

INTERNATIONAL STANDARD

NORME INTERNATIONALE

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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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



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INTERNATIONAL ELECTROTECHNICAL COMMISSION

**ELECTRIC AND OPTICAL FIBRE CABLES –
TEST METHODS FOR NON-METALLIC MATERIALS –****Part 401: Miscellaneous tests –
Thermal ageing methods – Ageing in an air oven**

FOREWORD

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International Standard IEC 60811-401 has been prepared by IEC technical committee 20: Electric cables.

This Part 401 of IEC 60811 cancels and replaces 8.1 and 8.4 of IEC 60811-1-2:1985, which is withdrawn. Full details of the replacements are shown in Annex A of IEC 60811-100:2012.

There are no specific technical changes with respect to the previous edition, but see the Foreword to IEC 60811-100:2012.

The text of this standard is based on the following documents:

FDIS	Report on voting
20/1285/FDIS	20/1334/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

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

A list of all the parts in the IEC 60811 series, published under the general title *Electric and optical fibre cables – Test methods for non-metallic materials*, can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

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- withdrawn,
- replaced by a revised edition, or
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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);

- 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 mm². 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 mm² 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),

- 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 mm²

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.

[IEC 60811-401:2012](http://standards.itec.org/standards/iec/3-90209-4/8-4577-069)

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.

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.

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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.

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:

$$m = \frac{P1 - P2}{c_p (t_2 - t_1)} \quad (\text{A.1})$$

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

where

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

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

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.