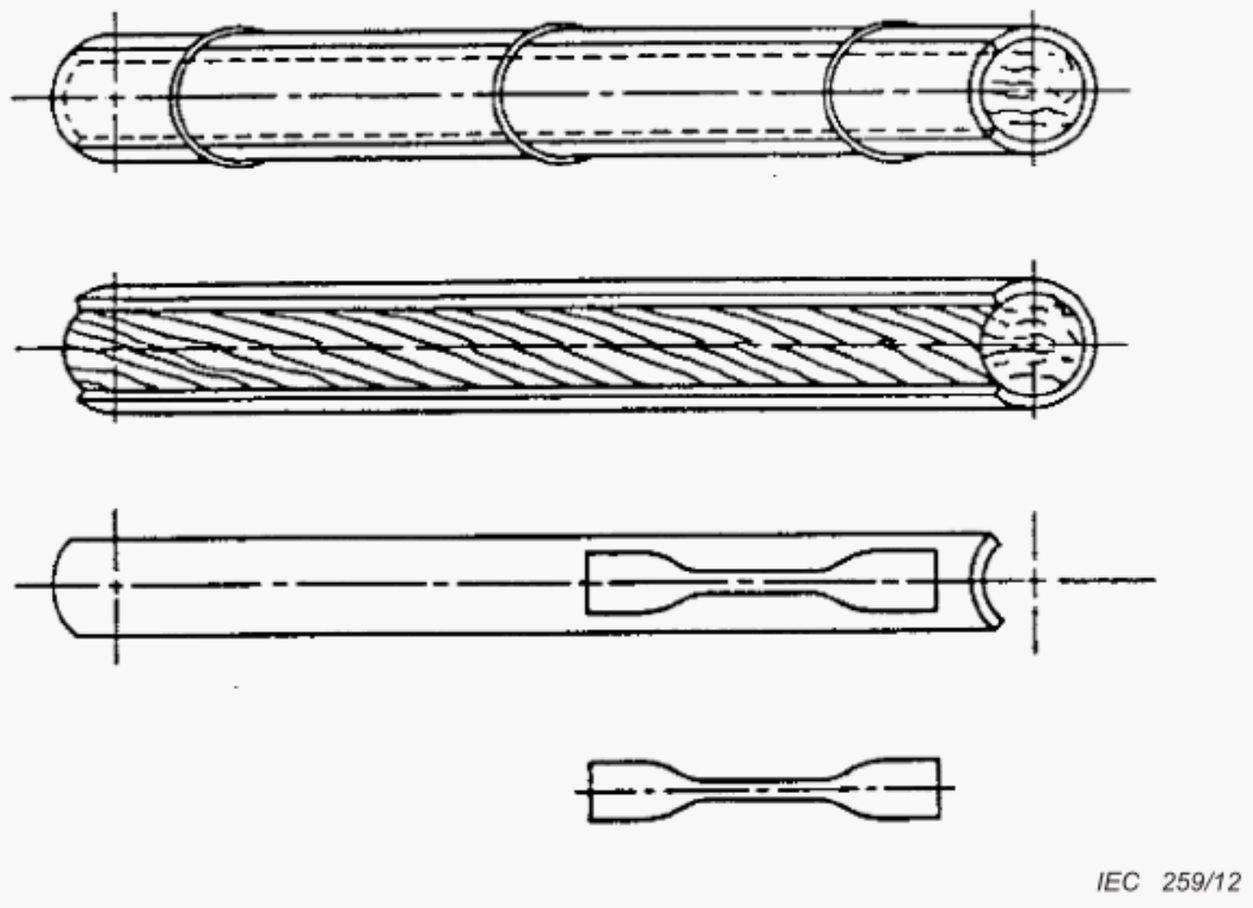

Figure B.2 – Dumb-bell test pieces preparation after ageing

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Annex C
(normative)

Sample and test pieces preparation for ageing of complete cable

C.1 Sampling and preparation of test pieces for ageing

Three test pieces of complete cable about 200 mm long shall be taken, preferably from positions close to that from which the samples for the tensile tests without ageing (see IEC 60811-501) are taken.

C.2 Dumb-bell or tubular tests pieces preparation after ageing

The aged three test pieces of cable shall be dismantled. Two dumb-bell or tubular test pieces shall be prepared from the insulation of each core (up to a maximum of three cores) and from the sheath of each piece of cable, as specified in IEC 60811-501 so that there are six test pieces from each core and from the sheath.

If the test pieces need to be cut or ground to reduce their thickness to not more than 2 mm, this operation shall be effected, so far as possible, on the side which was not facing a material of different type in the complete cable. If ridges need to be cut or ground on the side which was facing the different type of material, the material removed on that side shall be the minimum compatible with adequate smoothing.

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Bibliography

IEC 60811-1-2:1985, *Common test methods for insulating and sheathing materials of electric cables – Part 1: Methods for general application – Section Two – Thermal ageing methods* (withdrawn)

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