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Heat-shrinkable moulded shapes –

Part 2:
Methods of test

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International Electrotechnical Commission, 3, rue de Varembé, PO Box 131, CH-1211 Geneva 20, Switzerland
Telephone: +41 22 919 02 11 Telefax: +41 22 919 03 00 E-mail: inmail@iec.ch Web: www.iec.ch

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

HEAT-SHRINKABLE MOULDED SHAPES –

Part 2: Methods of test

FOREWORD

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International Standard IEC 62329-2 has been prepared by IEC technical committee 15: Standards on specifications for electrical insulating materials.

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

FDIS	Report on voting
15/316/FDIS	15/338/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.

The committee has decided that the contents of this publication will remain unchanged until the maintenance result 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

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

INTRODUCTION

This International Standard is one of a series which deals with heat-shrinkable moulded shapes. The series consists of the following parts:

Part 1: Definitions and general requirements (IEC 62329-1)

Part 2: Methods of test (IEC 62329-2)

Part 3: Specification requirements for shape dimensions, material requirements and compatibility performance (IEC 62329-3) (in consideration)

HEAT-SHRINKABLE MOULDED SHAPES –

Part 2: Methods of test

1 Scope

This part of IEC 62329 gives methods of test for heat-shrinkable moulded shapes in a range of configurations and materials suitable for insulation, environmental sealing, mechanical protection and strain relief for connector/cable terminations and multi-way transitions.

The tests specified are designed to control the quality of the moulded shapes but it is recognized that they do not completely establish the suitability of moulded shapes for impregnation or encapsulation processes or other specialized applications. Where necessary, the test methods in this Part will need to be supplemented by appropriate impregnation or compatibility tests to suit the individual circumstances.

2 Normative references

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

IEC 60093:1980, *Methods of test for volume resistivity and surface resistivity of solid electrical insulating materials*

IEC 60212:1971, *Standard conditions for use prior to and during the testing of solid electrical insulating materials*

IEC 60216-4-1:2006, *Electrical insulating materials –Thermal endurance properties – Part 4-1: Ageing ovens – Single-chamber ovens*

IEC 60216-4-2:2000, *Electrical insulating materials – Thermal endurance properties – Part 4-2: Ageing ovens – Precision ovens for use up to 300 °C*

IEC 60243-1:1998, *Electric strength of insulating materials – Test methods – Part 1: Tests at power frequencies*

IEC 60250:1969, *Recommended methods for the determination of the permittivity and dielectric dissipation factor of electrical insulating materials at power, audio and radio frequencies including metre wavelengths*

IEC 60587:1984, *Test methods for evaluating resistance to tracking and erosion of electrical insulating materials used under severe ambient conditions*

IEC 60695-6-30:1996, *Fire hazard testing – Part 6: Guidance and test methods on the assessment of obscuration hazards of vision caused by smoke opacity from electrotechnical products involved in fires – Section 30: Small scale static method. Determination of smoke opacity. Description of the apparatus*

IEC 60695-11-10:1999*, Fire hazard testing – Part 11-10*: *Test flames – 50 W horizontal and vertical flame test methods*

IEC 60754-1:1994, *Test on gases evolved during combustion of materials from cables – Part 1: Determination of the amount of halogen acid gas*

IEC 60754-2:1991*, Test on gases evolved during combustion of materials from cables – Part 2: Determination of degree of acidity of gases evolved during the combustion of materials taken from electric cables by measuring pH and conductivity*

IEC 62329-1:2005, *Heat shrinkable moulded shapes – Part 1: Definitions and general requirements*

ISO 62:1999*, Plastics – Determination of water absorption*

ISO 105-A02:1993*, Textiles – Tests for colour fastness – Part A02: Grey scale for assessing changes in colour*

ISO 105-B01:1994*, Textiles – Tests for colour fastness – Part B01: Colour fastness to light: Daylight*

ISO 846:1997, *Plastics – Evaluation of the action of micro-organisms*

ISO 32611975*, Fire tests – Vocabulary* [1]

ISO 4589-2:1996, *Plastics – Determination of burning behaviour by oxygen index – Part 2: Ambient-temperature test*

ISO 4589-3:1996*, Plastics – Determination of burning behaviour by oxygen index – Part 3: Elevated-temperature test*

3 Test conditions

Unless otherwise specified, all tests shall be made under standard ambient conditions according to IEC 60212; i.e. at a temperature between 15 °C and 35 °C and at ambient relative humidity.

In cases of dispute, the tests shall be carried out at a temperature of 23 °C ± 2 K and at (50 ± 5) % relative humidity.

When heating at elevated temperature is specified for a test procedure, the specimen shall be maintained for the prescribed period in a uniformly heated oven complying with either IEC 60216-4-1 or IEC 60216-4-2.

Where a test at low temperature is specified, the specification sheets of IEC 62329-3 may require it to be carried out at *t* °*C* or lower, where *t* is the requested temperature. In such cases the operator may carry out the test at the specified temperature or any lower temperature which is convenient. If, however, at a temperature below that specified, the specimen fails to meet the requirements, the test shall be repeated at the specified temperature, subject to a tolerance of ±3 K as specified in IEC 60212. If the specimen then passes, it shall be considered to have met the requirements.

[1] This standard has been withdrawn.

4 Standard test specimens

4.1 Moulded shape material specimens

Moulded shape material specimens shall be prepared from (2 ± 0,15) mm thick sheets, unless otherwise specified, and shall be prepared from the same heat-shrinkable material that is to be used to manufacture the heat-shrinkable moulded shapes. The dimensions of the sheet shall be sufficient to enable any of the relevant tests to be performed.

NOTE A suitable size has been found to be 150 mm x 150 mm.

4.2 Moulded shape compatibility specimens

See IEC 62329-1, Subclause 4.2, and Clause 31 of this standard.

5 Dimensions

5.1 Number of test specimens

Three specimens of each size and style shall be tested.

5.2 Procedure

Measure the moulded shapes in the as supplied condition and after unrestricted shrinkage as specified in IEC 62329-3. Carry out unrestricted shrinkage by conditioning in an oven for the time and temperature specified in IEC 62329-3. Remove the shapes from the oven and allow to cool naturally to the ambient temperature specified in Clause 3. The method of measurement can be mechanical, or optical. Wall thickness shall be measured to an accuracy of ±0,05 mm and internal diameter to an accuracy of ±0,25 mm. In the case of dispute an optical method shall be used.

5.3 Result

Report all measured values as the result.

6 Density

6.1 Number of test specimens

At least three specimens shall be tested, cut from a test sheet in accordance with 4.1.

6.2 Procedure

Any method for the determination of the density may be used which can ensure an accuracy of ±0,01 g/cm^3.

6.3 Report

Record the method selected for the determination and report all measured values for density

6.4 Result

The result is the mean, unless specified otherwise in the specification sheets of IEC 62329-3.

7 Heat shock

7.1 Number of test specimens

Three specimens shall be tested.

7.2 Form of test specimens

Cut three specimens in accordance with Clause 10, from a test sheet in accordance with 4.1.

7.3 Procedure

The specimens shall be suspended vertically in an oven for 4 h ± 10 min at the temperature specified in IEC 62329-3.

The specimens shall be removed and allowed to cool to room temperature. They shall then be visually examined for any signs of dripping, cracking or flowing. In addition, when so specified in IEC 62329-3 the specimens shall be tested for tensile strength and elongation at break.

7.4 Report

Report all results from the visual examination. Report all calculated values.

7.5 Result

The results for each property is the central value unless otherwise specified in the specification sheets of IEC 62329-3.

8 Bending at low temperature

8.1 Number and form of test specimens

Cut three specimens from a test sheet in accordance with 4.1 approximately 150 mm × 6 mm.

8.2 Procedure

The specimens shall be suspended for 4 h ± 10 min in a chamber maintained at the temperature specified in IEC 62329-3. While still at that temperature, they shall be wound without jerking for one complete turn in a close helix round a mandrel also at the same temperature and having a diameter specified in IEC 62329-3. The time to achieve one complete turn shall not be greater than 5 s. The specimens shall then be allowed to return to room temperature.

The specimens shall then be visually examined without magnification while still on the mandrel for signs of cracking.

8.3 Result

Report whether there is any cracking.

9 Dimensional stability on storage

9.1 Number of test specimens

Three shapes shall be tested.

9.2 Procedure

The internal diameter of each outlet shall be measured in the expanded state as delivered. The shapes shall then be stored in a ventilated oven as detailed in Clause 3 for (336 ± 2) h at a temperature of 40 °C ± 3 K unless otherwise specified in the relevant sheet of IEC 62329-3. They shall then be removed from the oven, allowed to cool to ambient temperature and the same dimensions re-measured. The accuracy of measurement shall be in accordance with Clause 5.

Following this measurement, the shapes shall be allowed to fully recover, using the time and temperature specified in IEC 62329-3 for the shapes being evaluated. The shapes shall then be cooled to ambient temperature and the recovered dimensions measured.

9.3 Result

Report, as the result, all measured values for each of the three sets of measurements: expanded dimensions before and after storage at elevated temperature, and fully recovered dimensions after storage at elevated temperature.

10 Tensile strength and elongation at break

10.1 Number and form of test specimens

Cut five dumb-bell specimens from a test sheet in accordance with 4.1 to the dimensions and tolerances given in Figure 1. The specimens shall be stamped from the sheet using a single stroke of a press and a knife edge punch of appropriate form and dimensions.

NOTE The profile given in Figure 1 is that of type 2 of ISO 37.

10.2 Conditioning

Unless otherwise specified in IEC 62329-3, the test specimens shall be kept at an ambient temperature of 23 °C ± 2 K for at least 1 h before testing, or for a longer time to enable the specimens to reach a temperature of 23 °C ± 2 K.

10.3 Test temperature

The test shall be made at a temperature of 23 °C ± 2 K.

10.4 Procedure

The width and thickness of the central parallel portion of the specimen shall be measured between the gauge marks to the nearest 0,01 mm at a minimum of three points. The average cross-sectional area is then determined.

The specimen shall be mounted in the tensile test machine in axial alignment with the direction of pull. The jaws shall be separated at the uniform rate specified in IEC 62329-3 for a particular material. The range of the testing machine shall be such that the maximum load is between 15 % and 85 % of the maximum scale reading.

The distance between the reference lines at break may conveniently be measured by means of a rule, callipers or an extensometer.

The maximum load shall be measured to an accuracy of 2 %. The distance between the reference lines at break shall be measured to within 2 mm.

If the test specimen breaks outside the reference lines the result shall be discarded and a further test made using another specimen.

10.5 Calculations

The tensile strength shall be calculated from the maximum load and the original area of cross-section and the result expressed in megapascals (MPa):

$$\text{tensile strength} = \frac{F_{max}}{A} \text{ (MPa)}$$

where

F_{max} is the maximum load (N);

A is the original cross-sectional area (mm^2).

The elongation at break shall be expressed as a percentage of the original distance between the reference lines, i.e.:

$$\text{elongation at break (\%)} = \frac{(L - L_o)}{L_o} \times 100$$

where

L is the measured distance between the two marks on the stretched specimen at break;

L_o is the original distance between the marks.

10.6

Report all calculated values.

10.7 Result

The results for each property is the central value unless otherwise specified in the specification sheets of IEC 62329-3.

11 Secant modulus at 2 % elongation

11.1 Number and form of test specimens

Perform three tests on strips cut from a test sheet in accordance with 4.1. The width of the strips shall be approximately 20 mm.

11.2 Procedure

a) The secant modulus shall be calculated from the determination of the tensile stress necessary to produce in the specimen an extension of 2 % of the length between jaws or between reference lines.

b) Depending on the method of measurement chosen, the length of specimen between the jaws or reference lines shall be not less than 100 mm.

c) The extension may be measured by means of an extensometer or by jaw separation; the extension shall be measured to an accuracy of 2 %.

d) The strain rate shall be (0,1 ± 0,03) mm/min for each millimetre length between jaws (e.g. 12 mm/min for a 120 mm length between jaws).

e) An initial tensile force (F) may need to be applied to the specimen for the purpose of straightening it. This force shall not exceed 3 % of the final value.

f) The force shall be increased until the extension between the jaws or reference lines reaches 2 %. The force (F_1) required to produce this extension shall be recorded.

11.3 Calculation

The secant modulus of the specimen shall be calculated as follows:

$$2\ \%\ \text{secant modulus} = \frac{F_1 - F}{0{,}02A}\ \text{(MPa)}$$

where

A is the initial average cross-sectional area of the specimen (mm^2) (determined as specified in 10.4);

F_1 is the force required to produce a 2 % extension (N);

F is the force applied to produce the initial (straightening) stress (N).

11.4 Report

Report all measured values for secant modulus at 2 % elongation.

11.5 Result

The result is the central value unless specified otherwise in the specification sheets of IEC 62329-3.

12 Electric strength

12.1 Number and form of test specimens

Three specimens shall be tested using standard test sheets in accordance with 4.1.

12.2 Conditioning

In case of doubt or dispute, these tests shall be made on specimens which have been conditioned by exposure for not less than 24 h to an atmosphere of (50 ± 5) % relative humidity at a temperature of 23 °C ± 2 K.

12.3 Electrodes

The electrodes shall be in accordance with IEC 60243-1, unequal diameter electrodes for sheet materials.

12.4 Procedure

The electrodes shall be placed in the centre of the test sheet as described in IEC 60243-1 and the assembly placed in transformer oil.

The voltage used shall be in accordance with IEC 60243-1 applied between the two electrodes at a uniform rate from zero, such that breakdown occurs between 10 s and 20 s.

Calculate the electric strength by dividing the voltage at which breakdown occurs by the thickness of the test sheet. Express the result in MV/m.

12.5 Result

Report all values.

12.6 Result

The result is the central value, unless otherwise specified in the specification sheets of IEC 62329-3.

13 Volume resistivity after damp heat

13.1 Number and form of test specimens

Three specimens shall be tested using test sheets in accordance with 4.1.

13.2 Electrodes

The electrodes shall be conductive silver paint in accordance with IEC 60093 for flat specimens using a guard ring.

13.3 Procedure

Expose the specimens for four days to damp-warm conditions as specified in IEC 60212 (i.e. 96 h at 40 °C and 93 % relative humidity). While still at these conditions measure the resistance in accordance with IEC 60093 using (500 ± 15) V d.c. and an electrification time of at least 1 min.

Calculate the volume resistivity in accordance with IEC 60093.

13.4 Result

The result is the central value.

14 Permittivity and dissipation factor

14.1 Number and form of test specimens.

One test sheet in accordance with 4.1.

14.2 Electrodes

The electrodes shall be in accordance with IEC 60250, disk electrodes with a guard ring.

The electrodes may be either metal foil or conductive paint as described in IEC 60250.

14.3 Procedure

The temperature of test shall be 23 °C ± 2 K.

The measurement of permittivity shall be made with a suitable instrument complying with IEC 60250 and at a frequency of approximately 1000 Hz. The low-voltage lead shall be connected to the guarded electrode.

14.4 Calculation

The relative permittivity and dissipation factor shall be calculated in accordance with IEC 60250.

14.5 Result

Report the value for relative permittivity and dissipation factor as the result.

15 Resistance to tracking

The test shall be carried out in accordance with method 2 (criterion A) of IEC 60587, using a test sheet 4 mm to 6 mm thick.

15.1 Report

Report all values.

15.2 Result

The result is the minimum value.

16 Flammability

16.1 Number and form of test specimens

Test sheets in accordance with 4.1 except the thickness shall be 3 mm ± 0,2 mm. Cut three strips 13 mm ± 0,5 mm.

16.2 Procedure

Conduct the test in accordance with IEC 60695-11-10 except that after the flame is removed the time for the flame to extinguish shall be recorded.

16.3 Result

Record all values.

17 Oxygen index

17.1 Oxygen index at ambient temperature

17.1.1 Number and form of test specimens

Test sheets in accordance with 4.1 except the thickness shall be 3 mm ± 0,2 mm. Cut a sufficient number of 6,5 mm ± 0,5 mm strips to carry out the test in accordance with ISO 4589-2.

17.1.2 Procedure

Conduct the test in accordance with ISO 4589-2 Configuration IV. The specific ignition procedure shall be specified in the specification sheets of IEC 62329-3.

17.2 Oxygen index at elevated temperature

The test shall be carried out in accordance with ISO 4589-3 using specimens described in 17.1.1. The specific ignition procedure shall be specified in the specification sheets of IEC 62329-3.

18 Copper corrosion (presence of corrosive volatiles)

18.1 Principle

This test determines the effect of volatile constituents from moulded material on copper.

18.2 Apparatus

– Test tubes: 13 mm × 300 mm.

– Copper backed glass mirrors 6 mm wide by 25 mm long. Store them in a properly conditioned desiccator. The mirrors shall be of vacuum deposited copper, with a thickness giving (10 ± 5) % transmission of normal incident light of a wavelength of 500 nm. Use them for the test only if no oxide film is present and the copper is not visibly damaged.

– Corks.

– Aluminium foil.

– Fine copper wire having a diameter not greater than 0,25 mm.

– Oil bath capable of maintaining oil temperature to within ±2 K.

18.3 Number and form of test specimens

Cut two strips 25 mm × 6,5 mm from a test sheet in accordance with 4.1.

One test shall be carried out using the two specimens from the test sheet, each inserted into a separate test tube with a third test tube being used as a control without a test specimen.

18.4 Procedure

Place each specimen in a test tube as described above and use a third test tube as a control.

Suspend a copper mirror as defined in 18.2, with its lower edge 150 mm to 180 mm above the bottom of each test tube. Support the mirror by forming a single loop of the fine copper wire about its upper end and attaching the other end of the wire to the cork and ensure that each mirror is vertical. Seal each test tube with the cork wrapped in aluminium foil.

Immerse the lower 50 mm of the three test tubes in an oil bath at the temperature and for the time specified in IEC 62329-3.

Keep the temperature of that part of each test tube containing the mirror at a temperature below 60 °C.

After cooling, remove the mirrors and examine each one by placing it against a white background in good light and estimate the percentage removal. Any removal of copper from the mirror will be a sign of corrosion. However, disregard any removal of copper from the bottom of the mirror, provided the area does not exceed 8 % of the total area of the mirror, since condensation may cause this condition. Do not consider discolouration of the copper film or reduction of its thickness as corrosion. Consider only the area over which the removal of copper has made the mirror transparent as the corrosion area.

If the mirror in the control tube shows any sign of corrosion the test shall be repeated.

18.5 Report

Report the estimated percentage removal of copper from each mirror.

18.6 Result

The result is the average of the observed percentage removal of copper from each mirror.

19 Colour fastness to light

19.1 Principle

This test compares the relative rate of colour change of a specimen to that of a recognized standard under specified conditions.

19.2 Test specimen

Cut a suitable specimen from a test sheet in accordance with 4.1.

19.3 Procedure

A half-covered specimen and a dyed woollen light fastness standard as specified in ISO 105-B01 shall be exposed simultaneously to a xenon or enclosed carbon arc light source until the change in colour of the exposed part of the fastness standard is equal to grade 4 on the geometric grey scale of ISO 105-A02. The ambient temperature shall not exceed 40 °C and there is no specific control of relative humidity. The identification number of the fastness standard to be used shall be specified in IEC 62329-3.

Examine the exposed fastness standard frequently to ensure that the prescribed degree of fading is not exceeded.

Compare the relative colour change between the two halves of the exposed specimen and the exposed standard. Make this comparison in good light against a white background.

19.4 Result

Report all observations as the result.

20 Resistance to selected fluids

20.1 Principle

It is necessary to define the following:

– choice of fluid;
– temperature of immersion;
– duration of immersion;
– method of assessment.

20.2 Choice of fluid

When not specified in IEC 62329-3, the fluids shall be agreed between purchaser and supplier. The quantity of fluid in which the specimens are immersed shall be at least 20 times the volume of the specimens.

WARNING: Adequate precautions should be taken to protect personnel from any health or fire hazards resulting from the use of a particular fluid.

20.3 Methods of assessment

a) Electric strength, Clause 12.
b) Tensile strength and/or elongation at break, Clause 10.

c) Visual examination.

d) Change in mass.

e) Any other method as specified in IEC 62329-3.

20.4 Number and form of test specimens

The number of test specimens is dependent on the method of assessment. In cases a) or b) of 20.3, the specimens shall be selected in accordance with the requirements of Clause 10 or Clause 12. In cases c) and d) of 20.3, three specimens each approximately 50 mm × 25 mm shall be used.

Alternatively, specimens in accordance with Clause 10 may be used in cases c) and d) of 20.3.

20.5 Procedure

The specimens shall be immersed in the fluid at a temperature of 23 °C ± 2 K for (24 ± 1) h unless otherwise specified in IEC 62329-3.

The specimens shall then be removed from the fluid, allowed to drain for 45 min to 75 min unless otherwise specified in IEC 62329-3 and then lightly wiped. They shall then be tested by one or more of the methods given in 20.3. The change in mass is calculated as a percentage of the pre-immersion mass.

In case b) of 20.3, the cross-sectional area should be determined before immersion. In case d) of 20.3, the specimens should be weighed to the nearest 0,0002 g before immersion.

20.6 Result

The results are the observations/determinations appropriate to the specified method of assessment. The results may be related to a fixed requirement value or else to a percentage degradation from the control value.

If qualitative assessment is being used or is required in addition, report whether the specimens show deterioration such as swelling, tackiness, crumbling, splitting or blistering immediately after removal from the fluid.

21 Long term heat ageing (3000 h)

21.1 Number and form of test specimens

Cut dumb-bell specimens in accordance with Clause 10, sufficient to enable six sets of measurements to be performed.

21.2 Procedure

Retain and test one set of specimens to establish the initial (unaged) value of the elongation. Expose all other specimens by suspending them from one end in an oven conforming to IEC 60216-4-1 or IEC 60216-4-2, at the temperature specified in the appropriate sheet of IEC 62329-3. See note 2 in the scope of IEC 60216-4-2 for guidance on the type of oven to use. At the end of each (25 ± 0,5) days or (600 ± 12) h, remove a set of test specimens and allow them to cool to room temperature, unless otherwise specified. Perform the elongation on that set of test specimens. Continue until (125 ± 1) days or (3 000 ± 24) h of ageing time have elapsed and perform the test(s) on the set of specimens aged for that period.

21.3 Report

Report all values of elongation.

21.4 Result

The result is the central value unless otherwise specified in IEC 62329-3.

NOTE Where comparisons are to be made between similar materials or against a known reference material, then the use of the test method detailed in Clause 7 of IEC 60216-5 is recommended.

22 Mass

22.1 Number of test specimens

Three shapes shall be tested.

22.2 Procedure

Any method for the determination of the mass may be used which can ensure an accuracy of 1 % or 0,01 g (whichever is the lower value).

22.3 Result

Report all values.

23 Heat ageing

23.1 Number and form of test specimens

Prepare five specimens in accordance with Clause 10.

23.2 Procedure

Expose these specimens by suspending from one end in an oven for a period of (168 ± 2) h, unless otherwise specified, and at the temperature specified in IEC 62329-3. Remove the specimens from the oven and allow them to cool. Perform the test for tensile strength and/or elongation at break in accordance with Clause 10 and as specified in IEC 62329-3.

24 Water absorption

Perform this test in accordance with method 1 of ISO 62, unless specified otherwise in the specification sheets of IEC 62329-3.

25 Colour stability to heat

25.1 Number of test specimens

Three specimens shall be tested.

25.2 Form of test specimens

Cut three lengths approximately 6 mm wide from a standard test sheet.

25.3 Procedure

Suspend the specimens in an oven for the time and at the temperature specified in IEC 62329-3. If no time is specified, an exposure of (24 ± 1) h shall be used.

Remove the specimens from the oven and allow to cool to room temperature.

Compare the specimens to the colour standard specified in IEC 62329-3.

25.4 Report

Report the time and temperature used.

25.5 Result

The outcome of the visual examination for each specimen is the result.

26 Smoke index

26.1 Definitions

For the purpose of this test method, the following definitions apply:

a) **smoke index**: numerical summation of the rates of change in specific optical density of smoke produced from the start of the test to 70 %, 40 %, 10 % and to the minimum light transmittance values as applicable;

b) the definitions for combustion and pyrolysis given in ISO 3261 apply.

26.2 Principle

Test samples 76 mm × 76 mm square (cut from a standard test sheet made in accordance with 4.1) are exposed to specified standard thermal conditions of pyrolysis and combustion in a continuous procedure. The change in optical density of the smoke produced when dispersed within a fixed volume of air is determined throughout the period of the test. The resulting density/time curve is used to calculate the smoke index.

26.3 Apparatus

The apparatus shall comply with that specified in IEC 60695-6-30 modified as follows.

a) Mixing fan

A small mixing fan shall be positioned centrally near the top of the chamber to ensure complete dispersion of the smoke homogeneously throughout the chamber. This fan shall consist of four radially mounted blades with a dimension across the opposing blade tips of 250 mm and a maximum blade width of 70 mm. The fan shall rotate at a speed of between 60 r/min and 120 r/min.

b) Burner

A multi-jet burner constructed as shown in Figure 2 shall be used with premixed air/propane gas fuel. The burner shall be centred in front of the test piece holder, level with the bottom edge of the test piece and 10 mm away from it. The air and propane gas shall be metered using calibrated rotameters, the rate being such that a blue flame is obtained which touches the test piece over at least 90 % of its width at a height approximately 5 mm above its bottom edge.

An ignition system shall be provided such that the burner can be ignited remotely without opening the chamber. Platinum glow-wire, piezo-electric crystal or pilot flame ignition systems have been found suitable. The system used shall have no effect on the value of the smoke index of the material under test.

26.4 Number and form of test specimen

Cut 3 specimens from test sheets in accordance with 4.1, sufficient to completely cover the face area of the test piece holder.

26.5 Conditioning

Prior to mounting into the test piece holder, condition the specimens at 23 °C ± 3 K and (50 ± 5) % relative humidity for at least 24 h.

26.6 Mounting of test pieces

To prevent excessive buckling and distortion of the test piece during test, a wire mesh, manufactured from 1,5 mm diameter stainless steel wire with a spacing of 12,5 mm and a square mesh configuration, shall be used to support the specimens.

Place the test piece holder face down onto a flat surface and insert the wire mesh. Position each specimen in the holder.

Completely wrap the insulating block in heavy-duty aluminium foil, approximately 0,04 mm thick, and place over the arranged specimens in a test piece holder, position the tensioning spring and secure with the locking pin.

26.7 Safety of operations

During the following testing, there is a danger that flammable and/or toxic fumes will evolve from the test piece. Operators shall take adequate precautions to avoid possible exposure to such fumes.

26.8 Procedure

26.8.1 Set up the smoke chamber and carry out all necessary checks and calibration as required in IEC 60695-6-30, in accordance with the manufacturer's instructions.

26.8.2 Turn on the propane and air supplies to the burner and ignite. With a blank test piece holder in position in front of the flame, adjust the gas flow rates to obtain the correct flame height as in 26.3 b). Note the settings of the rotameters. Turn off the gases.

26.8.3 Clean the optical windows of the chamber and switch on the auxiliary heating system. Allow the apparatus to stabilize with the vents open until the chamber wall temperature is within the range 33 °C ± 4 K. Close the inlet vent.

26.8.4 Stabilize the output at 2,5 W/cm^2 and close the exhaust vent. Set the zero and 100 % levels of the amplifier and the recorder. Start the recorder at a minimum speed of 10 mm/min.

26.8.5 Place the test piece holder containing the material under test in its position in front of the furnace and mark this point on the recorder as the start of the test. Simultaneously start the timing device.

26.8.6 Turn on the gas supply ($300\ ^{+10}_{0}$ l/s) after the start of the test and immediately adjust its flow rate to that previously noted in 26.8.2.

26.8.7 Expose the material simultaneously to the output from the furnace and the burner for a further 15 min ± 15 s. Record the percentage light transmission continuously and observe the burning characteristics of the material throughout this period. If the test piece shows unusual burning behaviour such as de-lamination, sagging, shrinkage, melting or collapse, report this in the test report together with the time at which the particular behaviour was observed. If the light transmission falls below 0,01 %, cover the observation window in the chamber door and withdraw the range extension filter from the light path.

26.8.8 Without opening the chamber, turn off the gases to the burner and move the test piece holder from in front of the furnace using the attenuator arm. Maintain the current to the furnace and the recorder. Evacuate the chamber according to the manufacturer's instructions. Continue to record the percentage light transmission and the elapsed time until a steady value is obtained. This is the clear beam value, T_c.

26.8.9 Throughout the test period, adjusting the ranging of the photo detector amplifier system to maintain the level of the readings recorded for the percentage light transmission of at least 10 % of the full-scale value.

26.8.10 At the end of the test, ensure that the inside of the chamber, auxiliary apparatus and supporting framework is clean.

26.8.11 Repeat the test on two further test pieces.

26.9 Calculation of results

26.9.1 Because of the progressive build-up of deposits on the optical window during the test run, the recorded transmittance values are artificially depressed. It may therefore be necessary to apply a correction to the recorded values before calculating the smoke index. This is carried out by constructing a new plot of the transmittance/time relationship in accordance with 26.9.2.

26.9.2 Correction of transmittance values

26.9.2.1 Using the trace obtained from the recorder, identify the following values T_c and T_{min},

where

T_c is the clear beam transmittance at the end of the test run;

T_{min} is the minimum transmittance obtained during the test run.

26.9.2.2 Convert T_c and T_{min} to the equivalent specific optical densities D_{sc} and D_{smax}

where

D_{sc} is the specific optical density for clear beam transmittance, and

D_{smax} is the specific optical density for minimum transmittance.

The conversion of percentage transmittance to specific optical density for the chamber is given by

$$\text{specific optical density } (D_s) = F \times \log_{10} \frac{100}{T}$$

where

D_s is the specific optical density for the chamber;

T is the percentage transmittance;

F is the chamber factor = 132.

The chamber factor is given by $V/(A \cdot L)$ where V is the volume of the chamber; A is the exposed area of the test piece, and L is the length of the light path.

26.9.2.3 If D_{sc} is 3 % or less of D_{smax}, no further correction to the recorded trace is required.

26.9.2.4 Subtract D_{sc} from D_{smax} to obtain the corrected maximum specific density $D_{smax\ c}$. Convert $D_{smax\ c.}$ to percentage transmittance and plot this value on the recorded chart as the corrected minimum transmittance at the same time interval, i.e. $T_{min\ c}$.

26.9.2.5 If D_{sc} is more than 3 % of D_{smax} and where $T_{min\ c}$ is less than 70 %, produce a new plot from the recorder trace as follows:

Convert the percentage transmittance to specific optical density as in 26.9.2.2 and correct this value using the correction factor as shown below. Convert this value back to percentage transmittance. Construct a new curve of transmittance against time from the corrected values of percentage transmittance, plotted at the same time interval as the original uncorrected values:

$$D_c = D_s - \frac{D_{sc} \times D_s}{D_{smax}}$$

where

D_s is the uncorrected value of specific optical density;

D_c is the corrected value of specific optical density;

D_{sc} and D_{smax} are as defined in 26.9.2.2.

26.9.2.6 For example, to obtain the corrected specific optical density at 70 % transmittance (where D_s = 20):

$$D_{sT70} = D_{20c} = \frac{D_{sc} \times 20}{D_{smax}}$$

Similarly, corrected values for specific optical density at 40 % transmittance (D_{sT40}) and 10 % transmittance (D_{sT10}) may be calculated.

26.9.2.7 Convert the corrected values for specific optical density obtained using 26.9.2.6 back to percentage transmission. Construct a new curve of transmittance against time from the corrected values plotted at the same time interval as the original uncorrected values.

Read off from the graph the corrected times (in minutes) from the start of the test to reach 70 %, 40 % and 10 % transmittance.

26.9.3 Calculation of the smoke index

26.9.3.1 Where the corrected minimum transmittance value is not less than 70 %, calculate the smoke index from the relevant curve as follows:-

$$Smoke\ index = \frac{D_{sT\min(c)}}{t_{min}}$$

where

$D_{sTmin.(c)}$ is the specific optical density corresponding to the minimum light transmittance value from the corrected curve;

t_{min} is the time in minutes at which the minimum light transmittance value is recorded.

26.9.3.2 Where the corrected minimum transmittance value is less than 70 %, calculate the smoke index from the relevant curve as follows:

$$\text{smoke index} = \frac{D_{sT(70)}}{t_{(70)}} + \frac{D_{sT(40)}}{t_{(40)}} + \frac{D_{sT(10)}}{t_{(10)}} + \frac{D_{sTmin(c)}(X - T_{min})}{t_{min}(X - Y)}$$

where

$D_{sT(70)}$ is the specific optical density corresponding to 70 % light transmittance (20.0);

$D_{sT(40)}$ is the specific optical density corresponding to 40 % light transmittance (51.9);

$D_{sT(10)}$ is the specific optical density corresponding to 10 % light transmittance (130.5);

$t_{(70)}$ is the corrected time, in minutes, from the start of the test to reach 70 % light transmittance;

$t_{(40)}$ is the corrected time, in minutes, from the start of the test to reach 40 % light transmittance;

$t_{(10)}$ is the corrected time, in minutes, from the start of the test to reach 10 % light transmittance;

$t_{min.}$ is the corrected time, in minutes, from the start of the test at which the minimum light transmittance occurs;

X the lowest reference transmittance value reached during the test, i.e. 70 %, 40 %, or 10 %;

Y is the next lowest reference value reached during the test, i.e. 40 %, 10 % or 0 %.

26.10 Results

26.10.1 Report the value of each smoke index measurement for the replicate tests (a minimum of three) to the first decimal place; the result is the central value unless specified otherwise in the specification sheets of IEC 62329-3.

26.10.2 Report also a description of the burning behaviour (see 26.8.7) as a result.

26.10.3 The following statement shall be added to the report.

This test result alone does not assess the fire hazard of the material or a product made from this material under actual fire conditions. Consequently, the results of this test alone shall not be quoted in support of claims with respect to the fire hazard of the material or product under actual fire conditions. The results when used alone should only be used for research and development, quality control and material specification.

27 Toxicity index

27.1 Definition

For the purpose of this test the following definition applies.

Toxicity index: Numerical summation of the toxicity factors of selected gases produced by complete combustion of the material in air under the conditions specified. Toxicity factors are derived from the calculated quantity of each gas produced when 100 g of the material is burnt in 1 m^3 of air and the resulting concentration expressed as a factor of the concentration fatal to man at a 30 min exposure time (see 27.9). An index of 1 for a given volume will, on average, produce fatality in 30 min.

27.2 Principle

Analytical data of certain small molecular gaseous species arising from the complete combustion under flaming conditions of the material under test are mathematically computed, using the exposure level (in parts per million) of each gas to produce fatality in 30 min as a base, to derive the combined toxicity index.

27.3 Apparatus

27.3.1 As far as is practicable, all surfaces and all items of equipment within the test chamber shall be constructed of, or coated with, a non-metallic material, as far as possible inert to the gases evolved from the material during the test.

27.3.2 Test chamber

The test chamber shall consist of an airtight enclosure of at least 0,7 m^2 in volume, lined with an opaque plastic material and having a hinged or sliding door fitted with a transparent plastic window.

The material from which the chamber is constructed shall not react with the gases produced during the test and shall keep their absorption to a minimum.

NOTE Polypropylene has been found suitable for lining the chamber and polycarbonate sheet for the window.

The chamber shall be fitted with a forced air extraction system which can be closed at the exit from the chamber when required during the test.

A mixing fan shall be installed horizontally and centrally at roof level within the chamber. The fan shall have a minimum diameter of 200 mm and shall consist of six, axially-mounted blades rotating at between 1 200 r/min and 1 500 r/min. A means shall be provided for switching the fan on and off from outside the chamber.

27.3.3 Burner

The burner shall be a Bunsen type burner operating on natural gas (methane) having a gross calorific value of approximately 30 MJ/m^3. The burner shall be provided with a supply of air, external to the chamber, connected by means of a modified collar in order to prevent oxygen depletion and the consequential reduction of the flame temperature or its extinguishment during the combustion of the sample under test.

The burner shall be capable of producing a flame approximately 100 mm in height and having a temperature of 1 150 °C ± 50 K at its hottest point.

NOTE A Bunsen burner of 125 mm in height, 11 mm bore burner tube and 5 mm bore gas and air inlet tubes is recommended, when gas and air flow rates of approximately 10 l/min and 15 l/min will be required.

Provision shall be made for igniting and extinguishing the burner from outside the chamber.

27.3.4 Sample support

A support in the form of an annulus, cut from 2 mm to 4 mm thick non-combustible material, of (100 ± 1) mm outside diameter and (75 ± 1) mm internal diameter, over which a wire mesh is stretched, shall be provided. The mesh shall consist of temperature-resistant wires approximately 10 mm apart in the form of a square lattice.

27.3.5 Timing device

A timing device shall be capable of measuring up to 5 min within an accuracy of ±1 s.

27.3.6 Gas sampling and analytical equipment

27.3.6.1 Gas sampling

In order to minimise the losses of toxic products of combustion through absorption or condensation prior to measurement, all sampling lines shall be as short as practicable.

Sampling ports fitted to the chamber shall be such that they do not interfere with the air tightness of the chamber.

27.3.6.2 Analytical equipment

The equipment used for the analysis of the gases from the combustion of the test sample shall be such as to allow rapid detection and measurement of those gases detailed in 27.9.

The use of colourimetric gas reaction tubes is acceptable. Where these are used, they shall be positioned within the chamber.

27.3.6.3 Test pieces

From a standard test sheet, cut the test piece of a size and shape such that during each test the sample is entirely engulfed in the flame. The mass of the specimen shall be chosen to provide optimum analytical precision, dependent on the nature of the combustion products and sensitivity of the analytical procedure.

Prepare a sufficient number of test specimens to obtain three complete combustions.

27.4 Conditioning

Prior to mounting into the test piece holder, condition the strips at 23 °C ± 2 K and (50 ± 5) % relative humidity for at least 24 h.

27.5 Safety of operations

During the following test, there is a danger that flammable and/or toxic fumes will evolve from the test piece. Operators shall take adequate precautions to avoid exposure to such fumes.

27.6 Test procedure

27.6.1 Determination of background correction factor

27.6.1.1 Position the burner in the centre of the test chamber floor. Close the chamber and all inlet and outlet vents to the chamber. Ignite the burner and adjust the gas and air flow rates to achieve the flame condition described in 27.3.3. Record or otherwise control these reference level flow rates in order that the flame condition may be re-established as rapidly as practicable when required during the test. Extinguish the burner and ventilate the chamber.

27.6.1.2 After allowing sufficient time for any fumes produced during the adjustment of the reference level gas and air flow rates to disperse, prepare the chamber for the analysis of carbon monoxide, carbon dioxide and nitrogen oxides. Close all sampling ports other than those required for the analysis to these gases. Where the method of analysis is to be carried out using colourimetric tubes, these shall be placed in position within the chamber.

27.6.1.3 Close the chamber. Ignite the burner and simultaneously start the level timing device. Maintain the flame condition at the reference level of gas and air flow rates for 1 min ± 1 s. Extinguish the flame and start the mixing fan. After (30 ± 1) s, stop the fan and sample the atmosphere within the chamber and determine the concentration of carbon monoxide, carbon dioxide and nitrogen oxides.

27.6.1.4 Forcibly extract all fumes from the chamber with it open to free air for a period of 3 min. Repeat the procedure from 27.6.1.2 to 27.6.1.3 but maintain the burning conditions for 2 min ± 1 s and 3 min ± 1 s in separate determinations.

27.6.1.5 Plot curves of the concentration of carbon monoxide, carbon dioxide, and nitrogen oxides against time of burning to show the rate of build-up of the gases due to the burner alone. Zero time is at a level of 0,03 % for carbon dioxide and 0 % for carbon monoxide and nitrogen oxides.

27.6.2 Determination of evolved gases

27.6.2.1 In order to eliminate the unnecessary analysis for gases that are not produced during the combustion of the material under test, a preliminary qualitative elemental analysis may be performed. Where it can be shown that no halogens are present in the material, the quantitative analysis for halogen-containing gases may be omitted. Similarly, where nitrogen is shown to be absent, quantitative analysis for nitrogen containing gases is not required, etc.

27.6.2.2 Ensure that the chamber is clear of evolved gases by forcibly ventilating the chamber for at least 3 min with it open to the free passage of air.

27.6.2.3 Weigh the test piece to the nearest milligram and place it on the test piece support in the centre of the chamber at a height above the burner such that the test piece will be sited within the flame boundary and subjected to the flame temperature of 1 150 °C ± 50 K. In the case of tests on materials that are liable to melt and drip, a thin bed of glass wool shall be placed on the wire mesh support to prevent sample loss during the combustion.

27.6.2.4 Prepare the chamber for the analysis of the products of combustion. Close all sampling ports other than those required for the analysis. Where the method of analysis is to be by use of colourimetric tubes, these shall be placed in position within the chamber.

27.6.2.5 Close the chamber and all inlet and outlet vents. Ignite the burner and simultaneously start the level timing device. Maintain the flame condition at the reference level of gas and air flow rates until complete combustion of the test piece has occurred. Record this time. Extinguish the flame and start the mixing fan. After (30 ± 1) s, stop the fan and immediately start sampling the atmosphere within the chamber and determine the concentration of the gases evolved from the combustion of the test piece.

Where the presence of halogen acids is suspected, the concentration of these shall be determined first in order to reduce losses through absorption of condensation which may occur through delayed analysis.

27.6.2.6 After the analysis is complete, forcibly extract the remaining fumes from the chamber for at least 3 min with it open to the free passage of air.

27.6.2.7 Examine the residue of the test piece for signs of incomplete combustion. If any part of the test piece remains or appears to remain incompletely burnt the test shall be repeated using a further test piece.

27.7 Calculation of toxicity index

27.7.1 Calculate the concentration of each of the gases produced C_0 when 100 g of material is fully burnt and the product of combustion diffused in air in a volume of 1 m^3 from the following relationship:

$$C_0 = \frac{C \times 100 \times V}{m} \text{ (parts per million, ppm)}$$

where

C is the concentration of gas in the test chamber (ppm);

m is the mass of the test piece (g);

V is the volume of the test chamber (m^3).

In the cases of carbon monoxide, carbon dioxide and nitrogen oxides the values of C shall be corrected by subtracting the value for the background gas concentration, obtained from the plots for the burner alone, at the time for complete combustion of the test piece.

27.7.2 Using the mean values of C_0 for each gas from the triplicate test pieces, calculate the toxicity index as follows:

$$\text{toxicity index} = \frac{C1_0}{C_{f1}} + \frac{C2_0}{C_{f2}} + \frac{C3_0}{C_{f3}} + \frac{C4_0}{C_{f4}} + ... \frac{Cn_0}{C_{fn}}$$

where

$C1_0$, $C2_0$, $C3_0$, $C4_0$, ... Cn_0, represents the calculated concentration of each gas produced from 100 g of material (parts per million);

C_{f1}, C_{f2}, C_{f3}, C_{f4}, ... C_{fn}, is the concentration of each gas (parts per million) considered fatal to man in a 30 min exposure time.

27.8 Toxic constituents

The analysis of the product of combustion of the test piece shall include the quantitative determination of the following gases.

Carbon dioxide	(CO_2)	Sulphur dioxide	(SO_2)
Carbon monoxide	(CO)	Hydrogen sulphide	(H_2S)
Formaldehyde	(HCOH)	Hydrogen chloride	(HCl)
Nitrogen oxides	(NO and NO_2)	Ammonia	(NH_3)
Hydrogen cyanide	(HCN)	Hydrogen fluoride	(HF)
Acrylonitrile	(CH_2CHCN)	Hydrogen bromide	(HBr)
Phosgene	($COCl_2$)	Phenol	(C_6H_5OH)

NOTE The above list is not intended to be a complete list of all possible gases that can be found in the products of combustion but it does represent those most commonly produced in quantity upon which toxicity data can be based.

27.9 Values for C_f

Carbon dioxide	100 000	Carbon monoxide	4 000
Hydrogen sulphide	750	Ammonia	750
Formaldehyde	500	Hydrogen chloride	500
Acrylonitrile	400	Sulphur dioxide	400
Nitrogen oxides	250	Phenol	250
Hydrogen cyanide	150	Hydrogen bromide	150
Hydrogen fluoride	100	Phosgene	25

27.10 Result and report

The result is the value for the toxicity index as defined in this method. The report shall contain, at a minimum, the following details:

a) the full description of the material tested (the type, grade, etc.);

b) the toxicity index as defined in this method;

c) reference to this method of test;

d) a list of the gases detected during the test;

e) the following statement:

This test result alone does not assess the fire hazard of the material, or a product made from this material, under actual fire conditions. Consequently, the result of this test alone shall not be quoted in support of claims with respect to the fire hazard of the material or product under actual fire conditions. The result when used alone should only be used for research and development, quality control and material specifications.

28 Halogen content

28.1 Method for the determination of low levels of chlorine and/or bromine and/or iodine

28.1.1 Principle

The method depends upon the extraction of the halogen by means of the oxygen flask technique and estimating the amount present by using a colourimetric procedure. The chloride/bromide/iodide is reacted with mercuric thiocyanate to liberate thiocyanate ions which react with ferric ammonium sulphate to produce the characteristic ferric thiocyanate colour. The percentage halogen is expressed as chlorine.

28.1.1.1 Apparatus

a) Oxygen flask

b) Pipettes

c) Volumetric flasks

d) Ultraviolet/visible spectrophotometer

28.1.1.2 Reagents

a) Alcoholic mercuric thiocyanate solution ($Hg(SCN)_2$): (0,3 g in 100 ml of industrial methylated spirit).

b) Ferric ammonium sulphate solution ($NH_4Fe(SO_4)_2$ 12 H_2O): (6,0 g in 100 ml of 6-molar nitric acid).

c) 1 molar sodium hydroxide solution.

d) Hydrogen peroxide (30 %)

e) Standard chloride / bromide / iodide solutions: (1, 2, 5, 7, 10 µg/ml).

28.1.2 Procedure

A 30 mg sample of the material is burned in a 1 litre oxygen flask with 5 ml of molar sodium hydroxide and three drops of hydrogen peroxide as absorbing solution. After the mist has settled and the flask is cool, the flask is unstoppered and the contents are boiled to destroy residual hydrogen peroxide. The contents of the flask are transferred quantitatively to a 25 ml volumetric flask using small quantities of distilled water. 4 ml of the ferric ammonium sulphate and 2 ml of mercuric thiocyanate solution are added to the flask using a pipette, and the contents are brought to the mark with distilled water. The solution is then mixed and allowed to stand for 10 min for the colour development to occur.

Prepare a calibration curve for chlorine using standard solutions containing 1, 2, 5, 7, and 10 µg/ml in a 25 ml volumetric flask and develop the colour as described above; also prepare a reagent blank using distilled water in place of the halogen solutions.

The absorbance of the solutions is measured at 470 nm with a suitable spectrometer and the concentration of halogen found from the relevant calibration curve.

28.1.3 Using this method ≥ 0,014 % of halogen may be measured.

28.2 Determination of low levels of fluorine

28.2.1 Principle

The sample is burnt in an oxygen flask, and the resulting solution is used to measure the fluorine content. The fluorine content may be measured using either of the following methods:

A – a fluoride ion selective electrode, or

B – colourimetrically, by formation of the blue-red oligomer fluorine blue complex [1][2]

28.2.1.1 Apparatus

a) Oxygen flask

b) Pipettes

c) Volumetric flasks

NOTE All apparatus used in the fluorine determination should be made of polycarbonate or polypropylene, as fluoride ions react with glassware.

For method A, ion selective electrode (fluoride) with suitable millivolt meter; for method B, visible spectrophotometer.

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[2] Figures in square brackets refer to the Bibliography.

28.2.1.2 Reagents

Method A: electrode filling solution – buffer solution as recommended by electrode manufacturer.

Method B: alizarin fluorine blue reagent – dissolve 2,5 g alizarin fluorine blue complex in 15 ml 2–propanol plus 35 ml water. Filter before use.

Standard fluoride solution prepared from sodium fluoride.

Dodecanol.

0,5 M sodium hydroxide solution.

28.2.2 Procedure

Place an accurately weighed sample of material (25 mg – 30 mg) in a 1 litre oxygen flask using 2 to 3 drops of dodecanol on the sample to assist burning. Add 5 ml of 0,5 M sodium hydroxide solution as absorbent. Burn the sample and allow mist to settle. Transfer the contents of the flask with minimum washing to a 50 ml volumetric flask and proceed with method A or B.

28.2.2.1 Method A – Ion selective electrode method fluoride

Add 5 ml of recommended buffer reagent to the sample solution and washings, and make up to the mark. Construct a calibration curve for the fluoride ion electrode according to the manufacturer's instructions. Measure the fluoride concentration of the sample solution and calculate the percentage of fluorine in the sample.

28.2.2.2 Method B – Alizarin fluorine blue method

Add 5 ml alizarin fluorine blue reagent to the sample solution and washings and make up to the mark. Allow to stand for the colour to develop. Measure the absorbance of the solution at 630 nm using a 1 cm cell with water as blank.

Construct a calibration curve by suitably diluting the standard fluoride solution to give concentrations in the range 0 µg/ml to 2 µg/ml. Also measure the absorbance of a reagent blank using reagent and water only. Calculate the fluorine concentration in the sample.

28.2.3 Using this method, it is estimated that fluorine levels with values greater than 0,02 % can be detected.

28.3 In order to determine total halogen content of the material under test, the methods described in both 28.1 and 28.2 shall be used.

29 Acid gas generation

29.1 Tests shall be performed in accordance with the method specified in IEC 60754-1.

29.2 Tests shall be performed in accordance with the method specified in IEC 60754-2.

30 Resistance to mould growth

Test in accordance with ISO 846. Use a standard sheet as specified in 4.1 and cut dumb-bells after exposure. Exposure time and test variant shall be as specified in IEC 62329-3.

31 Compatibility

31.1 Dynamic shear at room temperature

31.1.1 Principle

This test is designed to evaluate the strength of heat-shrinkable shapes bonded to cables sheathed with heat-shrinkable sleevings under shear conditions.

31.1.2 Apparatus

Tensile test machine

Oven (for elevated temperature testing)

31.1.3 Form and number of test specimens

Three test specimens shall be prepared in accordance with Figure 3 for each test temperature.

31.1.4 Procedure

Insert each specimen vertically in the tensile test machine by screwing the adaptor firmly onto a suitable jaw fixture, as shown in Figure 5. Then clamp the cable in the upper jaws so that the distance between the end of the shape and the upper jaw is at least 150 mm.

The jaw separation rate shall be (50 ± 5) mm/min.

Record the maximum breaking load for each specimen.

31.1.5 Report

Record all maximum breaking loads.

31.1.6 Result

The result shall be the mean of the three maximum breaking loads.

31.1.7 Dynamic shear at elevated temperatures

The specimens shall be pre-conditioned at the temperature specified in IEC 62329-3 in a suitable chamber as shown in Figure 6 for at least 60 min and tested at that temperature in accordance with 31.1.4.

31.2 Static load

31.2.1 Principle

This test is designed to evaluate the strength of heat-shrinkable shapes bonded to cables sheathed with heatshrink sleeving under strain conditions.

31.2.2 Apparatus

Static load jig (see Figure 7).

Oven (specially modified as outlined in Figure 7)

Weights

31.2.3 Form and number of test specimens

Three test specimens shall be prepared in accordance with Figure 3 for each test temperature.

The length of cable protruding from the heat-shrinkable shape shall be long enough to guarantee a minimum distance of 150 mm between the cable exit end of the shape and the load clamp.

31.2.4 Procedure

Each specimen is to be clamped into the static load oven, Figure 7, and left to condition for at least 60 min at the specified temperature without the load being applied.

After this conditioning period the load shall be carefully applied and left for 4 h ± 5 min. At the end of this period the load is removed and the specimen taken out of the oven and allowed to cool to room temperature. Any movement of the cable out of the shape shall be measured to the nearest millimetre.

The specimens are then tested in accordance with 31.1.4.

31.2.5 Report

Record all measured values of cable movement and maximum breaking loads.

31.2.6 Result

The result is the highest maximum measured movement of the three specimens and the mean of the three maximum breaking loads.

31.3 Fluid resistance

31.3.1 Principle

This test is designed to evaluate the strength of heat-shrinkable shapes bonded to cables sheathed with heatshrink sleevings after being exposed to fuels, oils, and cleaning fluids.

31.3.2 Apparatus

Glass jars and flasks and distillation condenser

Ovens

Heated water bath

Tensile test machine

31.3.3 Form and number of test specimens

Three test specimens shall be prepared in accordance with Figure 3 for each test fluid. The adaptor shall be sealed using a suitable blank to prevent ingress of fluids (these blanks are later removed for the conditioning period and the dynamic shear).

31.3.4 Procedures

Each specimen is immersed in the relevant fluid for the time and temperature specified in IEC 62329-3 with the cable end out of the fluid.

The specimens shall be removed from the fluids and allowed to condition for (24 ± 0,25) h at room temperature. After the conditioning period the specimens shall be wiped to move any fluid on the surface and tested for dynamic shear in accordance with 31.1.4.

31.3.5 Report

Record all maximum breaking loads.

31.3.6 Result

The result shall be the mean of the three maximum breaking loads.

31.4 Thermal ageing

31.4.1 Principle

This test is designed to evaluate the strength of heat-shrinkable shapes bonded to cables sheathed with heatshrink sleevings at elevated temperature.

31.4.2 Apparatus

Tensile test machine

Oven

31.4.3 Form and number of test specimens

Three test specimens shall be prepared in accordance with Figure 3.

31.4.4 Procedure

The specimens shall be placed in the oven for the time and temperature specified in IEC 62329-3.

The specimens shall be removed from the oven and allowed to cool to room temperature before testing for dynamic shear in accordance with 31.1.4.

31.4.5 Report

Record all values of maximum breaking loads.

31.4.6 Result

The result shall be the mean of the three maximum breaking loads.

31.5 Peel adhesion

31.5.1 Principle

This test is designed to evaluate the adhesion between heat-shrinkable shapes and cables sheathed with heatshrink sleevings and aluminium adaptors.

31.5.2 Apparatus

Tensile test machine

Rolling peel jig

31.5.3 Form and number of test specimens

Three test specimens shall be prepared in accordance with Figure 3 except that narrow strips of masking tape shall be inserted as shown in Figure 8.

31.5.4 Procedure

Remove the internal wiring from the cable.

For peel to the cable, cut out the parallel section shown in Figure 8, and, for peel to the adaptor, cut out the section also as shown in Figure 8.

Cut the heatshrink shape parallel to one edge of the masking tape and peel back the heatshrink shape from the area over the masking tape to form a flap.

Figure 9 shows the test arrangement for heatshrink sleeved cable to moulded shape and Figure 10 shows the test arrangement for the aluminium adaptor to moulded shape.

Fix the rolling drum jig to the lower jaw of the tensile test machine and slide the specimen over the rolling drum. Clamp the heatshrink shape flap into the top jaw of the tensile tester. Measure the width of the heatshrink shape to be peeled.

The jaw separation rate shall be 50 mm/min.

Record the peel force over the entire peeling operation.

31.5.5 Calculation

Ignoring the first and last 10 % of the peel take readings of peel force from the remainder of the peel operation at five equally spaced distances. Average these five values and record this as the peel force.

Calculate the peel strength using the following formula.

$$\text{Peel strength (N/25 mm)} = \frac{\textit{Peel force}\,(\text{N}) \times 25}{\textit{Specimen width}\,(\text{mm})}$$

31.5.6 Report

Record all values of peel strength.

31.5.7 Result

The result is the average of the three cable peel strengths and the average of the three adaptor cable peel strengths.

31.6 Altitude immersion

31.6.1 Principle

This test is designed to evaluate the performance of heat-shrinkable shapes bonded to heat-shrinkable sleevings when subjected to reduced pressure to simulate high altitude.

31.6.2 Apparatus

Vacuum chamber

Water bath

Anionic wetting agent (e.g. P-D-410)

Sodium chloride

500 V d.c. insulation resistance tester

31.6.3 Form and number of test specimens

Three test specimens shall be prepared in accordance with Figure 3 except that all the internal wires of the cable shall be stripped back at the ends to expose the conductors. The exposed conductors shall be twisted together into two bundles at each end ensuring the same wires are twisted together at each end and the bundles are not touching at each end. Also, the adaptor end shall be sealed using a solid plug.

31.6.4 Procedure

The sealed specimen shall be immersed in the water bath containing 0,5 % of an anionic wetting agent (e.g. P-D-410) and 5,0 % sodium chloride. The sealed end of the specimen shall be at least 100 mm ± 10 mm below the surface of the water solution.

The immersed specimen and water bath shall then be placed in a vacuum chamber and the chamber pressure reduced to 35 mbar and maintained for 30 min.

The chamber is then returned to ambient pressure to complete one cycle. A further two cycles shall be carried out.

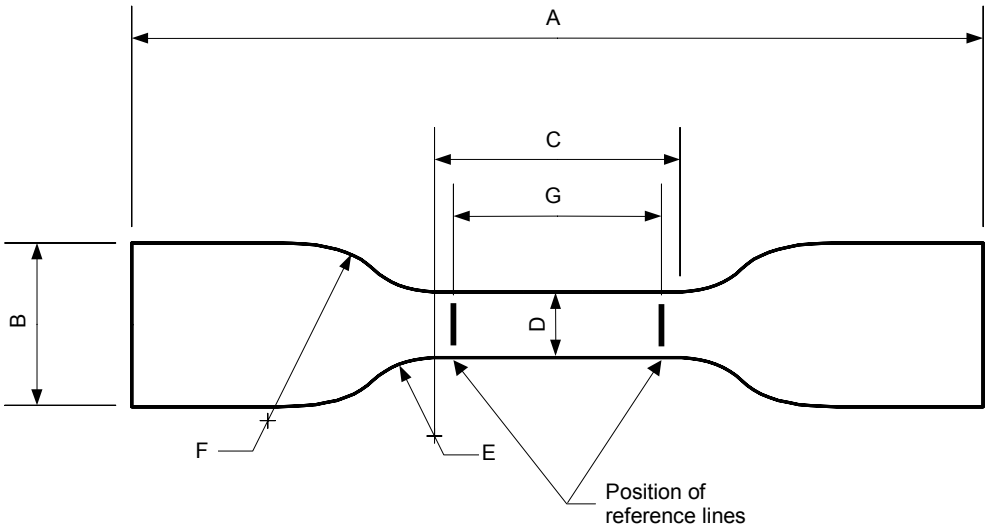
After completing the three cycles the specimen shall be removed from the vacuum chamber and while still immersed in the water solution the insulation resistance shall be measured between the two wire bundles after at least 1 min electrification.

31.6.5 Report

Record all insulation resistance values.

31.6.6 Result

The result is the mean of the three insulation resistance values.



A overall length, minimum	75 mm
B width at ends	(12,5 ± 1,0) mm
C length of narrow parallel portions	(25 ± 1) mm
D width of narrow parallel portion	(4,0 ± 0,1) mm
E small radius	(8,0 ± 0,5) mm
F large radius	(12,5 ± 1,0) mm
G distance between reference lines	20 mm maximum

In any one specimen, the thickness of the narrow portion shall nowhere deviate by more than 2 % from the mean

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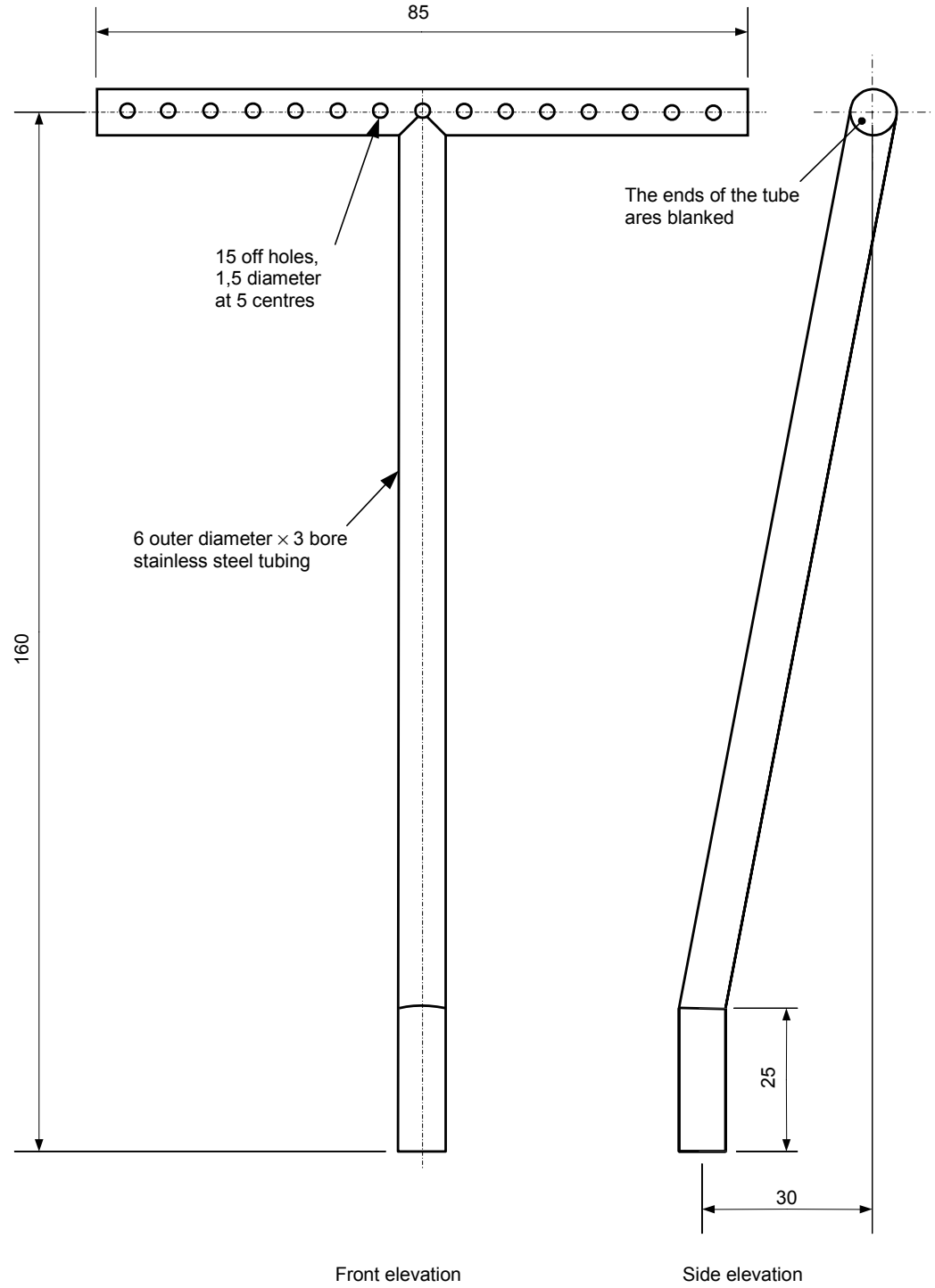
Figure 1 – Dumb-bell specimen for tensile strength test

All dimensions in millimetres



All dimensions are nominal

IEC 1231/06

Figure 2 – Schematic details of burner for smoke index test

All dimensions in millimetres

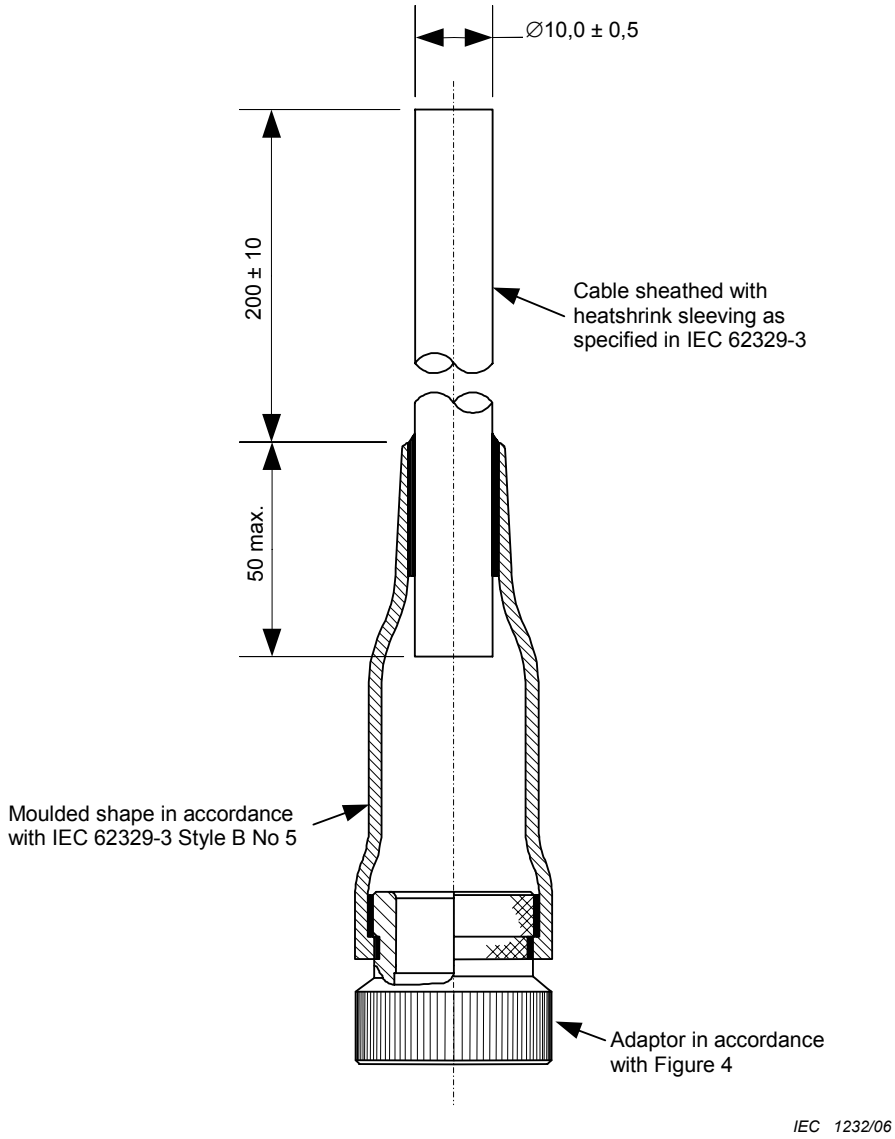


Figure 3 – Compatibility test specimen

All dimensions in millimetres

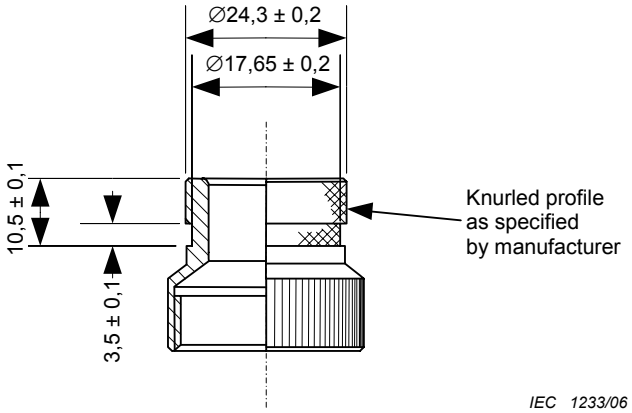


Figure 4 – Aluminium test adaptor

All dimensions in millimetres

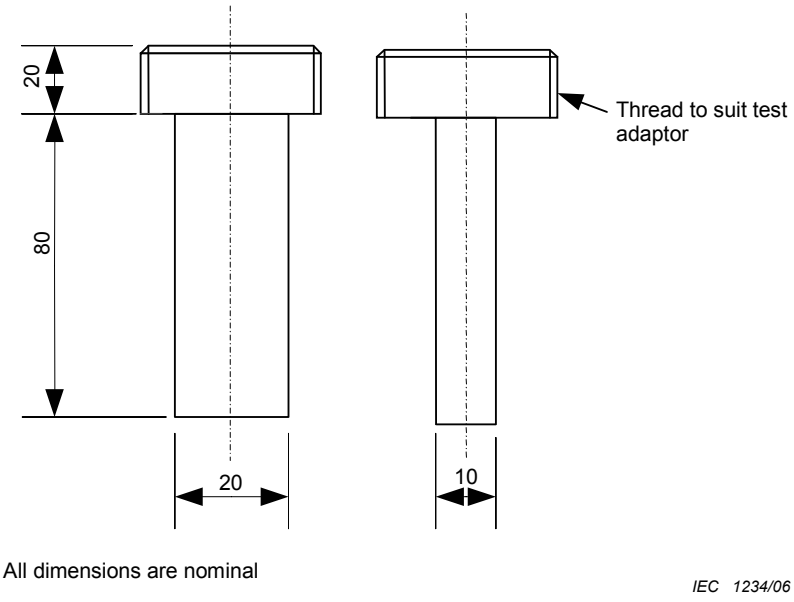


Figure 5 – Tensile test fixture for adaptor

All dimensions in millimetres

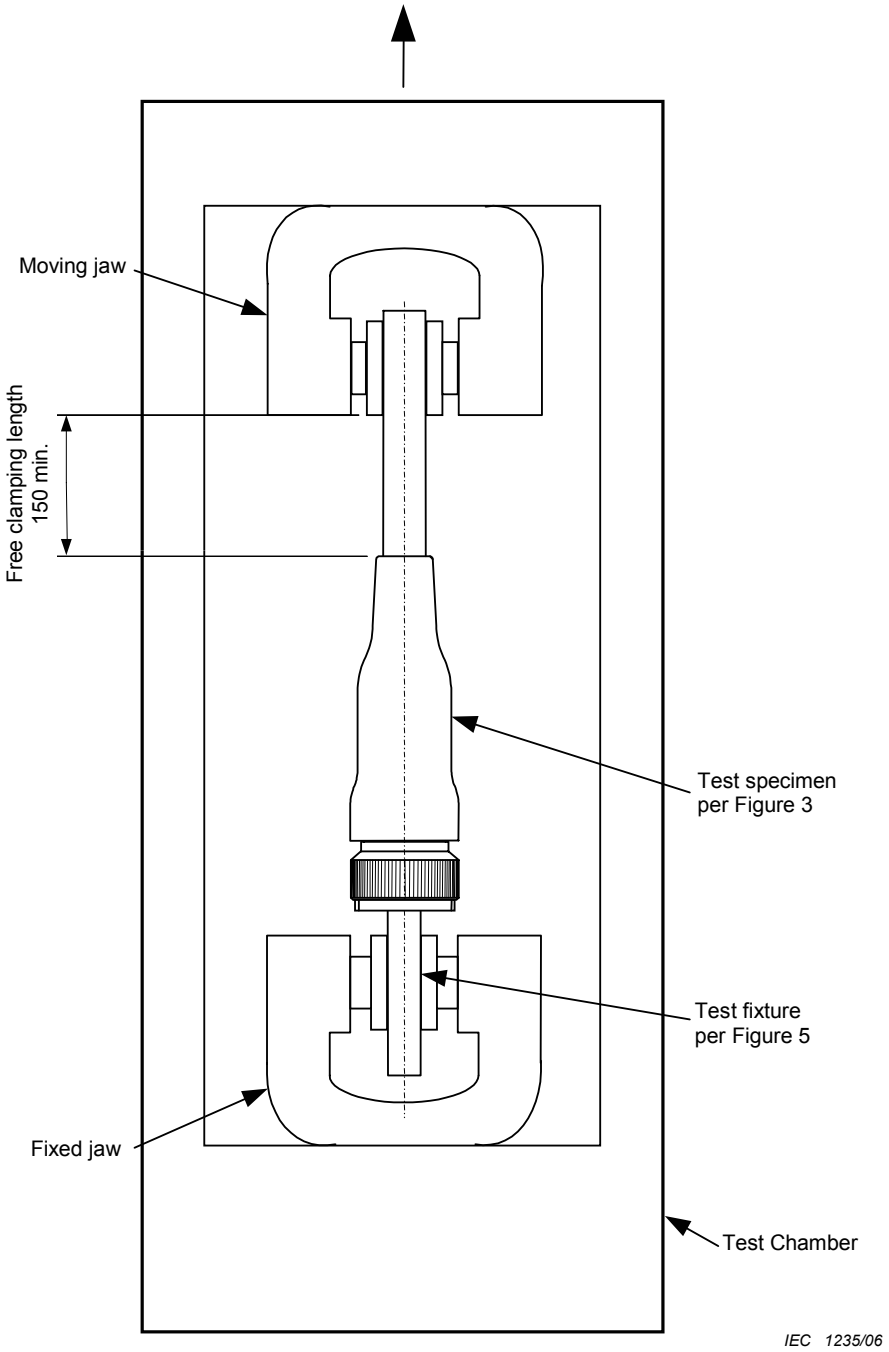


Figure 6 – Test arrangement for dynamic shear

All dimensions in millimetres

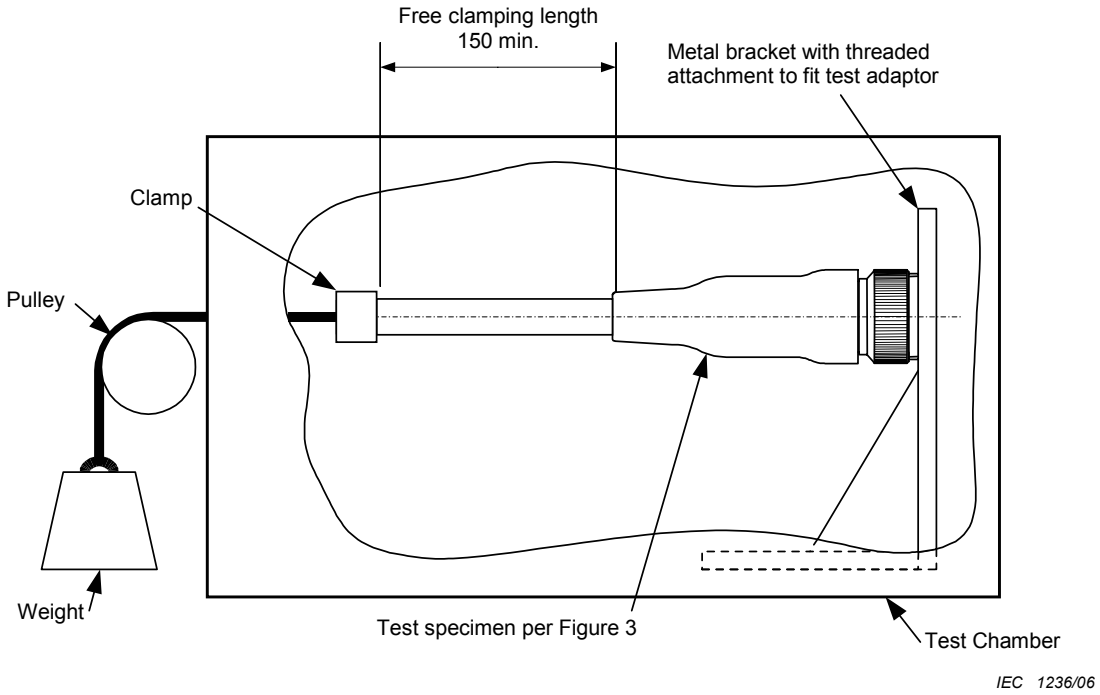


Figure 7 – Test arrangement for static load

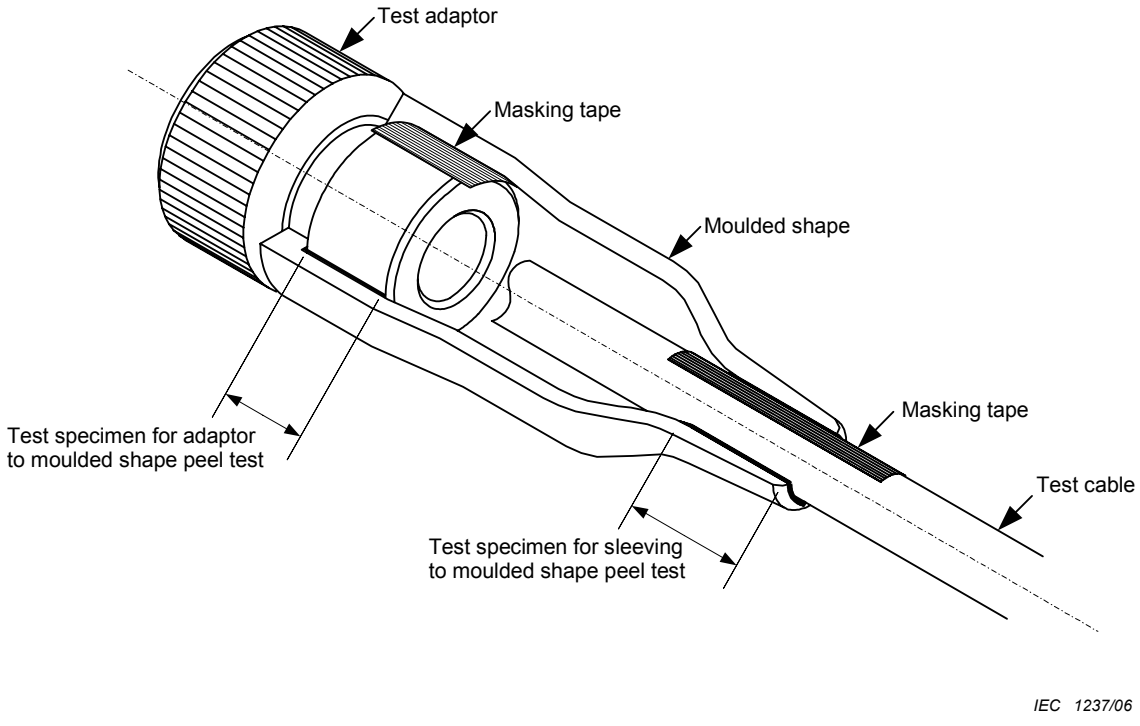


Figure 8 – Test assembly for peel adhesion

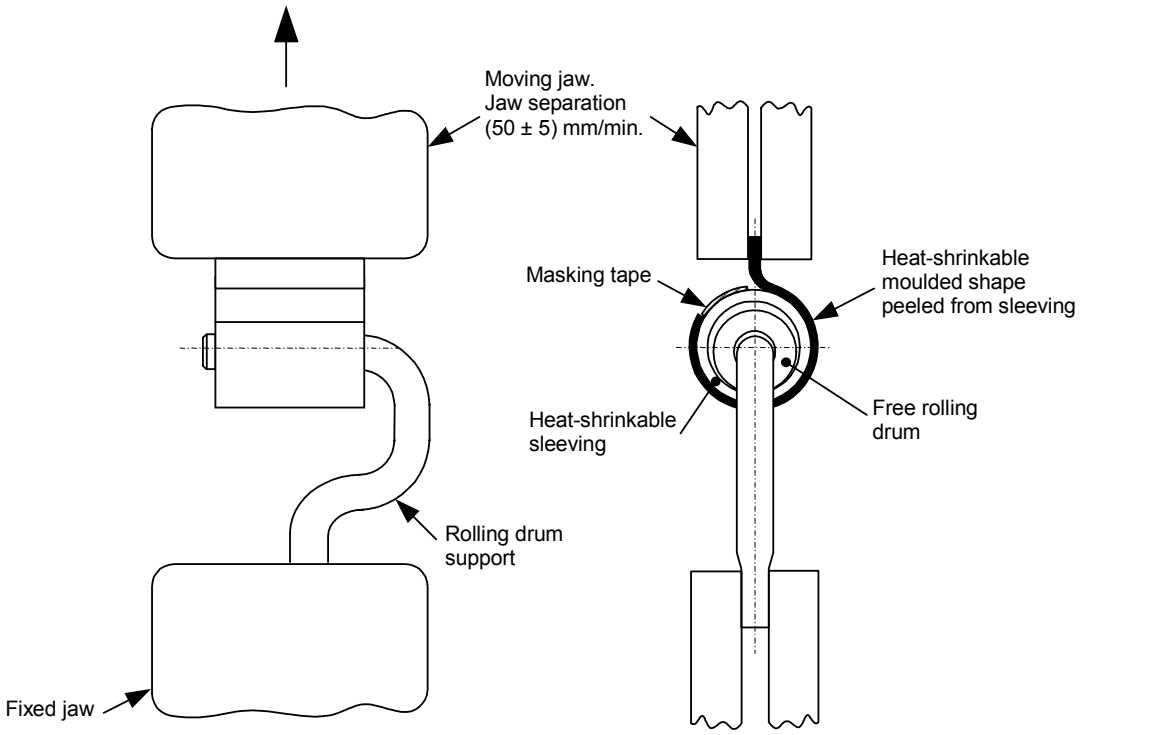


Figure 9 – Test arrangement for heat shrink sleeved cable to moulded shape

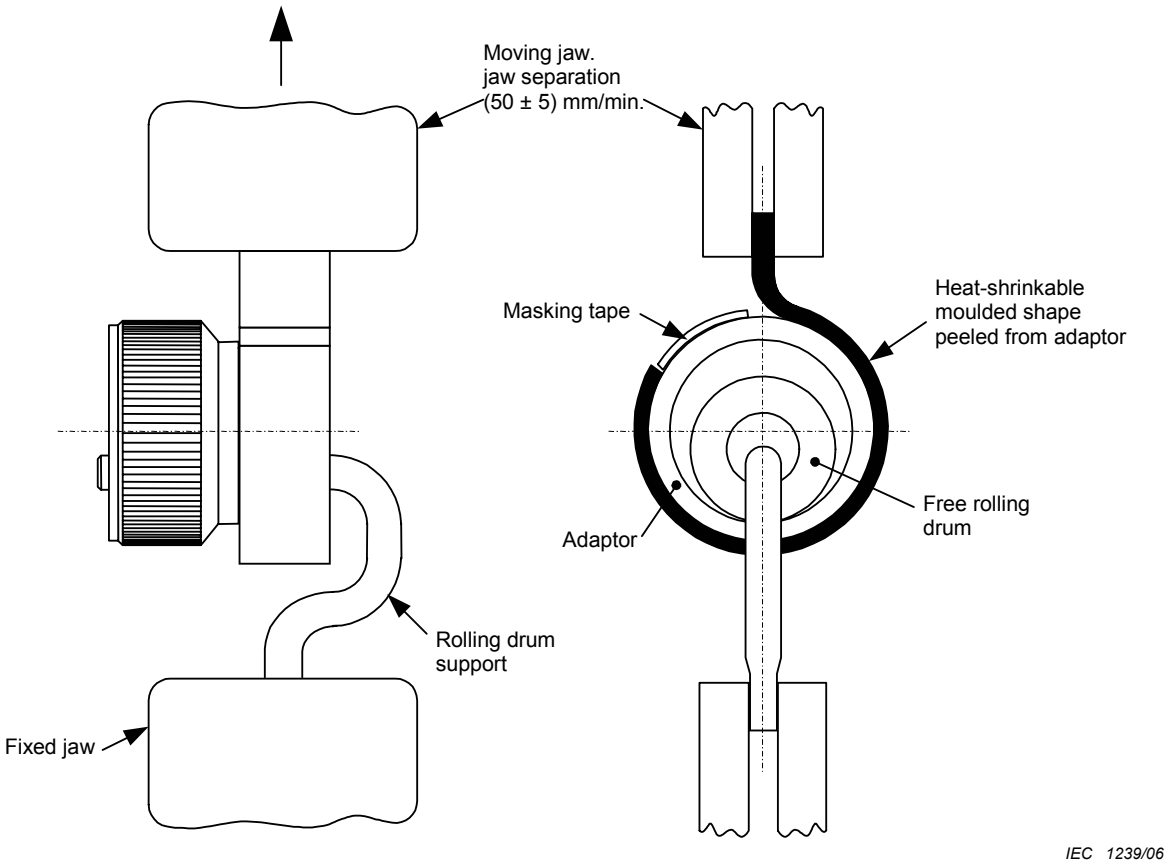


Figure 10 – Test arrangement for aluminium adaptor to moulded shape

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[1] Hill & Walsh, *Anal. Chi. Acta*:1969, Volume 45, p. 431

IEC 62329-3, *Heat-shrinkable moulded shapes – Part 3: Specification requirements for shape dimensions, material requirements and compatibility performance* [3]

ISO 37:2005*, Rubber, vulcanized or thermoplastic – Determination of tensile stress-strain properties*

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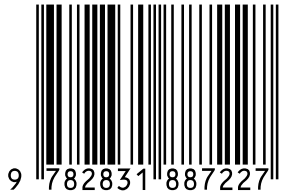

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