BS EN 60684-2:2011

BSI Standards Publication

Flexible insulating sleeving

Part 2: Methods of test

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National foreword

This British Standard is the UK implementation of EN 60684-2:2011. It is identical to IEC 60684-2:2011. It supersedes BS EN 60684-2:1997, which will be withdrawn on 14 September 2014.

The UK participation in its preparation was entrusted by Technical Committee GEL/15, Solid electrical insulating materials, to Subcommittee GEL/15/5, Flexible insulating sleeving for electrical purposes.

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

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English version

Flexible insulating sleeving -
Part 2: Methods of test
(IEC 60684-2:2011)

Gaines isolantes souples -
Partie 2: Méthodes d'essai
(CEI 60684-2:2011)

Isolierschläuche – Teil 2: Prüfverfahren
(IEC 60684-2:2011)

This European Standard was approved by CENELEC on 2011-09-14. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CENELEC member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the Central Secretariat has the same status as the official versions.

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CENELEC

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

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Foreword

The text of document 15/634/FDIS, future edition 3 of IEC 60684-2, prepared by IEC TC 15, Solid electrical insulating materials, was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 60684-2:2011.

This document supersedes EN 60684-2:1997 + A1:2003 + A2:2005.

The main changes from EN 60684-2:1997 + A1:2003 + A2:2005 are as follows: three additional methods for circumferential extension, voltage proof and thermal shock and alignment with North American methods.

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)	2012-06-14
– latest date by which the national standards conflicting with the document have to be withdrawn	(dow)	2014-09-14

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Endorsement notice

The text of the International Standard IEC 60684-2:2011 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following notes have to be added for the standards indicated:

[2] IEC 60068-2 series	NOTE	Harmonized in EN 60068-2 series (not modified).
[3] IEC 60068-2-10:2005	NOTE	Harmonized as EN 60068-2-10:2005 (not modified).
[4] IEC 60216-2:2005	NOTE	Harmonized as EN 60216-2:2005 (not modified).

Annex ZA
(normative)
Normative references to international publications with their corresponding European publications

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.

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 60068-2-20	2008	Environmental testing - Part 2-20: Tests - Test T: Test methods for solderability and resistance to soldering heat of devices with leads	EN 60068-2-20	2008
IEC 60093	1980	Methods of test for volume resistivity and surface resistivity of solid electrical insulating materials	HD 429 S1[1)]	1983
IEC 60212	2010	Standard conditions for use prior to and during the testing of solid electrical insulating materials	EN 60212	2011
IEC 60216	Series	Electrical insulating materials - Thermal endurance properties	EN 60216	Series
IEC 60216-4-1	2006	Electrical insulating materials - Thermal endurance properties - Part 4-1: Ageing ovens - Single-chamber ovens	EN 60216-4-1	2006
IEC 60216-4-2	2000	Electrical insulating materials - Thermal endurance properties - Part 4-2: Ageing ovens - Precision ovens for use up to 300 °C	EN 60216-4-2	2000
IEC 60243-1	1998	Electrical strength of insulating materials - Test methods - Part 1: Tests at power frequencies	EN 60243-1	1998
IEC 60250[2)]	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 60426	2007	Electrical insulating materials - Determination of electrolytic corrosion caused by insulating materials - Test methods	EN 60426	2007
IEC 60587	2007	Electrical insulating materials used under severe ambient conditions - Test methods for evaluating resistance to tracking and erosion	EN 60587	2007
IEC 60589	1977	Methods of test for the determination of ionic impurities in electrical insulating materials by extraction with liquids	HD 381 S1	1979

[1)] HD 429 S1 is superseded by EN 62631-1:2011, which is based on IEC 62631-1:2011.

[2)] IEC 60250 is superseded by IEC 62631-1:2011.

Publication	Year	Title	EN/HD	Year
IEC 60684-3	Series	Flexible insulating sleeving - Part 3: Specification for individual types of sleeving	EN 60684-3	Series
IEC 60695-6-30	1996	Fire hazard testing - Part 6: Guidance and test methods on the assessment of obscuration hazard 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/TS 60695-11-21	-	Fire hazard testing - Part 11-21: Test flames - 500 W vertical flame test method for tubular polymeric materials	-	-
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 (mod)	1991	Test on gases evolved during combustion of electric 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	HD 602 S1[3)]	1992
ISO 5-1	2009	Photography and graphic technology - Density measurements - Part 1: Geometry and functional notation	-	-
ISO 5-2	2009	Photography and graphic technology - Density measurements - Part 2: Geometric conditions for transmittance density	-	-
ISO 5-3	2009	Photography and graphic technology - Density measurements - Part 3: Spectral conditions	-	-
ISO 5-4	2009	Photography and graphic technology - Density measurements - Part 4: Geometric conditions for reflection density	-	-
ISO 37	2005	Rubber, vulcanized or thermoplastic - Determination of tensile stress-strain properties	-	-
ISO 62	2008	Plastics - Determination of water absorption	EN ISO 62	2008
ISO 105-A02	-	Textiles - Tests for colour fastness - Part A02: Grey scale for assessing change in colour	-	-
ISO 105-B01	-	Textiles - Tests for colour fastness - Part B01: Colour fastness to light: Daylight	EN ISO 105-B01	-

[3)] HD 602 S1 is superseded by EN 50267-1:1998 and EN 50267-2-3:1998.

Publication	Year	Title	EN/HD	Year
ISO 182-1	1990	Plastics - Determination of the tendency of compounds and products based on vinyl homopolymers and copolymers to evolve hydrogen chloride and any other acidic products at elevated temperature - Part 1: Congo red method	-	-
ISO 182-2	1990	Plastics - Determination of the tendency of compounds and products based on vinyl chloride homopolymers and copolymers to evolve hydrogen chloride and any other acidic products at elevated temperature - Part 2: pH method	EN ISO 182-2	1999
ISO 974	2000	Plastics - Determination of the brittleness temperature by impact	-	-
ISO 1431-1	2004	Rubber, vulcanized or thermoplastic - Resistance to ozone cracking - Part 1: Static and dynamic strain testing	-	-
ISO 4589-2	1996	Plastics - Determination of burning behaviour by oxygen index - Part 2: Ambient-temperature test	EN ISO 4589-2	1999
ISO 4589-3	1996	Plastics - Determination of burning behaviour by oxygen index - Part 3: Elevated-temperature test	EN ISO 4589-3	1996
ISO 13943	2008	Fire safety - Vocabulary	EN ISO 13943	2010

CONTENTS

INTRODUCTION

This International Standard is one of a series which deals with flexible insulating sleeving. The series consists of three parts:

Part 1: Definitions and general requirements (IEC 60684-1)

Part 2: Methods of test (IEC 60684-2)

Part 3: Specifications for individual types of sleeving (IEC 60684-3)

FLEXIBLE INSULATING SLEEVING –

Part 2: Methods of test

1 General

1.1 Scope

This part of IEC 60684 gives methods of test for flexible insulating sleeving, including heat-shrinkable sleeving, intended primarily for insulating electrical conductors and connections of electrical apparatus, although they may be used for other purposes.

The tests specified are designed to control the quality of the sleeving but it is recognized that they do not completely establish the suitability of sleeving for impregnation or encapsulation processes or for 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.

1.2 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 60068-2-20:2008, *Environmental testing – Part 2-20: Tests – Test T: Test methods for solderability and resistance to soldering heat of devices with leads*

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

IEC 60212:2010, *Standard conditions for use prior to and during the testing of solid electrical insulating materials*

IEC 60216 (all parts), *Electrical insulating materials – Thermal endurance properties*

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, *Electrical 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 60426:2007, *Electrical insulating materials – Determination of electrolytic corrosion caused by insulating materials – Test methods*

IEC 60587:2007, *Electrical insulating materials used under severe ambient conditions – Test methods for evaluating resistance to tracking and erosion*

IEC 60589:1977, *Methods of test for the determination of ionic impurities in electrical insulating materials by extraction with liquids*

IEC 60684-3 (all parts), *Flexible insulating sleeving – Part 3: Specifications for individual types of sleeving*

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/TS 60695-11-21, *Fire hazard testing - Part 11-21: Test flames - 500 W vertical flame test method for tubular polymeric materials*

IEC 60754-1:1994, *Tests 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 electric 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*
Amendment 1 (1997)

ISO 5-1:2009, *Photography and graphic technology – Density measurements – Part 1: Geometry and functional notation*

ISO 5-2:2009, *Photography and graphic technology – Density measurements – Part 2: Geometric conditions for transmittance density*

ISO 5-3:2009, *Photography and graphic technology – Density measurements – Part 3: Spectral conditions*

ISO 5-4:2009, *Photography and graphic technology – Density measurements – Part 4: Geometric conditions for reflection density*

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

ISO 62:2008, *Plastics – Determination of water absorption*

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

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

ISO 182-1:1990, *Plastics – Determination of the tendency of compounds and products based on vinyl chloride homopolymers and copolymers to evolve hydrogen chloride and any other acidic products at elevated temperature – Part 1: Congo red method*

ISO 182-2:1990, *Plastics – Determination of the tendency of compounds and products based on vinyl chloride homopolymers and copolymers to evolve hydrogen chloride and any other acidic products at elevated temperature – Part 2: pH method*

ISO 974:2000, *Plastics – Determination of the brittleness temperature by impact*

ISO 1431-1:2004, *Rubber, vulcanized or thermoplastic – Resistance to ozone cracking – Part 1: Static and dynamic strain test*

ISO 13943: 2008*, Fire safety – Vocabulary*

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*

2 Test conditions

2.1 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.

2.2 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 IEC 60216-4-1.

2.3 Where a test at low temperature is specified, the specification sheets of IEC 60684-3 may require it to be carried out at –*t* °C or lower. 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.

3 Measurements of bore, wall thickness and concentricity

NOTE Within this standard, the terms "bore" and "internal diameter" are interchangeable.

3.1 Bore

3.1.1 Number of test specimens

Three specimens shall be tested.

3.1.2 General method

Plug or taper gauges of appropriate diameter shall be used to establish that the bore lies between the maximum and minimum specified values. The gauge shall enter the bore without causing expansion of the sleeving. A lubricant in powder form will assist when some types of sleeving are being measured. For small bore sizes a micrometer microscope may be used and measurements shall be made to the nearest 0,05 mm.

3.1.3 Relaxed bore of expandable braided sleeving

Select a 250 mm long steel mandrel of the same diameter as the specified minimum relaxed bore of the sleeving.

Insert the mandrel completely into the sleeving so that 50 mm of sleeving projects beyond the mandrel at the cut end.

At the opposite end, wrap wire around the sleeving just beyond the end of the mandrel to prevent the mandrel penetrating further into the sleeving.

Smooth the sleeving firmly onto the mandrel from the secured end towards the cut end and twist the sleeving so that it traps the end of the mandrel. Secure by wrapping with wire.

Mark 200 mm gauge lines centrally on the sleeving using a marking medium which does not degrade the sleeving, e.g., typewriter correction fluid.

Release the cut end and allow sleeving to relax.

Measure the distance between gauge lines in millimetres.

If this measurement is 195 mm or greater, then the sleeving is of the maximum relaxed bore diameter.

If this measurement is less than 195 mm, repeat the determination with progressively larger mandrels until the measurement is equal to or larger than 195 mm.

3.1.4 Expanded bore of expandable braided sleeving

Select a plug gauge of the same diameter as the specified minimum expanded bore.

Grip the sleeving 50 mm below the cut end.

Open the cut end of the sleeving for 10 mm and insert the plug gauge.

Attempt to push the plug gauge further into the undisturbed gripped sleeving.

If the plug gauge enters further without undue force, the sleeving is of the minimum expanded bore.

If the plug gauge does not enter further without undue force, repeat the determination with progressively smaller mandrels.

3.1.5 Result

Report all measured values as the result.

3.2 Wall thickness for textile sleeving

3.2.1 Number of test specimens

Three specimens shall be tested.

3.2.2 Procedure

A plug gauge or mandrel shall be inserted so that it enters freely but has a diameter not less than 80 % of the bore. The overall dimension shall then be measured using a micrometer having flat anvils of approximately 6 mm in diameter. In making this measurement, the pressure applied by the micrometer shall be just sufficient to close the sleeving on to the inserted plug gauge or mandrel. The wall thickness shall be calculated by halving the difference between the overall dimension and the plug gauge or mandrel diameter.

3.2.3 Result

Report all measured values for wall thickness as the result.

3.3 Minimum/maximum wall thickness and concentricity for extruded sleeving

3.3.1 Number of test specimens

Three specimens shall be tested.

3.3.2 Wall thickness

This standard does not give mandatory methods for making this measurement. By means of a suitable number of tests, locate the points on the wall corresponding to the minimum and maximum wall thickness. All measurements shall be measured to the nearest 0,01 mm. In cases of dispute a calibrated micrometer microscope shall be used capable of measuring to the nearest 0,001 mm.

NOTE The following methods of measurement have proved suitable: optical profile projector, optical comparator, a suitable micrometer. In the event of a dispute, use one of the optical methods. A microscope micrometer has been found suitable for measuring small bore sizes and for determining the inner and outer wall thicknesses of dual wall sleeving.

3.3.3 Concentricity

Calculate the concentricity of each specimen of the sleeving by use of the following equation:

$$\text{concentricity (\%)} = \frac{\text{minimum wall thickness}}{\text{maximum wall thickness}} \, 100$$

3.3.4 Result

Report all values for minimum and maximum wall thickness and concentricity as the result.

4 Density

4.1 Number of test specimens

At least three specimens shall be tested.

4.2 Procedure

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

NOTE Small bore sleeving specimens should be cut longitudinally and opened out to avoid air entrapment during the determination.

4.3 Result

Identify the method selected for the determination and report all measured values for density; the result is the mean unless specified otherwise in the specification sheets of IEC 60684-3.

5 Resistance to splitting after heating

5.1 Number of test specimens

Three specimens shall be tested.

5.2 Form of test specimen

The specimens shall be produced by cutting rings whose cut length equals the wall thickness. Precautions shall be taken to ensure that the cut is clean since imperfections can affect the result.

NOTE Where practical difficulties do not permit a square section ring to be cut, the length may be increased to not more than 2,5 mm.

5.3 Procedure

The specimens shall be tested using a tapered mandrel which has an inclined angle of (15 ± 1)°. The specimens shall be maintained for a period of (168 ± 2) h at a temperature of 70 °C ± 2 K unless another temperature is specified in IEC 60684-3, and then allowed to cool to 23 °C ± 5 K. They shall then be rolled up the mandrel so that they are extended by an amount equal to the percentage of nominal bore specified in IEC 60684-3. The specimens shall be kept in that position and at a temperature of 23 °C ± 5 K for (24 ± 1) h and then examined for splitting.

5.4 Result

Report whether there is any splitting.

6 Heat shock (resistance to heat)

6.1 Number of test specimens

Five specimens shall be tested.

6.2 Form of test specimens

Lengths of approximately 75 mm of sleeving, or specimens in accordance with Clause 19 shall be prepared where tensile strength or elongation at break are to be measured. Where cut pieces of sleeving are used the length shall be measured to the nearest 0,5 mm.

6.3 Procedure

The specimens shall be suspended vertically in an oven conforming to IEC 60216-4-1 or IEC 60216-4-2 for 4 h ± 10 min at the temperature specified in IEC 60684-3.

The specimens shall be removed and allowed to cool to room temperature. They shall then be examined for any signs of dripping or cracking. Measure the length and calculate the percentage change. In addition, when so specified in IEC 60684-3, the specimens shall be tested for tensile strength and/or elongation at break. Also, when so specified in IEC 60684-3, the specimen shall be wound 360 degrees around a mandrel of diameter specified in IEC 60684-3 at a uniform rate and within 2 s to 4 s. The specimens shall then be examined for any signs of cracks. Side cracking of the flattened tubing shall not be cause for rejection.

6.4 Result

Report all results from the visual examination. Report all values of change in length. Report all measured values for tensile strength and/or elongation at break. The result is the central value unless otherwise specified in the specification sheets of IEC 60684-3. Report any cracks after the mandrel bend test.

7 Resistance to soldering heat

7.1 Number of test specimens

Three specimens shall be tested.

7.2 Form of test specimen

60 mm lengths of sleeving shall be used and approximately 150 mm of tinned copper wire, of a diameter which permits a sliding fit in the sleeving.

The wire shall be bent through 90° at its middle point round a mandrel of diameter three times the nominal bore of the sleeving.

The sleeving shall be slipped over the wire and worked round the bend so that it covers a length of the straight part of the wire which will be vertical during the test, equal to 1,5 times the nominal bore of the sleeving but with a minimum length of 1 mm (see Figure 1). The wire shall be cut off on the part to be vertical during the test 20 mm beyond the sleeving.

The wire shall be cut off on the part to be horizontal during the test at the end of the sleeving. Not less than 5 min after the wire has been bent, a high grade flux consisting of 25 % by mass of colophony in 75 % by mass of 2-propanol (isopropanol) or of ethanol (ethyl alcohol), shall be applied to the lower 6 mm of the protruding part of the wire. (Only non-activated colophony shall be used, the acid value of which is not less than 155 mg KOH/g. A full specification is given in Annex C of IEC 60068-2-20.)

7.3 Procedure

With the sleeving at a temperature of 23 °C ± 5 K, the test shall be started within 60 min of the application of the flux. The wire is supported on its horizontal part at least 25 mm from the bend. The vertical portion shall be immersed in the centre of a bath of molten solder so that 6 mm of the wire is immersed; a convenient way to achieve this is to mark the wire beforehand. The wire shall be held in this position for (15 ± 1) s or as specified in IEC 60684-3. The solder bath shall be not less than 25 mm in diameter and 12 mm deep and the temperature of the solder shall be maintained at 260 °C ± 5 K during the test. To pass the test, no specimen shall split or widen considerably, slight melting being permissible (see Figure 2).

7.4 Result

Report whether there is any splitting, widening or excessive melting.

8 Loss in mass on heating of uncoated textile glass sleeving

8.1 Number and mass of test specimens

Three specimens shall be tested, each consisting of a sufficient length to provide (5 ± 1) g.

8.2 Procedure

The specimens shall be conditioned by heating at 105 °C ± 2 K for 1 h and then allowed to cool in a desiccator to room temperature. They shall then be weighed to the nearest 0,0002 g (m_1) and then heated in a ventilated furnace at 600 °C ± 10 K for 60 min to 75 min. After cooling to room temperature in a desiccator, the specimens shall be re-weighed (m_2).

8.3 Calculation

The percentage loss in mass of each test shall be calculated as follows:

$$\frac{m_1 - m_2}{m_1} 100$$

8.4 Result

Report all calculated values for the percentage loss in mass. The result is the central value unless otherwise specified in the specification sheets of IEC 60684-3.

9 Longitudinal change

9.1 Number of test specimens

Three specimens shall be tested.

9.2 Form of test specimen

Each specimen of sleeving approximately 150 mm long is cut cleanly and marked with two gauge marks, nominally 100 mm apart and approximately centrally placed on the specimen, using a marking medium that is not detrimental to the material. The distance between gauge marks shall be measured to an accuracy of 0,5 mm (L_1).

9.3 Procedure

The specimens shall be supported horizontally on a medium on which they can recover freely. The supported specimens shall be maintained in an oven for the time and at the temperature specified in IEC 60684-3.

The sleeving shall be allowed to cool to room temperature and the distance between the gauge marks re-measured to an accuracy of 0,5 mm (L_2).

9.4 Calculation

Calculate the percentage longitudinal change (LC) from the formula

$$LC = \frac{L_2 - L_1}{L_1} 100$$

where

L_1 is the original length;

L_2 is the length after unrestricted shrinkage.

9.5 Result

Report all values for longitudinal change as the result.

10 Deformation under load (resistance to pressure at elevated temperature)

10.1 Method A

10.1.1 Number of test specimens

Three specimens shall be tested.

The tests shall be carried out not less than 16 h after the extrusion of the sleeving.

10.1.2 Form of test specimen

Each test specimen shall be formed by slitting the sleeving along its length and then cutting from the sleeving a section approximately 10 mm × 5 mm (or the full circumference of the sleeving if this is less than 5 mm), so that the long axis of the specimen is parallel to the length of the sleeving.

10.1.3 Apparatus

The apparatus consists of an instrument capable of measurement to ± 0,01 mm with a rectangular indentor blade with an edge (0,70 ± 0,01) mm which applies a load to the specimen of (1,2 ± 0,05) N, unless otherwise specified in IEC 60684-3. The specimen is placed on a metal mandrel (6,00 ± 0,1) mm in diameter which is supported on a V block. The essential features of this arrangement are shown in Figure 3.

The assembly shall be placed in an oven maintained at 110 °C ± 2 K during the heating period, unless another temperature is specified in IEC 60684-3. To minimize vibration, a gravity-circulated oven, mounted on suitable damping pads, shall be used.

10.1.4 Procedure

The wall thickness of the test specimen shall be measured by the method of 3.2, except that the plug gauge and the sleeving sample therein shall be replaced by the test specimen resting on the mandrel. The wall thickness shall be the measured difference between the overall dimensions and the mandrel diameter.

The assembly with mandrel but without the test specimen shall be conditioned for at least 2 h before the test in the oven at 110 °C ± 2 K, unless another temperature is specified in IEC 60684-3.

The indentor blade shall be raised, the test specimen placed on the mandrel with its long axis parallel to the mandrel and the indentor gently lowered on to the surface of the test specimen.

NOTE With small bore sleevings the manipulation of the test specimen may cause difficulty. In such cases it is recommended that the test specimen be flattened under a 1 kg weight for approximately 10 min at room temperature before placing it on the mandrel.

The assembly and test specimen shall then remain in the oven at the specified temperature for (60 ± 5) min.

The position of the indentor blade shall then be recorded. Remove the specimen, allow the indentor to rest directly on the mandrel and again record the position. Subtract the difference between these two readings from the original measured wall thickness to give the indentation.

Differences between any two of the three values for the position of the indentor resting directly on the mandrel shall be not more than 0,02 mm.

10.1.5 Result

The indentation of the specimen shall be expressed as a percentage of the initial wall thickness.

The percentage indentation shall be taken as the central value of the three determinations; the other two values are also reported.

10.2 Method B

10.2.1 Number of test specimen

As method A.

10.2.2 Form of test specimen

For sleeving with an inside diameter (fully recovered for heat-shrinkable sleeving) of 4,22 mm, lengths of full section sleeving shall be used. A solid metal conductor having a diameter approximately equal to, but not greater than the inside diameter of the sleeving, shall be inserted into each specimen.

For larger sleeving, rectangular specimens (25 ± 1 mm) long and a maximum width of 14 mm shall be cut from the sleeving.

10.2.3 Apparatus

Apparatus of the type shown in Figure 4 shall be used.

Air circulating oven.

Weights as follows, mounted in the metal frame, so as to provide free vertical movement, as illustrated in Figure 4.

Sleeving inside diameter (fully recovered for heat shrinkable sleeving) mm	**Load exerted on specimen by presser foot** N
≤ 1,6	2,95
1,6 to 4,22	4,91
≥ 4,22	19,61

Pressure foot discs, (9,5 ± 0,1 mm), slightly rounded at the edges.

10.2.4 Procedure

For full section sleeving specimens on the metal conductors, measure the diameter over the sleeving at a marked position with a micrometer capable of measuring to the nearest 0,01 mm and the diameter of the conductor. Calculate the specimen wall thickness using the following formula;

$T_1 = (D_1 - d)/2$ where D is the diameter over the sleeving and d is the diameter of the metal conductor.

For strip specimens measure the thickness with a micrometer of the same accuracy at a marked position.

The appropriate weight as indicated above shall be conditioned with the metal frame, as shown in Figure 4, and the specimen in an oven at the temperature specified in IEC 60684-3 for a minimum of 1 h.

At the end of this period the specimens shall be carefully placed under the pressure foot with the marked position on the specimen in the centre of the pressure foot. Under these conditions, the specimens shall remain in the oven for a further period of 1 h minimum.

At the end of this period carefully remove the specimen from the load and measure the thickness within 15 s at the marked position.

Calculate the percentage deformation using the following formula:

$$\% \text{ deformation} = (T_1 - T_2)/T_1 \times 100$$

where

T_1 is the original thickness, and

T_2 is the thickness after conditioning.

NOTE For sleeving with a meltable liner, the thickness of the liner should not be included in determining the deformation.

10.2.5 Result

The percentage deformation shall be the average of the three measurements. All values shall be reported.

11 Thermal stability of PVC sleeving

11.1 Principle

This method determines the time taken for hydrogen chloride to be evolved from polyvinyl chloride (PVC), its copolymers or compounds or products based on them, when heated.

The evolution of hydrogen chloride is detected either by the use of Congo red paper (ISO 182-1) or by the change in pH of a potassium chloride solution contained in a measuring cell (ISO 182-2).

11.2 Form of test specimen

11.2.1 ISO 182-1 method

The specimen shall be sufficient to fill two of the specified test tubes to a depth of 50 mm and is formed by cutting the sleeving into pieces of maximum dimension 6 mm, slitting where necessary. The pieces of sleeving shall not be deliberately compacted in the test tubes.

11.2.2 ISO 182-2 method

To prepare specimens, cut pieces of sleeving approximately 5 mm^2 to 6 mm^2 in size and place approximately 1,0 g into each test tube.

11.3 Procedure

The test shall be carried out in accordance with either ISO 182-1 or ISO 182-2. The relevant specification sheet IEC 60684-3 will specify which test is to be used, the test temperature and, in the case of ISO 182-2, if a moving gas medium other than air is to be employed.

12 Volatile content of silicone sleeving

12.1 Number and mass of test specimens

Three specimens shall be tested, each consisting of sufficient length to provide (10 ± 1) g.

12.2 Procedure

The specimens shall be weighed to the nearest 0,001 g (m_1) and then heated in an oven at 200 °C ± 3 K for (24 ± 1) h. A convenient way to achieve this is to suspend the test pieces over a wire that is thermally insulated from the metalwork of the oven.

After cooling in a desiccator, the specimens shall be re-weighed (m_2).

12.3 Calculation

The percentage loss in mass of each test specimen shall be calculated as follows:

$$\frac{m_1 - m_2}{m_1} 100$$

12.4 Result

Report all values for percentage volatile content. The result is the central value of the three determinations unless otherwise specified in the specification sheets of IEC 60684-3.

13 Bending after heating

13.1 Number of test specimens

Three specimens shall be tested, each of length sufficient to wind conveniently round a mandrel of the size specified in IEC 60684-3 for the sleeving under test.

13.2 Form of test specimen

When the nominal bore does not exceed 2 mm, a length of wire giving a sliding fit shall be inserted in the sleeving.

When the nominal bore exceeds 2 mm but does not exceed 15 mm (or other value as specified in IEC 60684-3 for a particular type of sleeving), the specimen shall be filled by any suitable means (e.g., a number of wires) to prevent undue collapse of the sleeving during winding.

When the nominal bore exceeds 15 mm (or other value as specified in IEC 60684-3 for a particular type of sleeving), the specimen shall consist of a strip of sleeving 6 mm wide cut parallel to the longitudinal axis of the sleeving.

13.3 Procedure

The specimen, prepared as described in 13.2, shall be suspended for (48 ± 1) h in an oven maintained at the temperature specified in IEC 60684-3. It shall then be removed from the oven and allowed to cool to room temperature.

It shall then be wound without jerking for one complete turn in a close helix round a mandrel of the diameter specified in IEC 60684-3. For cut strips, the inside surface shall be in contact with the mandrel. The time to achieve one complete turn shall be not greater than 5 s. The specimen shall be held in this position for 5 s.

It shall then be visually examined without magnification while still on the mandrel for signs of cracking, detachment of coating, or delamination.

Detection of cracking in sleeving up to 15 mm bore by application of voltage using a method described in Clause 21 may be specified in IEC 60684-3.

13.4 Result

Report whether there is any cracking, detachment of coating or delamination.

14 Bending at low temperature

14.1 Number and form of test specimens

The number and form of test specimens shall be as in Clause 13, except that, when the nominal bore exceeds 6 mm (instead of 15 mm), the specimen shall consist of a strip of sleeving 6 mm wide, cut parallel to the longitudinal axis of the sleeving. Alternatively, where so specified in IEC 60684-3, specimens of nominal bore up to and including 6 mm shall be tested unfilled. Also where specified in IEC 60684-3 nominal bore sizes up to and including 10 mm may be tested as full section sleeving, filled or unfilled.

14.2 Procedure

The specimen, prepared as described in 14.1 shall be suspended for 4 h ± 10 min in a chamber maintained at the temperature specified in IEC 60684-3 and, while still at that temperature, shall be wound without jerking for one complete turn in a close helix round a mandrel at the same temperature and having a diameter specified in IEC 60684-3. For cut strips, the inside surface shall be in contact with the mandrel. The time to achieve one complete turn shall be not greater than 5 s. The specimen shall then be allowed to regain room temperature.

The specimen shall then be visually examined without magnification while still on the mandrel for signs of cracking, detachment of coating or delamination.

14.3 Result

Report whether there is any cracking, detachment of coating or delamination.

15 Brittleness temperature

The test is made in accordance with ISO 974 using specimens prepared as follows:

For sleeving of nominal bore up to 4 mm diameter, the specimen shall be cut in full section 40 mm long. For sleeving of bore larger than 4 mm, the specimen shall be 6 mm wide and 40 mm long, with the longer dimension parallel to the longitudinal axis. The strip specimens shall be mounted so that the hammer strikes the convex side of the specimen.

16 Dimensional stability on storage (applicable to heat-shrinkable sleeving only)

16.1 Number and length of test specimens

Three specimens shall be tested, each approximately 100 mm long.

16.2 Procedure

The bore of the sleeving shall be measured in the expanded state as delivered. The sleeving shall then be stored in a ventilated oven for (336 ± 2) h at a temperature of 40 °C ± 3 K unless otherwise specified in the relevant sheet of IEC 60684-3. It shall then be removed from the oven, allowed to cool to ambient temperature and the expanded bore re-measured.

Following this measurement, the sleeving shall be allowed to fully recover, using the time and temperature specified in IEC 60684-3 for the sleeving being evaluated. The sleeving shall then be cooled to ambient temperature and the recovered bore re-measured.

16.3 Result

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

17 Hydrolysis of coating

17.1 Number of test specimens

Three specimens shall be tested.

17.2 Form of test specimen

Each specimen of the sleeving shall be cut into lengths of 40 mm to 50 mm, which shall be wrapped in filter paper to form a bundle of a diameter to give a push fit into a 125 mm × 12 mm borosilicate glass test tube. Where the size of the sleeving requires it, specimens may be cut along their length to enable them to be rolled up before insertion in the test tube.

NOTE It is essential that heavy wall thickness test tubes are used for this test to minimize the risk of explosion and injury to personnel. As a further safety precaution, it is recommended that the test tubes are placed behind a screen protecting the observer.

17.3 Procedure

The sleeving shall be pushed to the bottom of the test tube and approximately 2 ml of distilled water added. A short length of copper wire, of approximately 0,6 mm diameter, shall then be inserted, the end nearest to the sleeving being bent into a somewhat circular shape at right angles to the length. The length of wire shall be such that it is totally within the test tube after sealing, with the formed end above the water level when the tube is inverted. The wire acts as a stop to prevent the sleeving from slipping down into the water.

The end of the test tube shall then be sealed. This is done conveniently by drawing it out in a flame.

The test tube shall then be held vertically, with the sealed end downwards, and maintained at 100 °C ± 2 K for (72 ± 1) h.

17.4 Result

Report whether there is any running of the coating, any adherence between sleeving and paper or between the pieces of sleeving, and any sign of discolouration of the paper.

18 Flexibility (extruded sleeving only)

18.1 Number and length of test specimens

Three specimens shall be tested, each approximately 300 mm long.

18.2 Procedure

Condition the specimens by suspending from one end in an oven conforming to IEC 60216-4-1 or IEC 60216-4-2 for a period of (168 ± 2)h, unless otherwise specified, and at the temperature specified in IEC 60684-3. Remove the specimens from the oven and allow them to cool to room temperature.

Each specimen shall then be bent back on itself 180 degrees and then immediately released. After a minimum of 1 min the specimens shall be examined without the aid of magnification.

18.3 Report

Report circular form is similar to that before bending (an oval shape is acceptable) and any cracks. Internal cracks can be detected by circumferential depressions on the outer surface of the specimen. External kink lines shall not be considered a failure.

19 Tensile strength, tensile stress at 100 % elongation, elongation at break and secant modulus at 2 % elongation

19.1 General

Specification sheets in IEC 60684-3 may stipulate some of the following tests according to the type of sleeving. In some cases, more than one of the following tests can be carried out in the same operation:

– tensile strength and elongation at break of full section sleeving;
– tensile strength and elongation at break of dumb-bell specimens;
– tensile strength of uncoated glass textile sleeving;
– secant modulus at 2 % elongation;
– tensile stress at 100 % elongation;
– tensile stress at 100 % elongation and at elevated temperature.

NOTE In all these tests, appropriate jaws should be used. Specimens should be protected to avoid damage caused by the jaws.

19.2 Tensile strength and elongation at break for full-section sleeving

19.2.1 Number of test specimens

Five specimens shall be tested.

19.2.2 Form of test specimen

The test specimen shall be a length of sleeving sufficient to allow 50 mm between the jaws of the testing machine and shall be marked with two parallel reference lines at least 25 mm apart, approximately mid-way between the jaws. The marking medium shall have no detrimental effect on the material and the marks shall be as narrow as possible. The use of a marker with parallel printing blades is recommended.

19.2.3 Conditioning

Unless otherwise specified in IEC 60684-3, the test specimen shall be kept at an ambient temperature of 23 °C ± 2 K for 1 h immediately before testing, or for a longer time to enable the specimen to reach a temperature of 23 °C ± 2 K.

19.2.4 Test temperature

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

19.2.5 Procedure

The cross-sectional area of the test specimen shall be calculated from measurements of bore and wall thickness made in accordance with Clause 3. For extruded sleeving the wall thickness shall be

$$\frac{\text{minimum wall thickness + maximum wall thickness}}{2}$$

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 60684-3 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 ruler, callipers or an extensometer.

The maximum load shall be measured to the nearest 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.

19.2.6 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):

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

where

$F_{\text{max.}}$ is the maximum load (N);

A is the original cross-sectional area (mm^2) calculated using the following formula:

$$A=(\pi/4) \times (D_o^2 - D_i^2) = 0{,}7854\ (D_o^2 - D_i^2)$$

where

D_o is the outside diameter, in mm, measured to the nearest 0,01 mm;

D_i is the inside diameter, in mm, measured to the nearest 0,01 mm.

For sleeving with a meltable liner, the thickness of the liner wall shall not be included when determining the cross-sectional area.

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

$$\text{elongation at break (\%)} = \frac{L - L_0}{L_0} 100$$

where

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

L_0 is the original distance between the marks.

19.2.7 Result

Report all calculated values. The result for each property is the central value unless otherwise specified in the specification sheets of IEC 60684-3.

19.3 Tensile strength and elongation at break on dumb-bell specimens

19.3.1 The test shall be carried out as in 19.2 but with the following changes.

19.3.2 Specimens shall be cut to the dimensions and tolerances given in Figure 5 or Figure 6, with the major axis in the longitudinal direction of the sleeving. The sleeving shall be slit along its length and laid flat on a slightly yielding material having a smooth surface (e.g., leather, rubber or high quality cardboard) on a flat rigid base. The specimen shall be stamped from the sheet of sleeving using a single stroke of a press and a knife edge punch of appropriate form and dimensions.

NOTE The profile given in Figure 5 is that of type 2 of ISO 37 and the profile given in Figure 6 is that of type 1 of ISO 37.

19.3.3 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.

19.3.4 The distance between the reference lines at break shall be measured to within 2 %.

19.4 Tensile strength of uncoated glass textile sleeving

19.4.1 The test shall be carried out as in 19.2 but with the following changes.

19.4.2 The initial jaw separation shall be (100 ± 10) mm and the rate of separation of jaws shall be (25 ± 5) mm/min.

The elongation at break shall not be measured and the reference lines are not required.

19.4.3 The average cross-sectional area shall be calculated from the product of twice the wall thickness as measured in 3.2 and the width of a flat tape prepared as follows.

The sleeving is held under a tensile stress of about 10 % of the breaking stress and lightly pressed between plates to form a tape.

Measure the width of this tape. This is facilitated if one of the plates has a scale engraved on its edge.

19.5 Secant modulus at 2 % elongation

19.5.1 Number and form of test specimens

Perform three tests on lengths of full section sleeving or on strips cut parallel to the longitudinal axis of the sleeving. When strips are used they shall have a width to thickness ratio of at least 8:1. The cross-sectional area is determined as in 19.3.3.

19.5.2 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 nor greater than 250 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. 25 mm/min for a 250 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.

19.5.3 Calculation

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

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

where

A is the initial average cross-sectional area of the specimen (mm^2) (determined as specified in 19.3.3);

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

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

19.5.4 Result

Report all measured values for secant modulus at 2 % elongation; the result is the central value unless specified otherwise in the specification sheets of IEC 60684-3.

19.6 Tensile stress at 100 % elongation

19.6.1 General

The test shall be carried out as in 19.2 or 19.3 as appropriate and in addition, the load shall be recorded when the distance between the reference lines is increased by 100 %.

19.6.2 Calculation

The tensile stress at 100 % elongation of the specimen shall be calculated as follows:

$$\text{tensile stress at 100 \%} = \frac{F_2}{A} \text{ (MPa)}$$

where

A is the initial average cross-sectional area of the specimen (mm^2);

F_2 is the force required to produce a 100 % extension (N).

19.6.3 Result

Report all measured values for tensile stress at 100 % elongation; the result is the central value unless specified otherwise in the specification sheets of IEC 60684-3.

19.7 Tensile stress at 100 % elongation and at elevated temperature

The test shall be carried out as in 19.6 and at the temperature specified in IEC 60684-3.

20 Fraying resistance test

20.1 Principle

Fraying of uncoated textile sleeving often occurs as a result of mechanical handling or impact at the cut end of the sleeving, as for example in installation processes or in shipping. This test serves to evaluate the resistance of sleeving to fraying by measuring dilatation at the cut end after controlled impacts.

20.2 Number and length of test specimens

Three specimens shall be tested, each being a 150 mm length of sleeving. Specimens shall be cut using sharp shears (do not guillotine-cut), care being taken to avoid disturbing the end fibres after cutting.

20.3 Procedure

Using a slide projector, project an image of the sleeving on to a screen in such a way that the outside diameter of the image can be measured and so that repeat measurements can be made without altering the value obtained. Measure the outside diameter of the image at a central point on the specimen (remote from the ends). Rotate the sleeving through 90° and repeat the measurement. Average the measurement and records as d to the nearest 0,05 mm.

Select a steel rod 350 mm long and of a size sufficiently smaller in diameter than the bore of the sleeving, so as to allow the specimen free vertical fall when mounted thereon.

Slip the specimen on the rod, with its upper end flush with the upper end of the rod held vertically (see Figure 7). Allow the specimen to fall freely under the influence of gravity against a hard horizontal surface. Repeat this procedure for a total of 10 impacts.

Remove the specimen from the rod, being careful not to disturb the impacted end. Using the slide projector as before, measure the image of the flared diameter of the impacted end. Rotate the sleeving through 90° and repeat the measurement. Average the measurements and record as D to the nearest 0,05 mm.

20.4 Calculation

Calculate the percentage of fray using the following expression:

$$\text{percentage of fray} = \frac{D - d}{d} 100$$

where

D is the average diameter of flared end of impacted specimen;

d is the average outside diameter of sleeving.

20.5 Result

Report all values for fraying resistance. The result is the central value of the three measurements unless otherwise specified in the specification sheets of IEC 60684-3.

21 Breakdown voltage

21.1 Principle

21.1.1 General

Two test methods are described for the determination of breakdown voltage:

a) straight mandrel test, 100 mm foil electrode;

b) test on cut-out specimens for large-size sleeving.

Each method may be performed at ambient temperature or elevated temperature. In addition, tests may also be performed after exposure to damp heat.

The specific method shall be as specified in the applicable sheet of IEC 60684-3.

21.1.2 Number and form of test specimens

Three specimens shall be tested. The form of the sleeving is full-section sleeving for the straight mandrel test and cut-out specimens for the large-size sleeving.

21.1.3 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.

21.1.4 Application of voltage

The voltage used shall be in accordance with IEC 60243-1 and be applied at the rate of increase specified in IEC 60684-3.

21.1.5 Test method modification

The breakdown voltage tests are normally conducted in air, but if flashover becomes a problem, longer specimens or, for tests in 21.3 and 21.4, immersion in a suitable insulating liquid may be used.

21.1.6 Result

The reporting requirement and result for all methods is described in 21.6.

21.2 Straight mandrel test, 100 mm foil electrode

21.2.1 Test specimen

The specimen shall be a length of sleeving not less than 200 mm long fitted over a smooth, straight, round conductor. For heat-shrinkable sleeving, the specimen shall be shrunk onto a metal mandrel having a diameter equal to the specified maximum recovered bore of the sleeving.

21.2.2 Electrodes

The internal electrode shall be the metal mandrel which fits snugly in the sleeving. The outer electrode shall be a strip of metal foil 100 mm wide and not more than 0,025 mm thick applied snugly round the sleeving. The mandrel shall extend beyond the specimen at each end and the distance between the foil electrode and the end of the specimen shall be sufficient to prevent flashover (see 21.1.5).

21.2.3 Procedure

The voltage shall be applied between the two electrodes as described in 21.1.4.

21.3 Test on cut-out specimens for large-size sleeving

21.3.1 Test specimen

The specimen shall be a strip of sleeving of sufficient size to prevent flashover.

21.3.2 Electrodes

The electrodes shall be two metal cylinders, each 25 mm in diameter and 25 mm long mounted vertically one above the other, so that the specimen is held between the faces of the squared ends of the cylinders. The upper and lower electrodes shall be coaxial. The sharp edges of the squared ends shall be removed to give a radius of approximately 3 mm.

21.3.3 Procedure

The voltage shall be applied between the two electrodes as described in 21.1.4.

21.4 Tests at elevated temperature

The appropriate number of prepared specimens shall be tested. The specimens, shot (method of 21.2) and electrodes shall be placed in an oven and maintained at the temperature specified in IEC 60684-3 for (60 ± 5) min. The voltage shall be applied as in 21.1.4 while the specimen is at the specified temperature.

21.5 Tests after damp heat

Pre-heat the specimens to between 40 °C and 45 °C and then expose for four days to the damp-warm conditions specified in IEC 60212, i.e. 96 h at 40 °C and 93 % relative humidity.

Remove the sleeving from the conditioning chamber, and allow to cool to room temperature in an atmosphere of 75 % relative humidity, then prepare and test the specimens to the appropriate method within 1 h to 2 h of removal.

21.6 Result

Report all measured values for breakdown voltage and the condition of temperature and relative humidity when applicable. The result is the central value unless specified otherwise in the specification sheets of IEC 60684-3.

NOTE Where the sheet of IEC 60684-3 only gives requirements for 25 mm and 250 mm outer electrode widths, the requirement for 100 mm should be calculated using the equation given below:

$$V_1 = \frac{2V_2 + V_3}{3}$$

where

V_1 is the breakdown voltage requirement using 100 mm electrodes;

V_2 is the breakdown voltage requirement using 250 mm electrodes;

V_3 is the breakdown voltage requirement using 25 mm electrodes.

22 Insulation resistance

22.1 Conditioning

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

22.2 Form of test specimen

A piece of solid copper conductor or tube which is a sliding fit shall be inserted in a sample of the sleeving. The specimen, when fitted, shall be at least 230 mm long. Materials other than textile based may require a suitable conductive lubricant to assist insertion. For heat-shrinkable sleeving, the specimen shall be shrunk on to a metal mandrel having a diameter equal to the specified maximum shrunk internal diameter of the sleeving.

Three pieces of metal foil, each (25 ± 1) mm wide, shall be wrapped around the specimen, one in the middle and one near each end so that two lengths of sleeving, each (50 ± 1) mm long, are left uncovered, as shown in Figure 8. The two wrappings of metal foil, near to the ends of the specimen, shall be connected to the inserted wire or tube and earthed during the test. Connecting leads shall be attached as shown in Figure 8.

NOTE A high-conductivity metal paint is a permitted alternative to metal foil, provided the sleeving is not affected by the solvent in the paint.

22.3 Measurement of insulation resistance

A voltage of (500 ± 15) V d.c. shall be applied to each specimen between the central and outer metal foils. The insulation resistance shall be measured not less than 1 min or more than 3 min after the application of the voltage.

22.4 Test conditions

22.4.1 Number of test specimens

For each of the conditions given below, three specimens shall be tested.

22.4.2 Tests at room temperature

Specimens shall be prepared as in 22.2 and the insulation resistance measured in accordance with 22.3 at 23 °C ± 2 K and (50 ± 5) % relative humidity.

22.4.3 Tests at elevated temperature

Specimens shall be prepared as in 22.2. They shall then be placed in an oven and maintained at the temperature specified in IEC 60684-3 for (60 ± 5) min. The insulation resistance shall be measured in accordance with 22.3, while the specimen is still maintained at the specified temperature.

22.4.4 Tests after subjection to damp heat conditions

Prepare the specimens as in 22.2 and then expose them for four days to the damp-warm conditions specified in IEC 60212 (i.e. 96 h at 40 °C and 93 % relative humidity). Perform the test under these conditions.

NOTE Moisture condensation on any specimen invalidates the test result for that specimen.

22.5 Result

Report all measured values for insulation resistance and the test temperature. The result is the geometric mean unless specified otherwise in the specification sheets of IEC 60684-3.

23 Volume resistivity

23.1 General

Not applicable to textile-based sleeving.

23.2 Conditioning

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

23.3 Form of test specimen

A specimen of sleeving 250 mm long shall be threaded over a solid copper conductor, or tube (the inner electrode) the diameter of which shall be smaller than the bore of the sleeving by the amount specified in IEC 60684-3. Some materials may require the use of a liquid to ease insertion and ensure good electrical contact between the sleeving and mandrel. The liquid used shall be specified in IEC 60684-3. For heat-shrinkable sleeving the specimen shall be shrunk on to a metal mandrel having a diameter equal to the specified maximum shrunk internal diameter of the sleeving.

The outer electrode shall be 200 mm long and of high conductivity metal paint applied to the outside of the sleeving. Guard rings shall be added at each end of the specimen according to the principles of IEC 60093.

23.4 Measurement of volume resistivity

The resistance shall be measured in accordance with IEC 60093 using (500 ± 15) V d.c. and an electrification time of 1 min.

The volume resistivity ρ shall be calculated according to the following formula:

$$\rho = 2\pi LR / \ln \frac{d+2s}{d} = 0{,}8687\ \pi LR / \log_{10} \frac{d+2s}{d}\ (\Omega \cdot \mathrm{m})$$

where

L is the length of the electrode (m);

R is the measured resistance (Ω);

d is the inner diameter of the sleeving (mm);

s is the wall thickness of the sleeving (mm);

ln is the natural logarithm;

$\log_{10}$ is the common (Briggsian) logarithm.

For L = 0,2 m, the formula becomes

$$\rho = 1{,}257R / \ln ((d + 2s)/d) = 0{,}546R / \log_{10} ((d + 2s)/d)\ (\Omega \cdot \mathrm{m})$$

23.5 Test conditions

23.5.1 Number of test specimens

For each of the conditions given below, three specimens shall be tested.

23.5.2 Tests at room temperature

Specimens shall be prepared as in 23.2 and the volume resistivity measured in accordance with 23.3 at 23 °C ± 2 K and (50 ± 5) % relative humidity.

23.5.3 Tests at elevated temperature

Specimens shall be prepared as in 23.2. They shall then be placed in an oven and maintained at the temperature specified in IEC 60684-3 for (50 ± 5) min. The volume resistivity shall be measured in accordance with 23.3 while the specimen is still maintained at the specified temperature.

23.5.4 Tests after subjection to damp heat conditions

Prepare the specimens as in 23.2 and then expose them for four days to the damp-warm conditions specified in IEC 60212 (i.e. 96 h at 40 °C and 93 % relative humidity). Perform the test under these conditions.

NOTE Moisture condensation on any specimen invalidates the test result for that specimen.

23.6 Result

Report all values for volume resistivity and the conditions for temperature and humidity when applicable. The result is the geometric mean unless specified otherwise in the specification sheets of IEC 60684-3.

24 Permittivity and dissipation factor

24.1 Number of test specimens

One specimen shall be tested.

24.2 Form of test specimen

The specimen shall be a length of sleeving sufficient to accommodate the electrodes specified below. Heat-shrinkable sleeving shall be shrunk onto the mandrel forming the inner electrode according to the directions of the supplier. Before this is done, the diameter of the mandrel d_1 shall be determined to the nearest 0,01 mm as the mean of 10 measurements made at points uniformly distributed along the length and around the circumference of the mandrel.

24.3 Electrodes

The inner electrode shall be a metal mandrel which provides good contact with the bore and for heat-shrinkable sleeving has a diameter equal to the maximum recovered diameter of the sleeving. The outer electrode and guard rings shall be bands of metal foil or suitable conducting paints. When metal foil is used, it shall be applied to the specimen using the smallest possible quantity of any low-loss grease or liquid. The guard rings shall be 25 mm wide and shall be applied to the sleeving at both ends of the outer electrode with a clearance of approximately 1,5 mm. The length of the outer electrode shall be such that the capacitance can be measured within the region of optimum sensitivity of the bridge. The inner electrode shall extend at least as far as the outer edges of the guard rings.

24.4 Procedure

The temperature of the test shall be 23 °C ± 2 K. The outer diameter of the specimen d_2 shall be determined after it has been applied to the mandrel and immediately before the capacitance is measured. It shall be determined to the nearest 0,01 mm as the arithmetic mean of 10 measurements made at points uniformly distributed along its length and around its circumference.

The measurement of permittivity shall be made with a suitable instrument complying with IEC 60250 and at a frequency of approximately 1 000 Hz. The low-voltage lead shall be connected to the guarded electrode.

24.5 Calculation

The relative permittivity ε_r shall be calculated according to the following formula:

$$\varepsilon_r = 18\,C \ln (d_2/d_1)/(l + w)$$
$$= 41{,}4\,C \log_{10} (d_2/d_1)/(l + w)$$

where

- C is the measured capacitance (pF);
- d_1 is the diameter of the mandrel (mm);
- d_2 is the outer diameter of the specimen (mm);
- l is the length of the guarded electrode (mm);
- w is the width of the gaps between the guarded electrode and the guard rings (mm);
- ln is the natural logarithm;
- $\log_{10}$ is the common (Briggsian) logarithm.

The dissipation factor is derived from the bridge readings in accordance with IEC 60250.

24.6 Result

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

25 Resistance to tracking

The test shall be carried out in accordance with method 2 (criterion A) of IEC 60587, using specimens as agreed upon between purchaser and supplier.

26 Flame propagation tests

26.1 Principle

Three methods are described. The tests are of different severities and IEC 60684-3 indicates which tests should be applied to a particular type or grade of sleeving.

26.2 Methods A and B

26.2.1 General

These tests shall be carried out in accordance with IEC 60695-11-21 except that the source of heat shall be in accordance with Subclause 26.3.

Test specimens

Three specimens shall be tested.

26.2.2 Method A, applicable to sleeving up to and including 10 mm bore only

NOTE For heat-shrinkable sleeving, this dimension is the specified recovered bore.

Non-heat shrinkable sleeving: a length of approximately 450 mm shall be centred on a 530 mm straight length of a steel rod which is a sliding fit in the sleeving.

Heat-shrinkable sleeving: the specimen shall be as above, but the sleeving shall be recovered on to a steel rod which shall have the same diameter as the specified recovered diameter of the sleeving.

26.2.3 Method B

A length of approximately 660 mm (recovered in the case of heat-shrinkable sleeving) shall be drawn on to a fine steel piano wire 900 mm in length. The sleeving shall be closed at the top end to prevent a chimney effect. The wire diameter to be used is given below:

Specimen diameter	Piano wire diameter (max.)
Less than 0,44 mm	0,25 mm
0,44 mm to 0,81 mm	0,41 mm
Greater than 0,81 mm	0,74 mm

26.3 Source of heat

26.3.1 Gas burner

The burner shall have a nominal bore of (9,5 ± 1) mm. For natural gas, a conventional Bunsen burner may be used, the burner being regulated to give a flame approximately 125 mm long with an inner blue cone approximately 40 mm long.

If propane is used, the burner in Figure 9 shall be used.

It may be convenient to use burners with a small pilot flame.

26.3.2 Check of burner operation

The satisfactory operation of the burner shall be checked as follows: with the base of the burner being horizontal, a bare copper wire, (0,71 ± 0,025) mm in diameter, having a free length of not less than 100 mm shall be inserted horizontally in the flame about 10 mm above the top of the blue cone, so that the free end of the wire is vertically above the edge of the burner on the side remote from the supported end of the wire. The time required for the wire to melt shall be not more than 6 s and not less than 4 s.

26.4 Specimen arrangements

The arrangements of specimen and burner are shown in Figure 10 for method A and in Figure 11 for method B.

The test shall be conducted in a three sided metal enclosure within the chamber. The metal enclosure shall be nominally 305 mm wide, 355 mm deep and 610 mm high, and the top and front shall be open.

The specimen shall be secured with its longitudinal axis vertical in the centre of the enclosure. For method B, this shall be achieved by securing the specimen to the middle of the upper support by kinking the sleeving and clamping (using a paper clip or clamp) to provide a closed end to the specimen thus preventing any chimney effects during the test. The lower end of the wire protruding from the open end of the sleeving shall be anchored, for example to a support rod as shown in Figure 11.

26.5 Method C

Test specimens

Five specimens shall be tested.

A length of approximately 560 mm sleeving (recovered in the case of heat-shrinkable sleeving) shall be drawn on to a fine steel piano wire at least 800 mm in length and having a diameter as specified for method B in 26.2.3.

26.6 Source of heat

In accordance with Subclause 26.3.

26.7 Cabinet and arrangements within it

The test shall be conducted in an exhaust hood or cabinet with the specimen surrounded by a three-sided metal enclosure to protect it from draught. The arrangements of specimen and burner are shown in Figure 12.

The specimen shall be secured with its longitudinal axis vertical in the center of the enclosure. Two fixed horizontal rods shall be provided in the enclosure positioned so that a wire stretched over them will be at a 70° angle with the horizontal. The lower rod shall be approximately 50 mm from the rear of the enclosure. The upper end of the specimen shall be clamped over the upper rod to provide a closed end to the specimen thus preventing any chimney effects during the test. The lower end of the wire protruding from the open end of the sleeving shall be anchored to the lower support rod with sufficient tension to maintain a straight alignment of the wire during the test.

A $(25 \pm 2)°$ wedge shall be used for tilting the burner barrel and the burner shall be aligned with the specimen in the same way as in methods A and B.

With method C, the indicator flag shall be used but not the cotton.

26.8 Procedure

Apply the flame to the specimen for 15 s and then extinguish it by turning off the gas supply from outside the cabinet.

Determine the duration of burning of the specimen from the time of extinction of the gas flame. Consider only flaming and not glowing as actual burning time. Determine the length of specimen burned either by direct measurement or by subtracting the length of the unburned portion from 250 mm.

26.9 Result (method C)

26.9.1 The following shall be reported for method C:

a) all measured values for the time of burning in seconds;
b) all measured values for length of specimen burned in millimetres.

26.9.2 The following are the results for method C:

a) the maximum time, in seconds, that any specimen continues to burn after removal of the gas flame, unless specified otherwise in the specification sheets of IEC 60684-3;

b) the maximum burned length, in millimetres, of any specimen, unless specified otherwise in the specification sheets of IEC 60684-3.

27 Oxygen index

27.1 Oxygen index at ambient temperature

The test shall be carried out in accordance with ISO 4589-2 upon specimens which conform to configuration IV. This will require that a (3 ± 0,25) mm thick molded sheet be prepared from the material from which the sleeving is fabricated. If the sleeving is crosslinked, the sheet shall be crosslinked to the same degree as the sleeving.

The specific ignition procedure shall be specified in the specification sheets of IEC 60684-3.

27.2 Oxygen index at elevated temperature

The test shall be carried out in accordance with ISO 4589-3 upon specimens described in 27.1.

The specific ignition procedure shall be specified in the specifications sheets of IEC 60684-3.

28 Transparency

28.1 Number of test specimens

One specimen shall be tested.

28.2 Form of test specimen

The bore and wall thickness of the sleeving to be tested shall be specified in IEC 60684-3. The sleeving shall be approximately 100 mm long, split longitudinally and opened flat.

28.3 Procedure

Place the split sleeving over printed text of 8-point Helvetica medium type, similar to that printed below:

A c k l d e w g y m 0

Observe if it is possible to read these characters through the specimen of sleeving using normal reading vision.

28.4 Result

Report the observation as the result.

29 Ionic impurities test

29.1 General

Conductivity values shall be determined on water extracts obtained and measured in accordance with IEC 60589.

29.2 Result

The result is the central value unless specified otherwise in the specification sheets of IEC 60684-3.

30 Silver staining test

30.1 Principle

In this test, specimens of sleevings are placed in contact with silver foil and both are exposed to an elevated temperature. The darkness of any stain on the silver foil is then compared with that of a strip of film of the standard shade which is part of the stain tester.

30.2 Number and form of test specimens

Three specimens shall be cut so as to expose a fresh annular surface. The length shall be not less than the wall thickness but short enough for the sleeving to be stable when standing vertically.

30.3 Stain tester

The stain tester consists of a rectangular piece of photographic film, with a strip exposed so that it darkens to a defined density known as the standard shade. This strip is approximately 3 mm wide and equidistant from each side.

The stain tester shall fulfill the following requirements when measured in accordance with ISO 5-1 to ISO 5-4:

– the clear photographic film background shall have a visual density not greater than 0,050;
– the difference in density between the standard shade and the clear photographic film background shall be 0,015 ± 0,005.

30.4 Procedure

Each test specimen shall be placed with the freshly cut surface downward on a larger piece of analytical silver foil which has been thoroughly cleaned and polished with jeweller's rouge and water and rubbed dry with a clean cloth.

The foil shall be placed with the specimens resting on it, in a suitable oven and maintained at 70 °C ± 2 K for (30 ± 2) min unless otherwise specified in the specification sheets of IEC 60684-3.

Each test specimen shall then be removed from the foil and the silver visually examined for staining. If any stain is observed, it shall be viewed through the clear part of the stain tester adjacent to the standard shade. Observe whether or not the specimen stain is darker than the standard shade.

30.5 Result

Report all observations as the result.

31 Electrolytic corrosion resistance

31.1 General

Tests shall be made in accordance with one or more of the three methods given in IEC 60426. The method to be used will be specified in IEC 60684-3.

31.2 Number of test specimens

The number of test specimens for each of the methods shall be as follows:

a) visual method: three specimens;

b) wire tensile strength method: five specimens;

c) insulation resistance method: five specimens.

32 Corrosion resistance (tensile and elongation)

32.1 Principle

This test determines the interaction between copper and sleeving.

32.2 Number and form of test specimens

Five specimens, each at least 150 mm long, shall be slit lengthwise and then placed over straight clean bare copper mandrels. The sleeving shall be secured at the ends using copper wire. The mandrel shall normally be a copper tube for specimens of bore greater than 6 mm, but for specimens of bore equal to 6 mm or less, the mandrel may be a solid copper rod. The mandrel diameter shall be 10 % to 20 % greater than the bore of the sleeving specimen.

32.3 Procedure

Each specimen, while still on the mandrel, shall first be conditioned for 24 h in an atmosphere of 23 °C ± 5 K and not less than 90 % relative humidity. It shall then be transferred to an oven and heated at 160 °C ± 3 K for (168 ± 2) h, unless otherwise specified in IEC 60684-3. After removal from the oven, it shall be allowed to cool.

Each specimen shall then be removed from the mandrel and both the mandrel and specimen examined for signs of chemical interaction, such as pitting or corrosion of the mandrel. Adhesion of the sleeving to the mandrel or darkening of the copper due to normal air oxidation shall be ignored.

Each specimen shall then be tested for tensile strength and/or elongation at break in accordance with Clause 19.

32.4 Result

Report all observations of chemical interaction as the result.

Report all measured values for tensile strength and/or elongation. The results for these characteristics shall be the central values unless specified otherwise in the specification sheets of IEC 60684-3.

33 Copper corrosion (presence of corrosive volatiles)

33.1 Principle

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

33.2 Apparatus

– Test tubes: 13 mm × 300 mm.

– Copper-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.

33.3 Number and form of test specimens

One test shall be carried out using two specimens of sleeving, each inserted into a separate test tube with a third test tube being used as a control.

For sleeving of bore less than 3 mm, each specimen shall be a cut length of sleeving having a total outer surface area of approximately 150 mm^2.

For sleeving of bore 3 mm or greater, each specimen shall be a strip approximately 6 mm × 25 mm cut longitudinally.

33.4 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 34.2, 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 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 60684-3.

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. 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 discoloration 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.

33.5 Result

Report the percentage corrosion on each mirror. The result is the average observed percentage corrosion.

34 Colour fastness to light

34.1 Principle

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

34.2 Test specimen

A suitable length of sleeving.

34.3 Procedure

A half-covered sleeving 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 60684-3.

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.

34.4 Result

Report all observations as the result.

35 Resistance to ozone

35.1 General

Perform the test in accordance with ISO 1431-1, but with the following changes.

35.2 Number and form of test specimens

Three specimens, each approximately 25 mm in length, shall be tested.

35.3 Procedure

The specimen shall be fitted onto a smooth, ozone-inert mandrel having a low coefficient of friction, for example PTFE, to normalize the stress. Choose a mandrel diameter that will increase the sleeving diameter by the amount specified in IEC 60684-3. The mounted sleeving shall be exposed for the time, temperature and ozone concentration specified in IEC 60684-3.

After removal from the ozone-rich atmosphere, the sleeving shall be examined for cracks using normal reading vision unless otherwise specified in IEC 60684-3.

35.4 Result

Report all observations as the result.

36 Resistance to selected fluids

36.1 Principle

It is necessary to define the following:

a) choice of fluid;
b) temperature of immersion;
c) duration of immersion;
d) method of assessment.

36.2 Choice of fluid

When not specified in IEC 60684-3, 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.

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

36.3 Methods of assessment

a) Breakdown voltage, Clause 21.
b) Tensile strength and/or elongation at break, Clause 19.
c) Visual examination.
d) Change in mass.
e) Any other method as specified in IEC 60684-3.

36.4 Number and form of test specimens

The number of test specimens is dependent on the method of assessment. Specimens shall be selected in accordance with the requirements of Clause 19 or Clause 21 or, if visual or change in mass assessment is used, then three specimens each approximately 25 mm long shall be used.

Alternatively, specimens in accordance with Clause 19 may be used for visual and change in mass assessment.

36.5 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 60684-3.

The specimens shall then be removed from the fluid, allowed to drain for 45 min to 75 min unless otherwise specified in IEC 60684-3 and then lightly wiped. They shall then be tested by one or more of the methods given in 36.3 at ambient temperature. When the change in mass test is required, they shall be re-weighed and the change in mass calculated as a percentage of the pre-immersion mass.

NOTE Where tensile strength is used for the assessment, the cross-sectional area should be determined before immersion. If change in mass is used, the specimens should be weighed to the nearest 0,0002 g before immersion.

36.6 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 a 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.

37 Thermal endurance

The principle is as follows: this test is to be made generally in accordance with the IEC 60216 series. As thermal endurance is a material-dependent phenomenon, individual test procedures and end points to be used are given in the appropriate sheets of IEC 60684-3.

38 Mass per unit length

38.1 Number of test specimens

Three specimens shall be tested.

38.2 Procedure

Masses shall be measured on sleeving in the as supplied state.

Unless otherwise specified, the test shall be carried out on squarely cut (with the cut face lying perpendicular to the longitudinal direction) specimens of sleeving approximately 100 mm in length. After cutting, the length (L) shall be measured to an accuracy of ± 1 mm. The length when measured from different positions around the circumference shall not vary by more than ± 1 mm from the value used for calculation purposes.

Any method for the determination of the mass may be used which can ensure an accuracy of 1 % or 0,01 g for the 100 mm length of sleeving (whichever is the lower value).

38.3 Result

The mass M for 1 m is calculated as follows:

$$M = \frac{m_1 \times 1000}{L} \text{ (g/m)}$$

where

m_1 is the mass of the specimen (g);

L is the measured length of the specimen (mm).

Report all values for mass per unit length. The result is the mean value unless specified otherwise in the specification sheets of IEC 60684-3.

39 Heat ageing

39.1 Number and form of test specimens

Prepare five specimens in accordance with Clause 19.

39.2 Procedure

Expose these specimens by suspending from one end in an oven conforming to IEC 60216-4-1 or IEC 60216-4-2 for a period of (168 ± 2) h, unless otherwise specified, and at the temperature specified in IEC 60684-3. Remove the specimens from the oven and allow them to cool **and then condition for between 16 h and 96 h at 23 °C ± 2 K**. Perform the test for tensile strength and/or elongation at break in accordance with Clause 19 and as specified in IEC 60684-3. Also, when specified in IEC 60684-3, lengths of full section sleeving, after removal from the oven and allowed to cool, shall be bent back on themselves 180 degrees and immediately released. After a minimum of 1 min the specimen shall be examined without the aid of magnification.

39.3 Report (Bend test)

Report circular form is similar to that before bending (an oval shape is acceptable) and any cracks. Internal cracks can be detected by circumferential depressions on the outer surface of the specimen. External kink lines shall not be considered a failure.

NOTE Do not age sleevings of different types in the same oven as this may influence the result.

40 Water absorption

40.1 General

Perform this test in accordance with method 1 of ISO 62, unless specified otherwise in the specification sheets of IEC 60684-3.

40.2 Result

Report all measured values; the result is the mean unless specified otherwise in the specification sheets of IEC 60684-3.

41 Restricted shrinkage (applicable to heat-shrinkable sleeving only)

41.1 Number of test specimens

Three specimens shall be tested.

41.2 Form of test specimen

Cut three lengths of sleeving, each approximately 150 mm long, from the sample of sleeving in the expanded state.

41.3 Apparatus

Provide a series of metallic mandrels having the form and dimensions shown in Figure 13. Care shall be taken that all sharp edges are deburred.

41.4 Procedure

Select a mandrel having a *D* diameter equal to the specified expanded diameter and a *d* diameter equal to the specified recovered diameter of the sleeving being tested. With the test mandrel at room temperature, position the specimen on the mandrel and place it in an oven preheated to the temperature specified in IEC 60684-3 for the sleeving being tested. Allow the specimen to shrink fully and then allow the assembly to remain in the oven at this temperature for an additional (30 ± 3) min.

At the end of the heating period, remove the mandrel and specimen from the oven and allow to cool to room temperature.

Examine each specimen for evidence of cracking or splitting.

Wrap a strip of electrically conductive foil approximately 13 mm wide and not more than 0,025 mm thick centrally over the section of diameter *D* (see Figure 13). Apply a second layer of foil tightly against the first to ensure electrical contact, leaving a short length free for an electrical connection. Remove a portion of the sleeving from one end of the mandrel to expose a short length for the purpose of making a second electrical connection, making sure that sufficient sleeving remains between the points of connection and the foil electrode to avoid flashover during the voltage proof test.

NOTE As an alternative to foil, a conductive paint may be used.

Apply a proof voltage between the electrodes at a rate of 500 V/s to the level specified in IEC 60684-3 and hold for a period of 1 min. Record the voltage used and any breakdown that may occur.

41.5 Result

Report any evidence of cracking or splitting, or lack thereof, and the outcome of the voltage proof test for each of the three specimens as the results.

42 Colour stability to heat

42.1 Number of test specimens

Three specimens shall be tested.

42.2 Form of test specimens

Cut three lengths of sleeving, each approximately 100 mm long, from the sample of sleeving.

42.3 Procedure

Suspend the specimens in an oven for the time and at the temperature specified in IEC 60684-3. 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 60684-3.

42.4 Result

Report the time and temperature used. The outcome of the visual examination for each specimen is the result.

43 Smoke index

43.1 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 13943 apply.

43.2 Principle

Strips cut from a sample sleeve 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.

43.3 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 14 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.

43.4 Number and form of test specimen

Split and open out a length of sleeving from which to prepare strips of material approximately 75 mm long. The thickness and minimum width of the strips shall be specified in the relevant sheets of IEC 60684-3. The number of strips shall be sufficient to completely cover the face area of the test piece holder.

43.5 Conditioning

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

43.6 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 strips.

Place the test piece holder face down onto a flat surface and insert the wire mesh. Position each strip in the holder without overlapping in a parallel arrangement, ensuring that spaces are not left between the strips, so that when the holder is in the test position the strips are vertical.

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

NOTE See Figure 15 which gives the front view of the smoke index test piece holder showing the vertically mounted strips.

43.7 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.

43.8 Procedure

43.8.1 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.

43.8.2 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 43.3 b). Note the settings of the rotameters. Turn off the gases.

43.8.3 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.

43.8.4 Stabilize the output of the furnace 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.

43.8.5 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.

43.8.6 Turn on the gas supply (300^{+10}_{0}) s after the start of the test and immediately adjust its flow rate to that previously noted in 43.8.2.

43.8.7 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 delamination, 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.

43.8.8 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.

43.8.9 Throughout the test period, adjust the ranging of the photodetector amplifier system to maintain the level of the readings recorded for the percentage light transmission at least 10 % of the full-scale value.

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

43.8.11 Repeat the test on two further test pieces prepared from the sample sleeve.

NOTE Providing no adjustments to the test apparatus have been made that would affect the calibration or the flame condition, the same settings may be used for the testing of the replicate test pieces.

43.9 Calculation of results

43.9.1 General

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 43.9.2.

43.9.2 Correction of transmittance values

43.9.2.1 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.

43.9.2.2 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

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.

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

43.9.2.4 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. $T_{min.c}$.

43.9.2.5 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 43.9.2.3 and correct this value using the correction factor calculated 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 43.9.2.2.

43.9.2.6 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.

43.9.2.7 Convert the corrected values for specific optical density obtained using 43.9.2.6 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.

43.9.3 Calculation of the smoke index

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

$$\text{smoke index} = \frac{D_{\text{sT min.(c)}}}{t_{\text{min.}}}$$

where

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

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

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

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

where

$D_{\text{sT(70)}}$ is the specific optical density corresponding to 70 % light transmittance (20,0);

$D_{\text{sT(40)}}$ is the specific optical density corresponding to 40 % light transmittance (51,9);

$D_{\text{sT(10)}}$ 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;

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

X is 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 %.

43.10 Results

43.10.1 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 60684-3.

43.10.2 Report also a description of the burning behaviour (see 43.8.7) as a result.

43.10.3 Report the wall thickness of the sleeving and width of the strips used to prepare each test piece.

43.10.4 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.

44 Toxicity index

44.1 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 considered concentration expressed as a factor of the concentration fatal to man at a 30 min exposure time (see 44.9). An index of 1 for a given volume will, on average, produce fatality in 30 min.

44.2 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 of each gas to produce fatality in 30 min as a base, to derive the combined toxicity index.

44.3 Apparatus

44.3.1 General

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.

44.3.2 Test chamber

The test chamber shall consist of an airtight enclosure of at least 0,7 m^3 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 of the chamber.

44.3.3 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.

44.3.4 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.

44.3.5 Timing device

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

44.3.6 Gas sampling and analytical equipment

44.3.6.1 Gas sampling

In order to minimize 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 airtightness of the chamber.

44.3.6.2 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 44.9.

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

44.4 Test pieces

44.4.1 General

From the sleeving, 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.

NOTE For heat-shrinkable materials, the test pieces should be cut from fully recovered sleeving.

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

44.4.2 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.

44.5 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.

44.6 Test procedure

44.6.1 Determination of background correction factor

44.6.1.1 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 44.3.3. 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.

44.6.1.2 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 of these gases. Where the method of analysis is to be carried out using colourimetric tubes, these shall be placed in position within the chamber.

44.6.1.3 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.

44.6.1.4 Forcibly extract all fumes from the chamber with it open to free air for a period of 3 min. Repeat the procedure from 44.6.1.2 to 44.6.1.3 but maintain the burning conditions for 2 min ± 1 s and 3 min ± 1 s in separate determinations.

44.6.1.5 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.

44.6.2 Determination of evolved gases

44.6.2.1 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.

44.6.2.2 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.

44.6.2.3 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.

44.6.2.4 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.

44.6.2.5 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 commence 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.

44.6.2.6 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.

44.6.2.7 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.

44.7 Calculation of toxicity index

44.7.1 Calculate the concentration of each of the gases produced C_0 when 100 g of material is fully burnt and the products 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.

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

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

where

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

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

44.8 Toxic constituents

The analysis of the products 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.			

44.9 Values for C_f

For the purpose of this test the following values for C_f (the concentrations of each gas considered fatal to a man in a 30 min exposure period, given in parts per million) shall be used to calculate the toxicity indices:

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

44.10 Result and report

The result is the central 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 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 specifications.

45 Halogen content

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

45.1.1 Principle

45.1.1.1 General

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.

45.1.1.2 Apparatus

a) Oxygen flask.

b) Pipettes.

c) Volumetric flasks.

d) Ultraviolet/visible spectrophotometer.

45.1.1.3 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).

45.1.2 Procedure

A 30 mg sample of the material is burned in a 1 l 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, 7,10 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.

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

45.2 Determination of low levels of fluorine

45.2.1 Principle

45.2.1.1 General

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][1]

45.2.1.2 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.

45.2.1.3 Reagents

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

b) 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.

c) Standard fluoride solution prepared from sodium fluoride.

d) Dodecanol.

e) 0,5 M sodium hydroxide solution.

45.2.2 Procedure

45.2.2.1 General

Place an accurately weighed sample of material (25 mg-30 mg) in a 1 l 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 absorbant. 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.

45.2.2.2 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.

45.2.2.3 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.

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1 Figures in square brackets refer to the Bibliography.

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.

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

45.3 In order to determine total halogen content of the material under test, the methods described in both 46.1 and 46.2 shall be used.

46 Acid gas generation

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

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

47 Hot elongation and hot set

47.1 Number and form of test specimens

Two specimens shall be tested. The specimen form marked with reference lines is specified in the applicable sheet of IEC 60684-3 and is described in 19.1 for full section sleeving and 19.2 for dumb-bell specimens.

47.2 Test apparatus

The apparatus shall consist of an oven, a set of specimen clamps and weights. The upper clamp shall be mounted in an oven such that the test specimen is suspended vertically. The lower detachable specimen clamp shall be provided with an arrangement for attaching weights.

NOTE An airtight seal should be avoided for full-section sleeving by inserting a short metal pin, smaller than the bore of the specimen, into the specimen at one end before clamping.

47.3 Procedure

The test temperature, weight and specimen form shall be as specified in the applicable sheet of IEC 60684-3.

NOTE The specified weight is the total of the weight of the lower clamp plus any attached weights.

Heat the clamps and weights to the specified temperature. Then insert the specimen into the upper and lower clamps such that the reference lines are exposed. Attach the weights carefully to the lower clamp and allow the oven to stabilise. Maintain the oven at the specified temperature for 15 min ± 30 s.

After this time, measure the distance between the reference lines by any of the means specified in 19.2.5. If the door must be opened, perform the measurement within 30 s.

Calculate the percentage elongation as specified in 19.2.6 or 19.2. This is the hot elongation.

Cut the weight from the test specimen at the lower clamp. Allow the specimen to recover at the specified temperature for 5 min ± 30 s. Then remove the specimen from the oven and allow the specimen to cool to standard ambient temperature. Remeasure the distance between the reference lines and calculate the percentage elongation as specified in 19.2.6 or 19.2. This is the hot set.

47.4 Results

Report all values. The result is the average of hot elongation and the average of the hot set.

48 Tension set (applicable to elastomeric sleeving only)

48.1 Number and form of test specimens

Two specimens shall be used.

For sleeving of nominal bore 8 mm or less, lengths of sleeving 120 mm or greater shall be used. Above 8 mm nominal bore, dumb-bells conforming to type 2 of ISO 37 (see Figure 5) shall be cut longitudinally from the sleeving. Mark each specimen with two lines 20 mm apart, perpendicular to the longitudinal axis of the specimen, and approximately equidistant from each end.

48.2 Conditioning

Unless otherwise specified in IEC 60684-3, the test specimens shall be kept at 23 °C ± 2 K for at least 1 h immediately before testing.

48.3 Procedure

Unless otherwise specified in IEC 60684-3 each specimen shall be stretched at 23 °C ± 2 K until the lines are (80 ± 2) mm apart, taking approximately 10 s to complete the stretching, and held in the stretched position for 10 min ± 30 s. They shall then be gently released and allowed to recover freely on a smooth flat surface for 10 min ± 30 s. For each specimen, measure the distance between the lines after recovery and calculate the percentage difference from the initial lengths.

48.4 Result

Report all values; the result is the mean unless specified otherwise in the specification sheets of IEC 60684-3.

49 Tear propagation (applicable to elastomeric sleeving only)

49.1 Number and form of test specimens

Two specimen sleeves 15 mm to 20 mm long shall be tested.

49.2 Without tear initiation

Each sleeve shall be fitted over a suitable nonferrous mandrel. The degree of expansion shall be specified in IEC 60684-3. The sleeves on the mandrel shall then be suspended in an oven for the time and at the temperature specified in IEC 60684-3. After the specified period, they shall be examined for splitting.

49.3 With tear initiation

Sufficient specimen sleeves to carry out the test shall be aged in an oven at the temperature and for the time specified in IEC 60684-3. Upon removal from the oven, the sleeves shall be allowed to stabilise at room temperature for 2 h ± 10 min.

Each sleeve shall be fitted over a suitable nonferrous mandrel. Unless specified otherwise in IEC 60684-3, the mandrel diameter shall be three times that of the nominal bore of the sleeves. To ease fitting, a minimum amount of a suitable non-deleterious lubricant having a low coefficient of friction, for example PTFE, may be applied to the mandrel. Each specimen shall be fitted onto the mandrel on the first attempt. If unsuccessful, the sleeve shall be discarded and another specimen used until two have been fitted. After fitting, a cut 1 mm ± 0,5 mm long shall be made in one end of each sleeve through the complete wall thickness, parallel to the axis of the mandrel. Unless specified otherwise in IEC 60684-3, examine the sleeves 1 h after making the cut.

49.4 Results

Report any splitting of the mandrel as the result.

50 Long term heat ageing (3 000 h)

50.1 Number and form of test specimens

The number and form of specimens depend on the method of test. Specimens shall generally be selected in accordance with the requirements of Subclause 19.2 or Clause 21 and shall be as specified in the appropriate sheet of IEC 60684-3. Prepare sufficient specimens to enable six sets of measurements to be performed.

50.2 Procedure

Retain and test one set of specimens to establish the initial (unaged) value of the property or properties to be measured. 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 60684-3. See note 2 in Clause 1 (Scope) of 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 appropriate test(s) on that set of test specimens. Continue until 125 days or 3 000 h of ageing time have elapsed and perform the test(s) on the set of specimens aged for that period.

50.3 Result

Report all values. The results shall meet the requirements of IEC 60684-3.

51 Dynamic shear at ambient temperature

51.1 Principle

This test is designed to evaluate the strength of dual wall sleevings under shear conditions when bonded to an aluminium substrate.

51.2 Apparatus

Aluminium strips (100 ± 5) mm × (25 ± 1) mm × (0,9 ± 0,1) mm

Degreasing solvent: Methyl ethyl ketone

Specimen assembly fixture (see Figure 16)

Silicone release paper

320 grit abrasive

Tensile test machine

Oven (for method 52, Dynamic shear at elevated temperature)

Mass 1,4 kg ± 0,1 kg

Suitable mass to flatten specimens

51.3 Form and number of test specimens

Three test specimens shall be prepared. Three strips of aluminium shall be abraded and degreased on one side on a length of at least 20 mm from one end. Three lengths of sleeving at least 120 mm long shall be recovered in an oven for the time and temperature as specified in IEC 60684-3. Immediately after removal the sleeving shall be cut open longitudinally and laid flat on the silicone release paper, with the inside coated surface in contact with the silicone paper. A weight of sufficient mass to keep the specimens flat shall be placed on top. This assembly shall be allowed to cool to room temperature before the weight is removed. Any other suitable method for flattening the sleeving may be used.

The three specimens of the sleevings shall be finally cut longitudinally, (100 ± 5) mm × (25 ± 1) mm.

The aluminium strips and cut sleeving specimens shall be assembled as shown in Figure 1, with the coated surface of the sleeving in contact with the abraded surface of the aluminium, overlapped between 12,5 mm and 14,2 mm. The 1,4 kg mass shall be preconditioned in an oven for at least 1 h at the assembly conditioning temperature as specified in IEC 60684-3. The whole assembly, as shown in Figure 1, shall be placed in an oven for the time and temperature as specified in IEC 60684-3. The assembly shall then be removed from the oven and allowed to cool to room temperature before the weight is removed.

51.4 Procedure

Insert the specimen in the tensile test machine by clamping at least 25 mm of the aluminum strip in the top jaw and at least 25 mm of the sleeving in the bottom jaw. The rate of jaw separation shall be (50 ± 5) mm/min. Record the breaking load for each specimen.

51.5 Result

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

52 Dynamic shear at elevated temperature

The test specimens shall be prepared in accordance with 51.3.

The procedure shall be in accordance with 51.4 except that the test is performed in an oven mounted in the tensile test machine. The test specimens shall be pre-conditioned in the test oven and at the temperature of test for at least 30 min. The test temperatures shall be as specified in IEC 60684-3.

53 Dynamic shear after heat shock and heat ageing

The test specimens shall be prepared in accordance with 51.3.

The test specimens shall be sandwiched between two PTFE or PTFE coated aluminium plates as shown in Figure 17 with the bolts just sufficiently tight to ensure the specimens remain flat during the heat shock or heat ageing periods. The assembly shall be conditioned in an oven for the time and temperature specified in IEC 60684-3. The test specimen shall be removed from the oven and allowed to cool to room temperature before they are removed from the aluminum plates.

The test specimens shall then be tested in accordance with 51.4.

54 Rolling drum peel to aluminium

54.1 Principle

This test is designed to evaluate the strength of dual wall sleevings under peel conditions when bonded to an aluminium substrate.

54.2 Apparatus

Aluminium tube with outside diameter of (9,5 ± 0,25) mm, approximately 35 mm long unless otherwise specified in IEC 60684-3

Degreasing solvent: methyl ethyl ketone

Free rolling drum (see Figure 18)

Paper or adhesive masking tape

320 grit abrasive

Tensile test machine

Oven

54.3 Form and number of test specimens

Three test specimens shall be prepared. Abrade the aluminium tubes with the 320 grit abrasive and then degrease with methyl ethyl ketone. Fix a narrow strip of adhesive masking tape longitudinally on the aluminium tube. Cut lengths of sleeving (25 ± 1) mm long and position centrally over the aluminium tube and condition in an oven for the time and temperature as detailed in the IEC 60684-3, by suspending horizontally. Remove the test specimens from the oven and allow to cool to ambient temperature. Cut longitudinally along the edge of the paper or adhesive tape and lift to provide a flap of material.

54.4 Procedure (see Figure 3)

Measure the width of the sleeving to the nearest millimetre on the aluminum tube. Insert the rolling drum into the aluminum tube of the test specimen. Clamp the rolling drum support into the bottom grip of the tensile test machine and the flap of material into the upper grip. Pull the test specimen apart at a constant rate of (50 ± 5) mm/min.

Record the peel force in newtons over the entire peeling operation. Calculate the average peel force by ignoring the first and last 10% of the peel trace, take 5 readings at equal distances apart from the remainder of the peel trace, add together and then divide by 5.

Calculate the peel strength using the following formula.

$$\text{Peel strength (N/25 mm)} = \frac{\text{Average peel force (N)} \times 25}{\text{Sleeving width (mm)}}$$

54.5 Result

The result shall be the mean of the three peel strengths.

55 Aluminium rod dynamic shear

55.1 Principle

This test is designed to evaluate the adhesive bond strength of dual wall sleevings under dynamic shear conditions when bonded to an aluminium rod.

55.2 Apparatus

Aluminium rods (100 ± 5) mm long × diameters as specified in IEC 60684-3

Degreasing solvent: methyl ethyl ketone

320 grit abrasive

Hot air gun

Masking tape approximately 25 mm wide (see Figure 19)

Tensile test machine (with oven when appropriate)

Oven

55.3 Form and number of test specimens

Three test specimens shall be prepared. Three aluminium rods shall be lightly abraded with a 300 grit abrasive and degreased with the Methyl ethyl ketone. Wrap a length of the 25 mm wide masking tape completely round the aluminium rod in the position shown in Figure 19. Three lengths of sleeving at least 100 mm long shall be recovered, using the hot air gun to ensure the correct positioning of the sleeving onto the aluminium rods as shown in Figure 19. The assembly shall then be conditioned in an oven for the time and temperature specified in IEC 60684-3. Remove the assemblies from the oven and allow to cool to room temperature. Remove the section of the sleeving which overlaps the masking tape as shown in Figure 20.

55.4 Procedure

Insert the specimen vertically in the tensile test machine. If the test is to be performed at elevated temperature, pre-condition all three test specimens in the tensile test machine oven for at least 30 min.

Grip at least 25 mm of each end of the test specimen in the jaws of the tensile test machine. The rate of jaw separation shall be (50 ± 5) mm/min. Record the maximum load for each test specimen.

55.5 Result

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

56 Sealing

56.1 Principle

This test is designed to evaluate the sealing of dual wall sleeving when bonded to an aluminium substrate and subjected to internal air pressure.

56.2 Apparatus

Sealed aluminum tube with air valve, (30 ± 1) mm external diameter × 400 mm long (Figure 21)

Aluminium foil approximately 25 mm wide × (0,2 ± 0,05) mm thick × approximately 100 mm long

320 grit abrasive

Tissue paper

Degreasing solvent: methyl ethyl ketone

Compressed air line

Water bath

56.3 Form and number of test specimens

Three test specimens shall be prepared. Lightly abrade the surface of the sealed aluminium tube with the 300 grit abrasive, degrease with the tissue soaked in methyl ethyl ketone. Pre-condition the aluminium tube in an oven at 100°C for at least 30 min.

Remove the mandrel from the oven and place the aluminium foil centrally over the four holes. Cut three 175 mm lengths of sleeving with a recovered diameter of 25 mm. Recover a length of sleeving centrally over the four holes in accordance with the manufacturer's recommendations. Place the assembly in an oven for the time and temperature specified in IEC 60684-3. Remove from the oven and leave at room temperature for at least 24 h.

56.4 Procedure

The assembly shall be maintained at a constant pressure as specified in IEC 60684-3 using clean dry compressed air, immersed in the water bath and then conditioned for (24 ± 1) h at the temperature specified in IEC 60684-3. The assembly shall be checked periodically and after 24 h for any air bubbles escaping from the ends of the sleeving.

56.5 Result

Observation of air bubbles escaping from the ends of the sleeve specimens.

57 Adhesive T peel strength of two bonded heat-shrinkable substrates

57.1 Principle

This test is designed to evaluate the strength of the adhesive bond between two pieces of heat-shrinkable sleeving.

57.2 Apparatus

Metal tube with outside diameter of (25 ± 5) mm

Degreasing solvent: methyl ethyl ketone

Paper cutter, shears or other cutting equipment capable of cutting thick specimens

Adhesive masking tape

320 grit abrasive

Tensile test machine

Heat gun

Oven

57.3 Form and number of test specimens

Three test specimens shall be prepared. Heat recover a length of the heat-shrinkable sleeving on the metal tube, approximately 150 mm long. Cool the recovered sleeving to room temperature and lightly abrade the outside of the sleeving and the insides of three 40 mm lengths of a second heat-shrinkable sleeving with a 320 grit abrasive. Wipe the abraded surfaces with a clean cloth or paper towel wet with methyl ethyl ketone and allow to dry 20 min to 30 min. For tape adhesives, spiral wrap the tape (with a 50 % overlap) over the recovered sleeving. For liquid adhesives, spread the adhesive over the entire bonding area of the recovered sleeving following the manufacturer's instructions for the application of the adhesive. Place a strip of 20 mm wide paper or adhesive masking tape lengthwise over the applied adhesive to provide free ends to insert into a tensile test machine (see Figure 22).

Place the three lengths of the second heat-shrinkable sleeving, abraded on the inside, over the adhesive and adhesive masking tape, as shown in Figure 22. Recover and condition according to the manufacturer's or supplier's instructions and allow the mandrel assembly to cool to room temperature. Cut the bonded assembly off the mandrel, following one edge of the adhesive masking tape as shown in Figure 23.

Cut approximately 25 mm wide specimens from the centre of each set of bonded sleevings as shown in Figure 24.

57.4 Procedure

Measure the average width of each of the three T peel specimens. Insert the free ends of each specimen into the jaws of the tensile testing machine. Pull the specimens at a jaw separation speed of (50 ± 5) mm/min. Record the peel force over the entire peeling operation. Calculate the average peel force by ignoring the first and last 10 % of the peel trace, take 5 readings at equal distances apart from the remainder of the peel trace, add together and then divide by 5.

Calculate the T peel strength using the following formula:

$$\text{T peel strength (N/25 mm)} = \frac{\text{Average peel force (N)} \times 25}{\text{Average specimen width}}$$

57.5 Result

The result shall be the mean of the three T peel strengths.

58 Circumferential extension

58.1 Principle

This test determines the ability of sleeves to withstand radial expansion using a commercially available sleeving tool.

58.2 Number and form of test specimens

Two sets of two specimen sleeves 15 mm to 20 mm long shall be tested.

58.3 Conditioning

One set of specimens shall be conditioned in an ambient temperature of 23 °C ± 2 K for at least 2 h. The second set of specimens shall be aged in an oven for 168 h ± 2 h at the temperature specified in IEC 60684-3. Upon removal from the oven, the sleeves shall be allowed to stabilize at room temperature for 2 h ± 10 min.

58.4 Apparatus

A three or four pronged commercially available device as recommended by the sleeve manufacturer, capable of achieving the required degree of expansion.

Suitable sized mandrels.

58.5 Procedure

For sleeve sizes 2 mm to 10 mm nominal internal diameter (D), the sleeves shall be expanded until they are able to pass over a mandrel of the extension ratio specified in IEC 60684-3.

58.6 Results

Report any splitting.

59 Voltage proof

59.1 Principle

This test determines the ability of sleeves to withstand a minimum proof voltage (R.M.S.).

59.2 Number and form of test specimens

Three 35 mm ± 1 mm long sleeves shall be tested each fitted to a smooth non-ferrous metal mandrel so that the mandrel protrudes from each end of the sleeve.

A mandrel diameter of twice the nominal internal diameter of the sleeve as specified in IEC 60684-3 shall be used. No lubricant other than distilled water shall be used. The sleeves shall be fitted so that they have uniform wall thickness and are not less than 32 mm long on the mandrel. Whilst on the mandrel, determine the wall thickness in accordance with Subclause 3.2.2.

59.3 Conditioning

The assemblies shall be immersed in distilled water for 24 h ± 15 min at a temperature of 23 °C ± 2 K.

59.4 Procedure

The assemblies shall be removed from the water and the surface moisture shall be immediately removed. A strip of metal foil 6 mm wide shall be wrapped round the centre of each sleeve. Alternating voltage with a nominal frequency of 50 Hz and waveform approximately sinusoidal with a peak factor within limits of $\sqrt{2}$ ± 7% (1,32 to 1,51) shall be applied between the foil and the mandrel. The voltage shall be increased at a uniform rate so that the required voltage as specified in IEC 60684-3 is reached in approximately 10 s and is maintained at this value for 1 min ± 5 s.

The test voltage shall be applied within 10 min after the removal of the mandrel from the water.

59.5 Results

Report any breakdown.

60 Thermal shock

60.1 Principle

This test determines the ability of sleeves to withstand extremes of temperature.

60.2 Number and form of test specimens

For each of the following tests, three sleeves shall be fitted to a smooth aluminium mandrel, the diameter of which is twice the nominal internal diameter of the sleeve, to make an assembly. The lengths of the sleeves shall be as follows:

Nominal internal diameter mm	Length of sleeve mm
0,5 to 1,5	4 ± 1
2,0 to 9,0	7 ± 2
10 to 25	12 ± 3

60.3 Conditioning

The assembly shall be conditioned for 48 h ± 2 h at a temperature of 23 °C ± 2 K.

60.4 Tests

60.4.1 Test 1

The assembly shall be placed in an oven for 168 h ± 2 h at the temperature specified in IEC 60684-3.

After this period the assembly shall be transferred within 10 s to a chamber at a temperature of -65 °C ± 3 K for 60 min ± 1 min. It shall then be removed from the chamber conditioned for 60 min ± 1 min, at 23 °C ± 2 K. The assembly shall be vertical throughout the test.

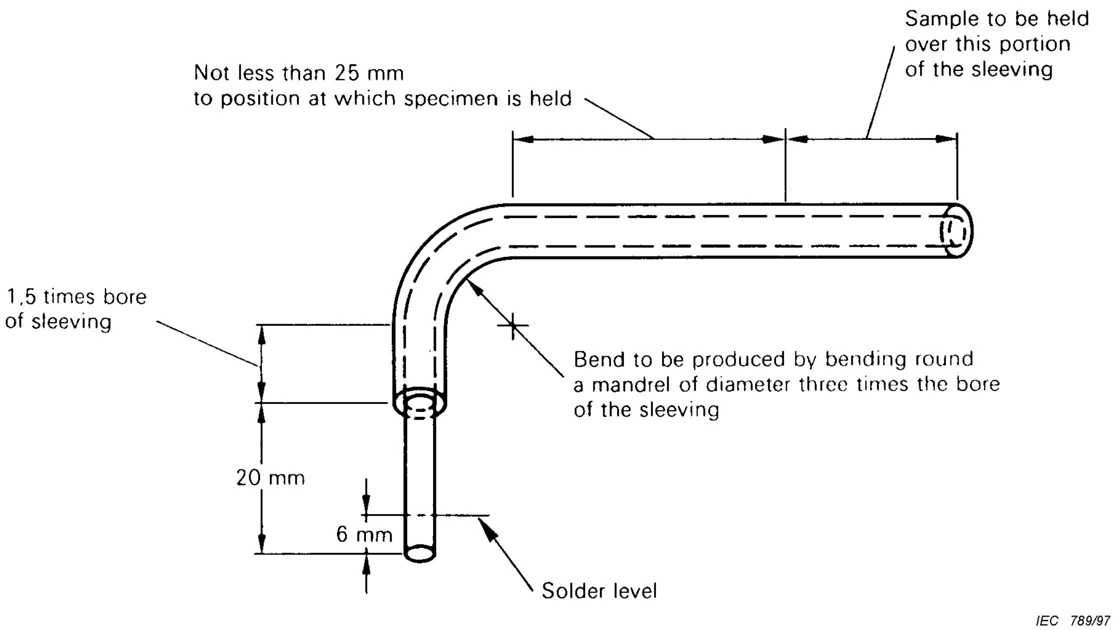
60.4.2 Test 2

The assembly described in test 1 shall be stored vertically for 5 min ± 5 s in an oven at the temperature specified in IEC 60684-3.

On removal from the oven, the assembly shall be examined.

60.4.3 Results

Report any signs of cracking, splitting, change of colour and slipping off the mandrel under its own weight at any time during the test.



Dimensions in millimetres

Figure 1 – Specimen for test resistance to soldering heat

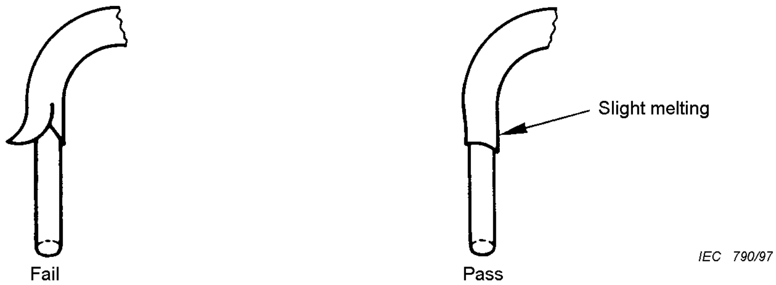
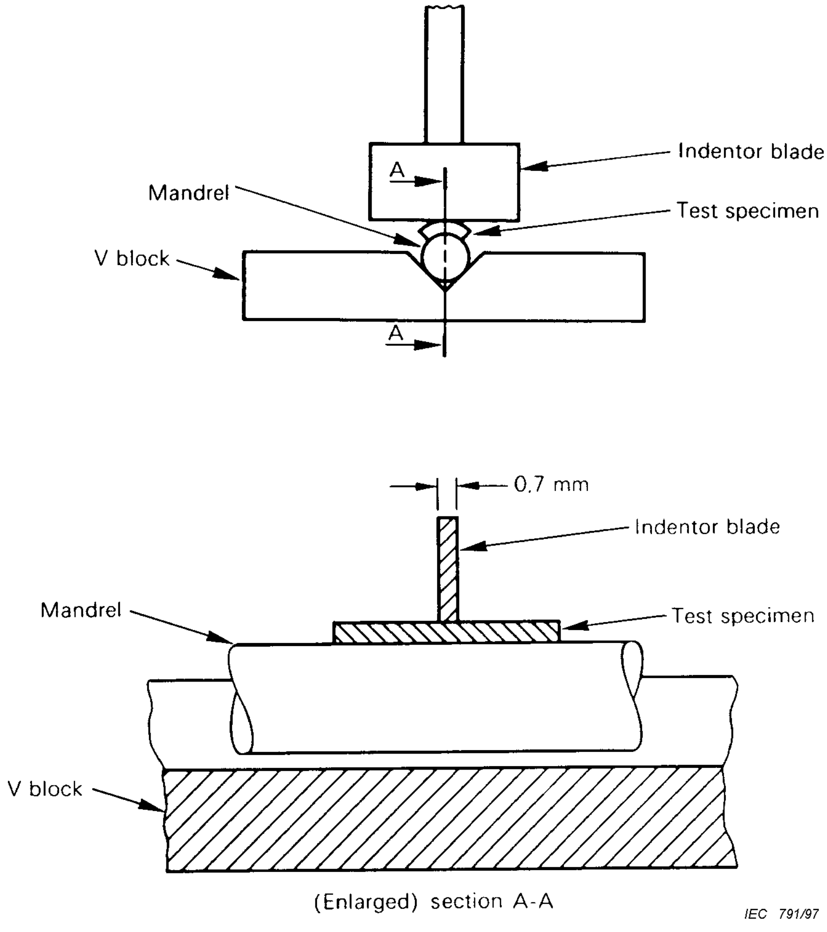


Figure 2 – Examples of sleeving after being subjected to test for resistance to soldering heat



Dimensions in millimetres

Figure 3 – Arrangement for the test for resistance to pressure at elevated temperature (Method A)

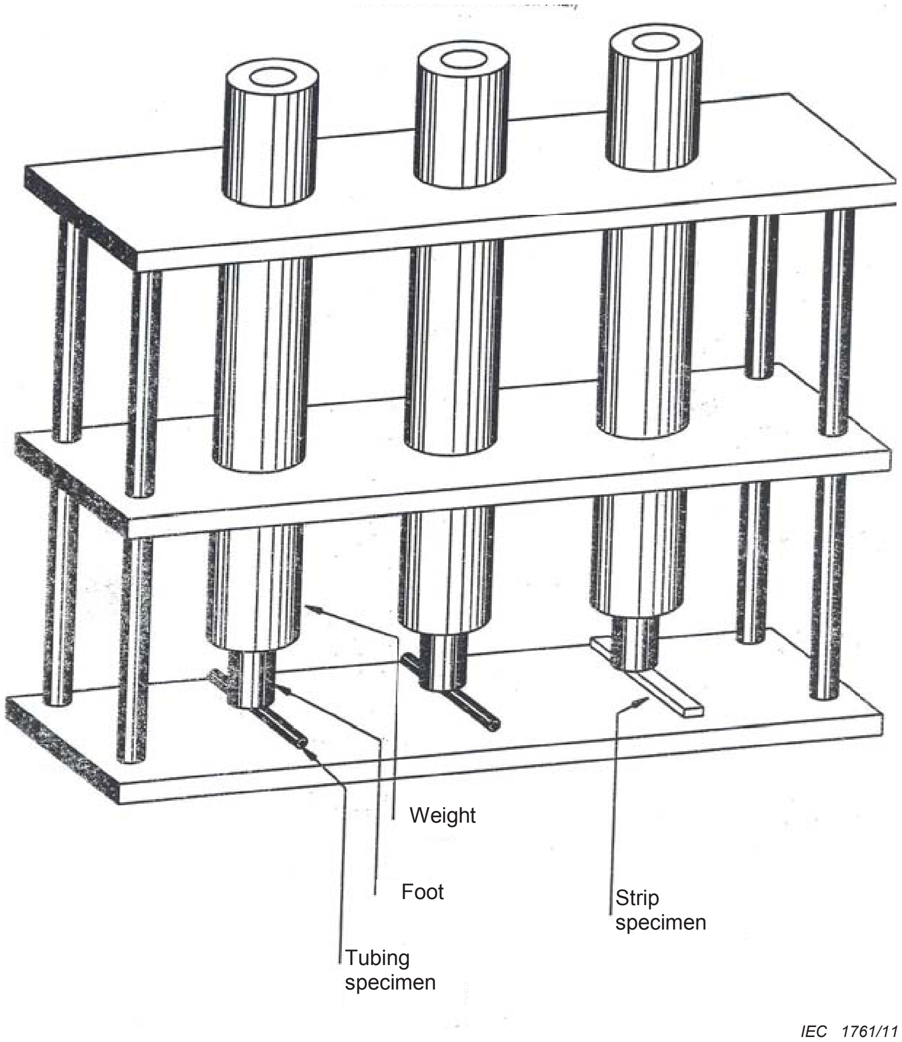
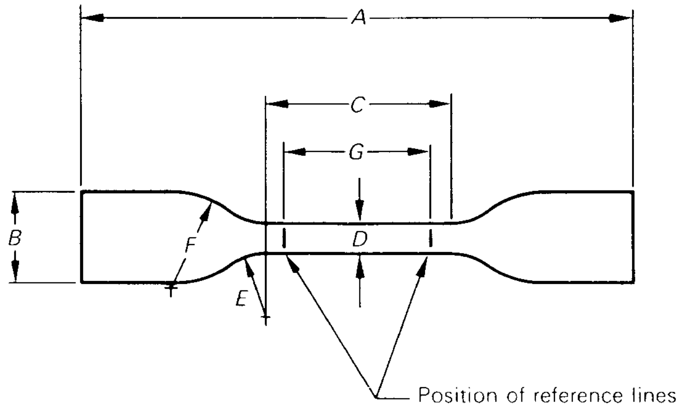


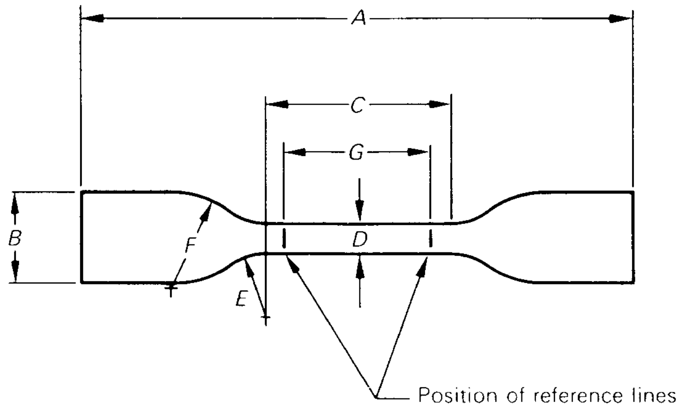
Figure 4 – Arrangement for deformation under load (Method B)



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

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

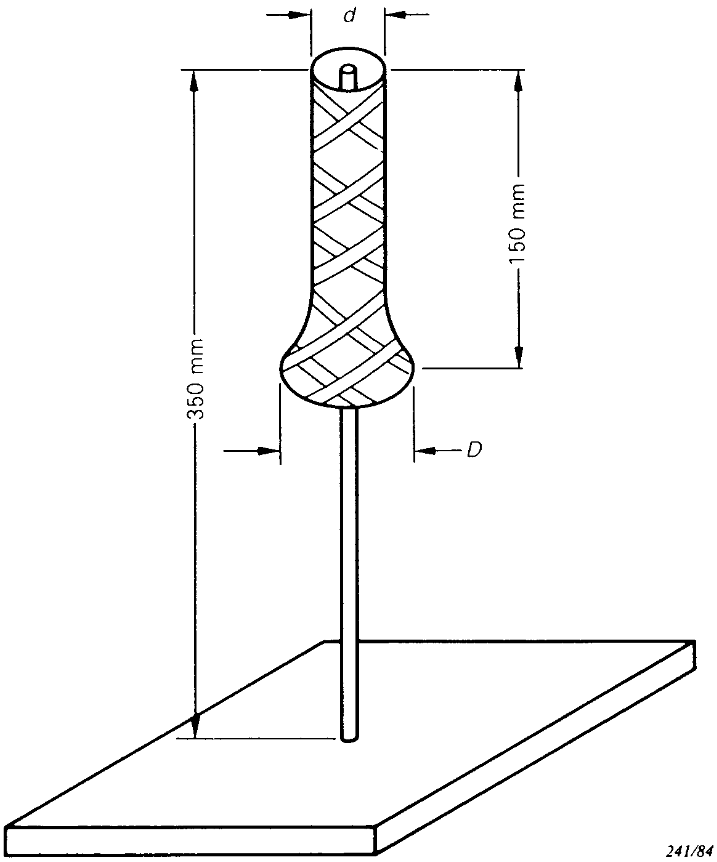
Figure 5 – Dumb-bell specimen for tensile strength test (ISO 37 Type2)



A	overall length, minimum	115 mm
B	width at ends	(25 ± 1,0) mm
C	length of narrow parallel portions	(33 ± 2,0) mm
D	width of narrow parallel portion	(6,0 ± 0,1) mm
E	small radius	(14 ± 1,0) mm
F	large radius	(25 ± 2,0) mm
G	distance between reference lines	≤25 mm

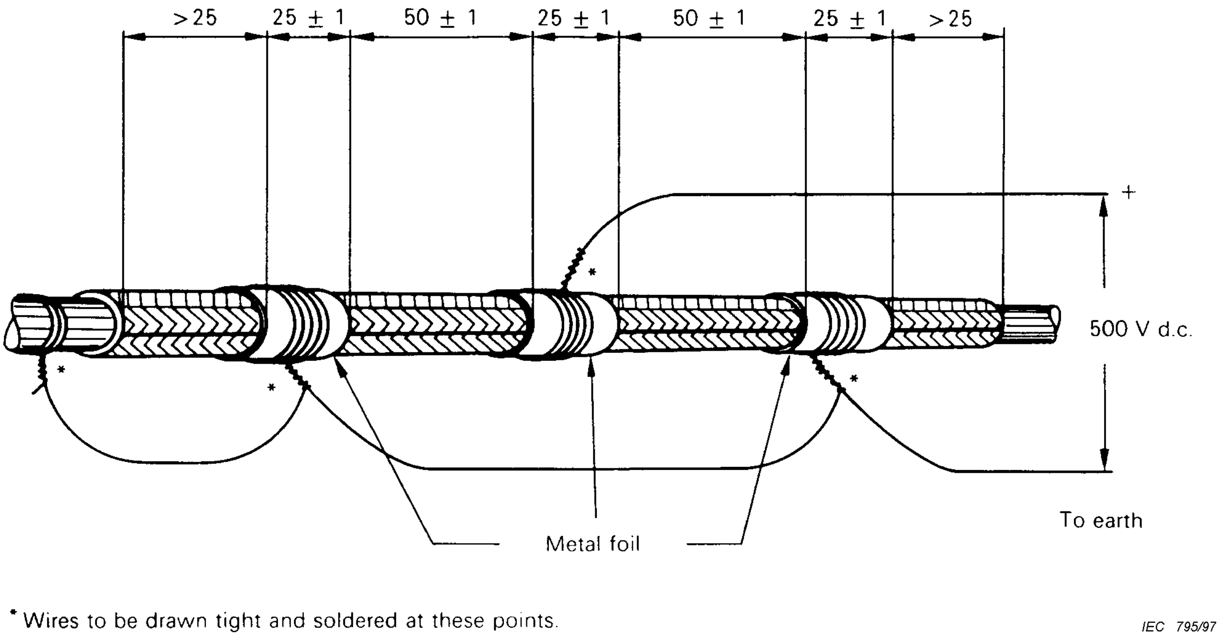
In any one specimen, the thickness of the narrow parallel portion shall nowhere deviate by more than 2 % from the mean.

Figure 6 – Dumb-bell specimen for tensile strength test (ISO 37 Type 1)



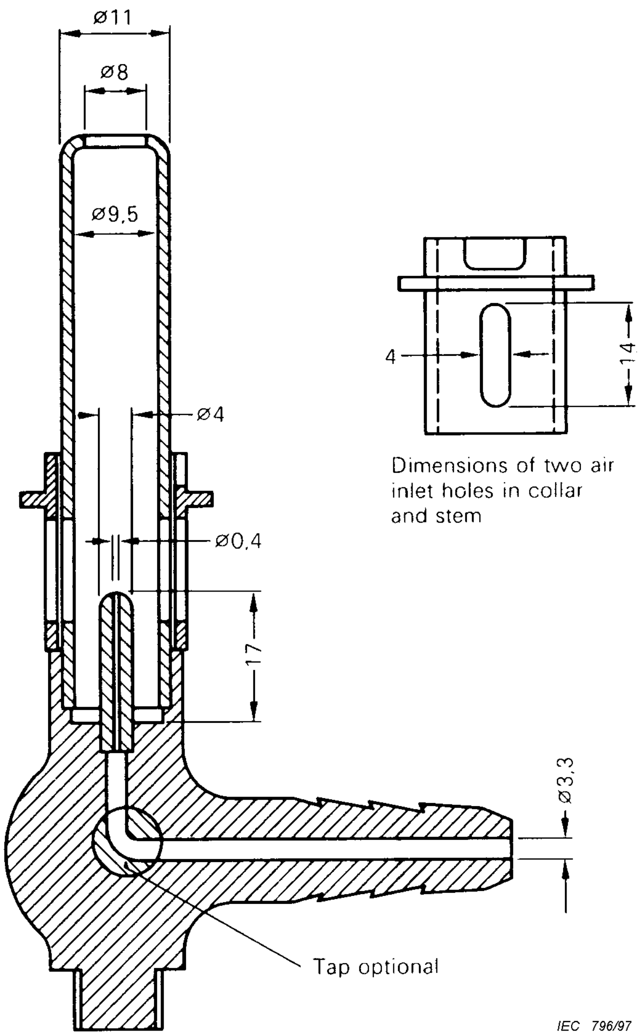
Dimensions in millimetres

Figure 7 – Sketch of fray test arrangement



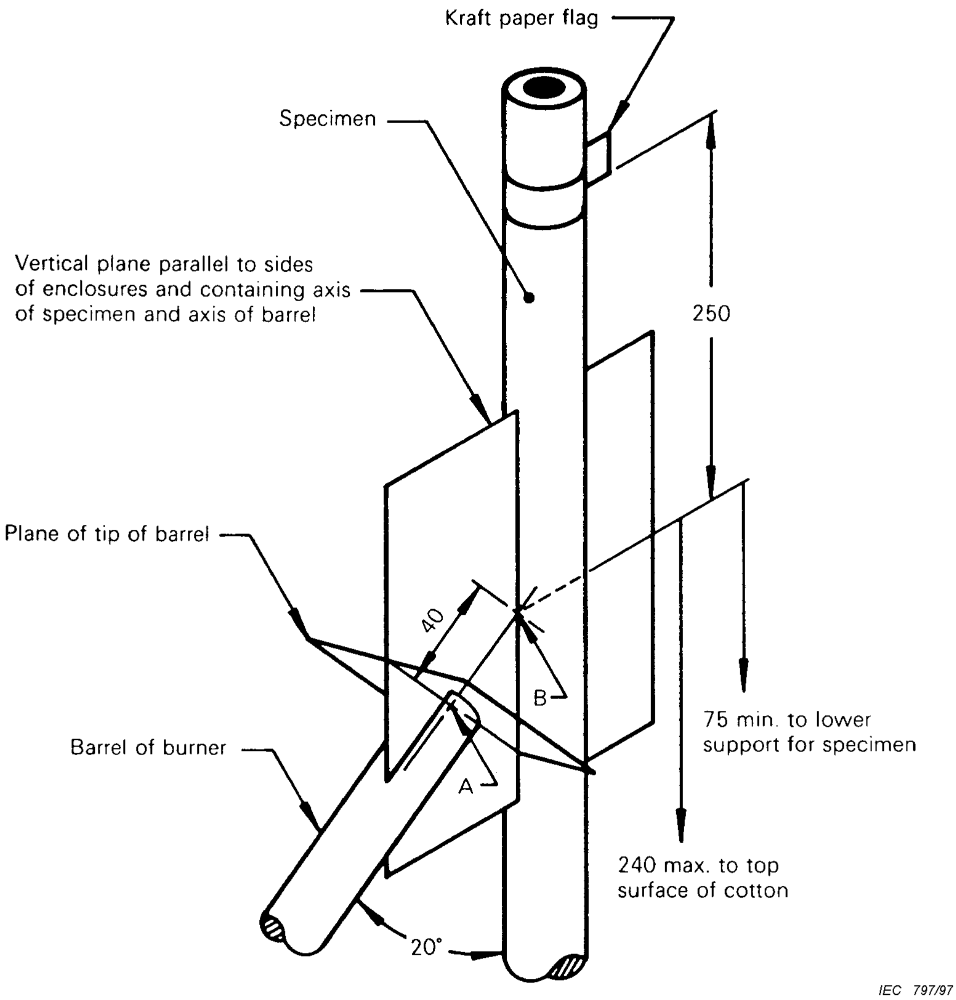
Dimensions in millimetres

Figure 8 – Specimen for insulation resistance test



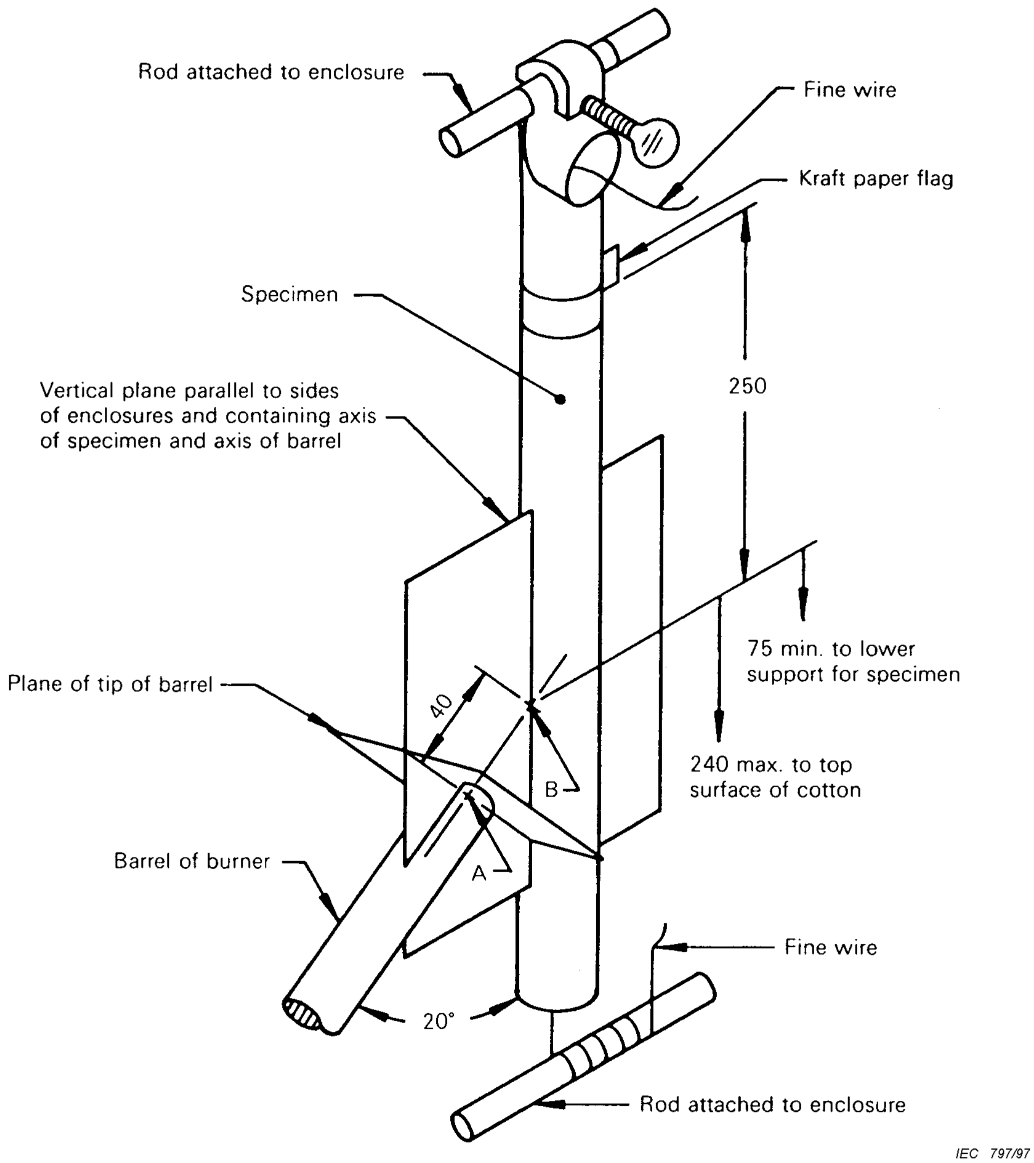
Dimensions in millimetres

Figure 9 – Standard propane burner for flame propagation test (sectional view)



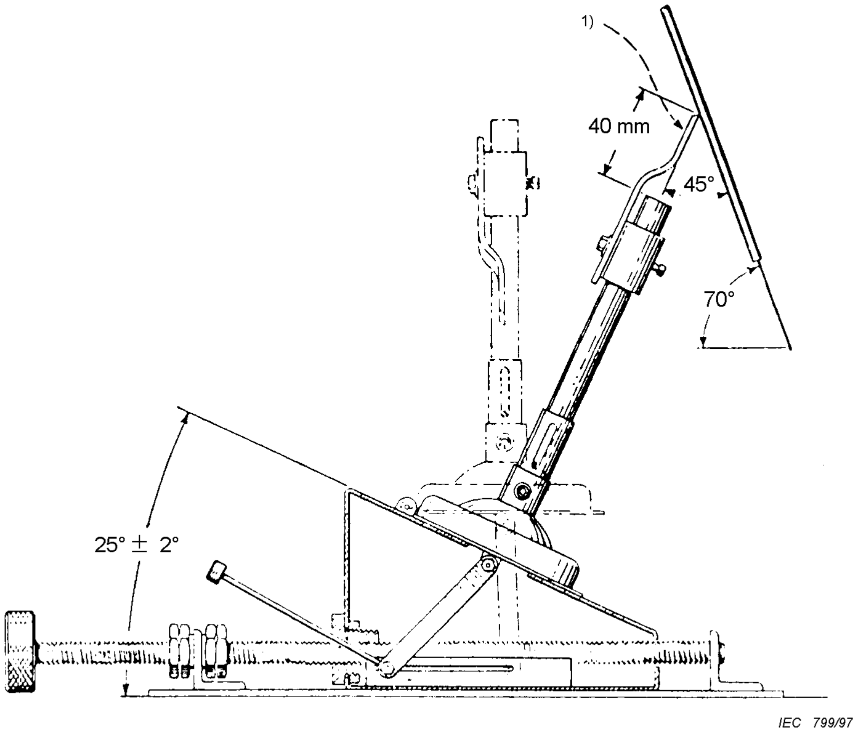
Dimensions in millimetres

Figure 10 – Flame propagation test – Method A
(Proportions exaggerated for clarity of detail)



Dimensions in millimetres

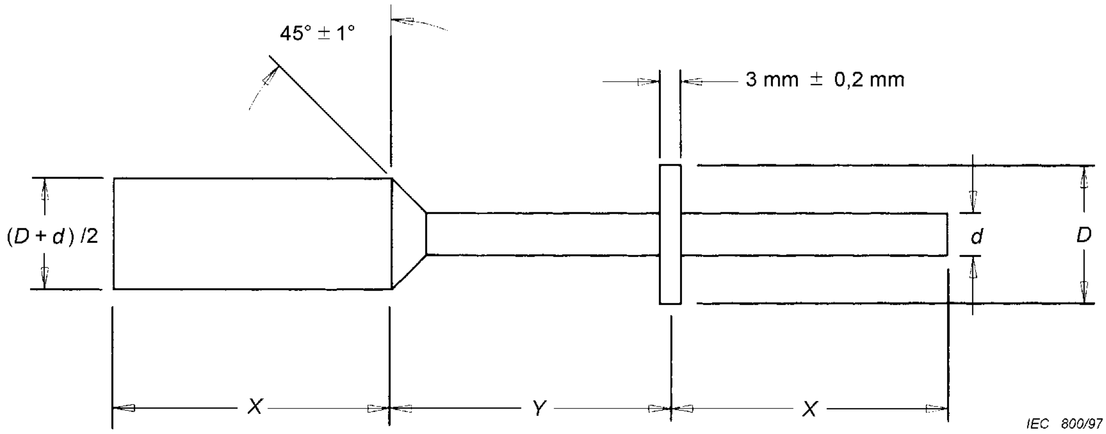
Figure 11 – Flame propagation test – Method B
(Proportions exaggerated for clarity of detail)



Dimensions in millimetres

1) Pivoted indicator to be turned down prior to ignition.

Figure 12 – Flame propagation test – Method C



Dimensions in millimetres

Specified maximum internal diameter of sleeving after unrestricted shrinkage mm	Mandrel section X (minimum) mm	 Y mm
<1,20 [a]	13	6,4 ± 0,05
1,20 to 3,2	13	6,4 ± 0,05
3,21 to 9,5	25	12,7 ± 0,05
9,51 to 58,0	50	50,8 ± 0,05

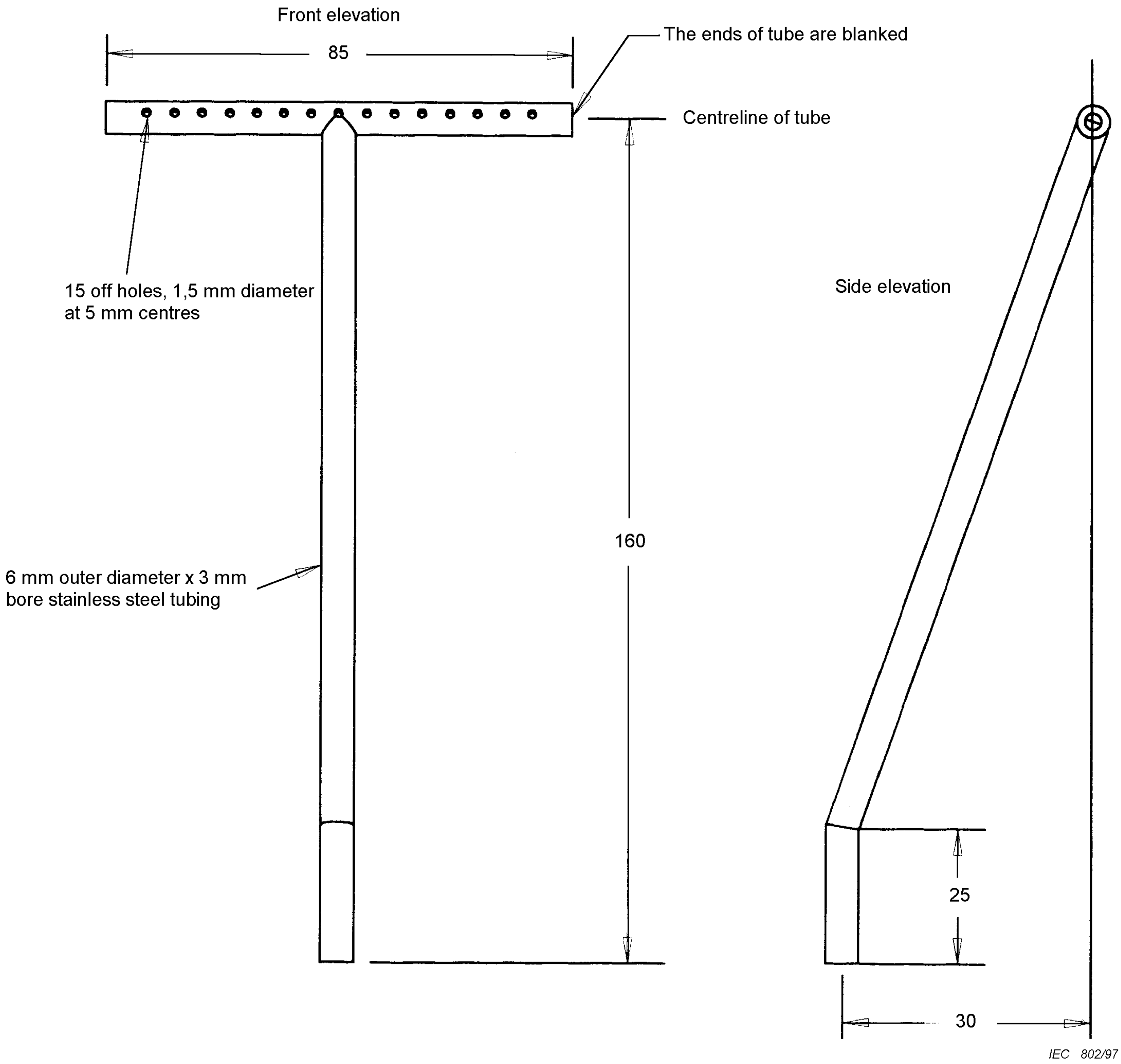
[a] For sleeving sizes less than 1,20 mm specified maximum internal diameter after restricted shrinkage, a straight cylindrical mandrel shall be made with an outside diameter equal to *D*.

d maximum internal diameter $\left(^{+5}_{0}\right)$ % of sleeving after unrestricted shrinkage

D minimum internal diameter $\left(^{0}_{-5}\right)$ % of sleeving as supplied

The mandrels shall be free from burrs and sharp edges.

Figure 13 – Mandrel for restricted shrinkage test



Dimensions in millimetres

Figure 14 – Schematic details of burner for smoke index test

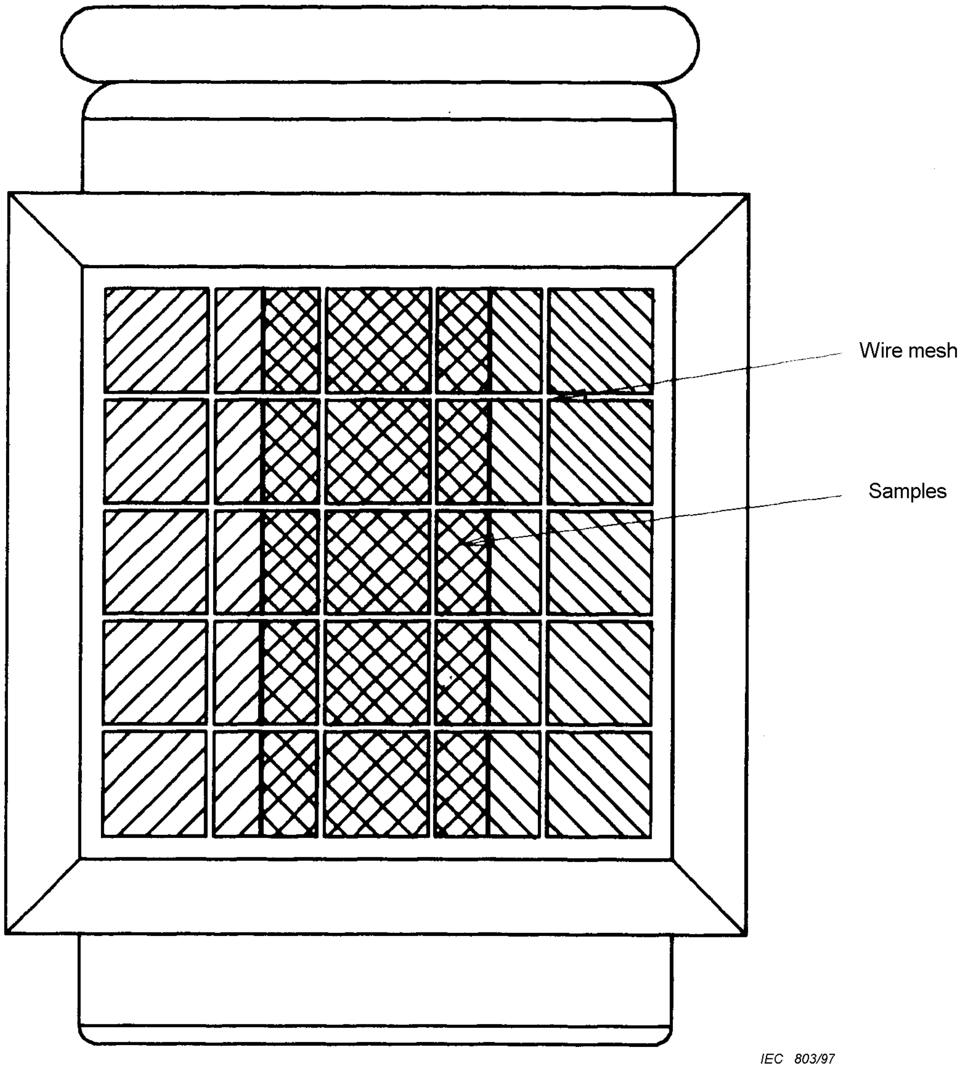
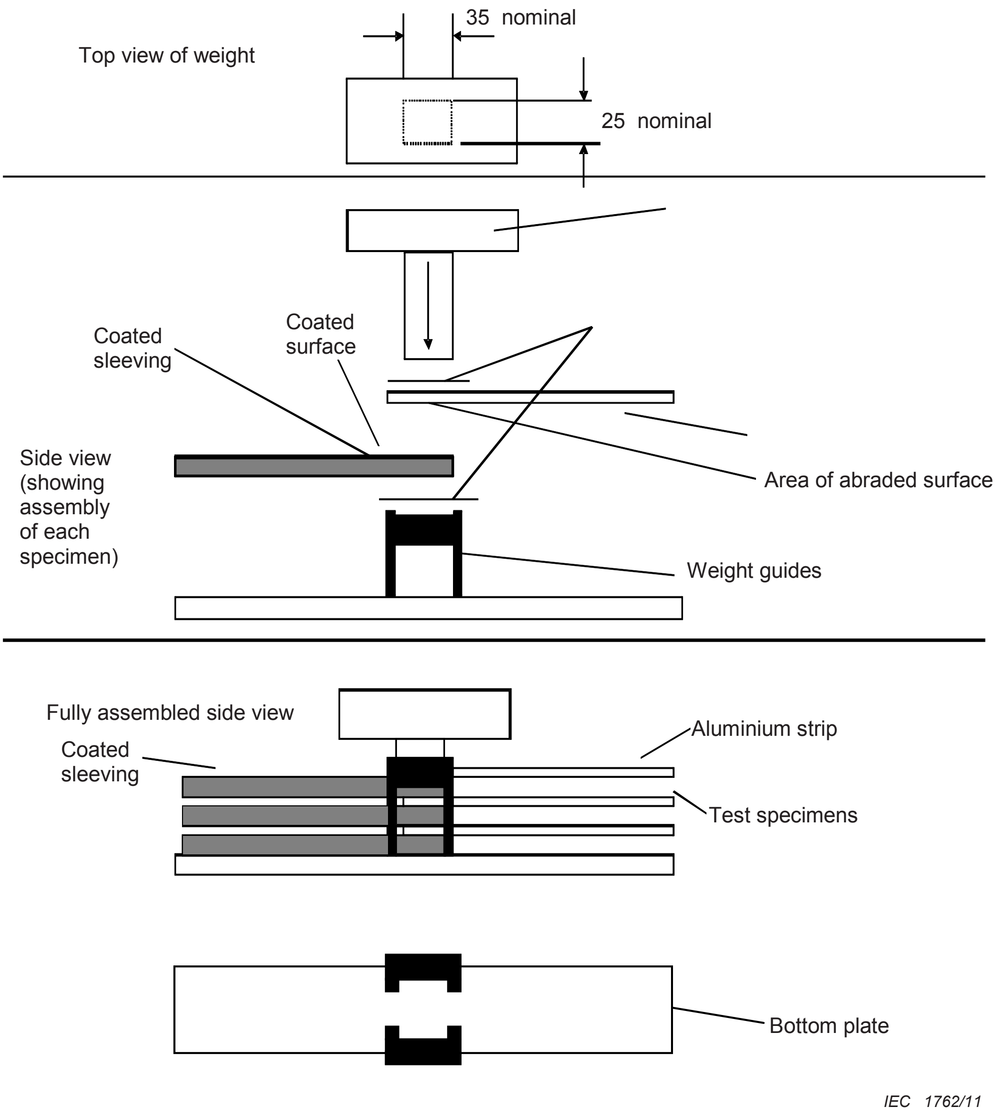
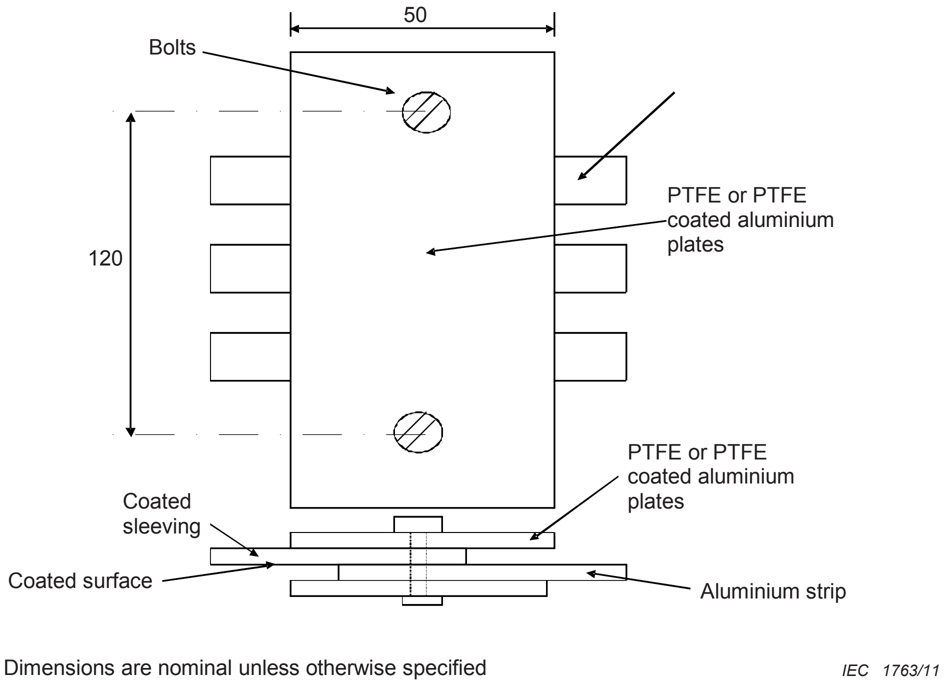


Figure 15 – Schematic front view of smoke test sample holder, showing vertically mounted sleeving samples



Dimensions in millimetres

Figure 16 – Assembly and fixture for dynamic shear at ambient temperature



Dimensions in millimetres

Figure 17 – Assembly for heat shock and heat ageing

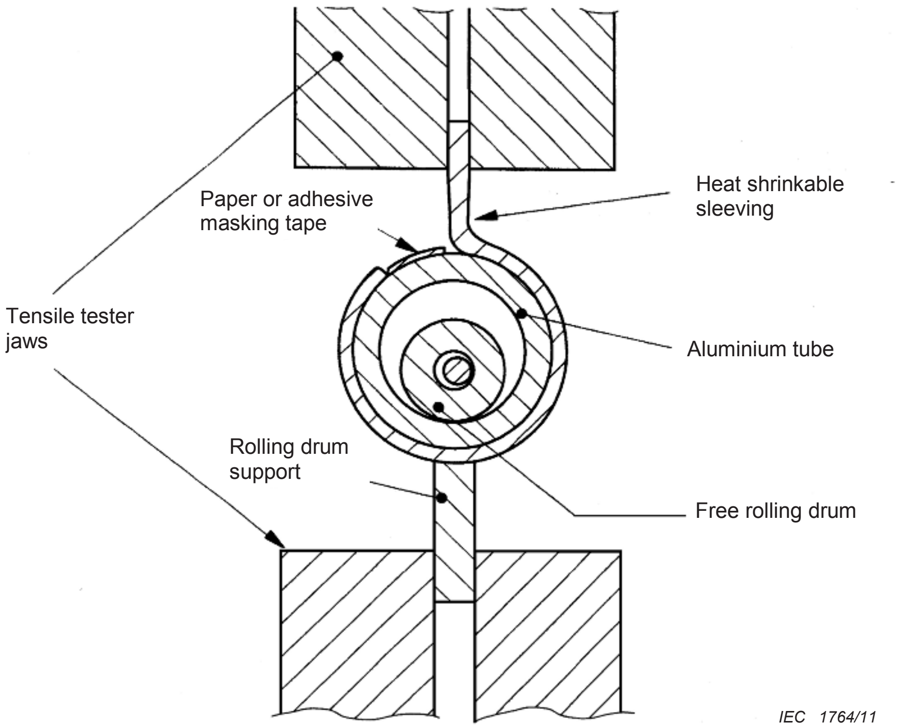
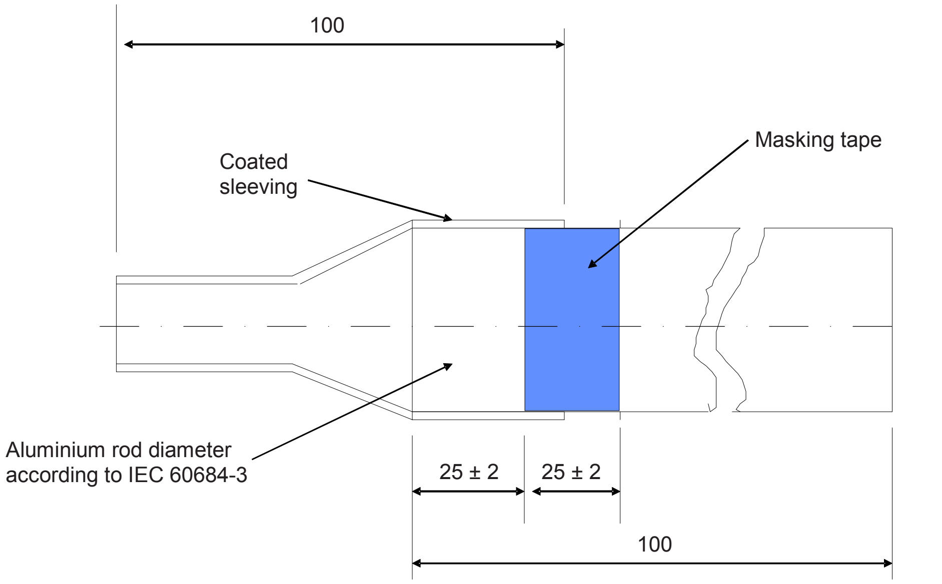


Figure 18 – Schematic arrangement of rolling drum peel

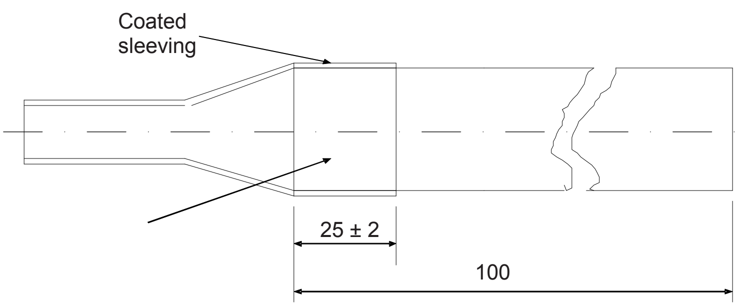


Note Dimensions are nominal unless otherwise specified

IEC 1765/11

Dimensions in millimetres

Figure 19 – Assembly preparation for aluminium rod dynamic shear

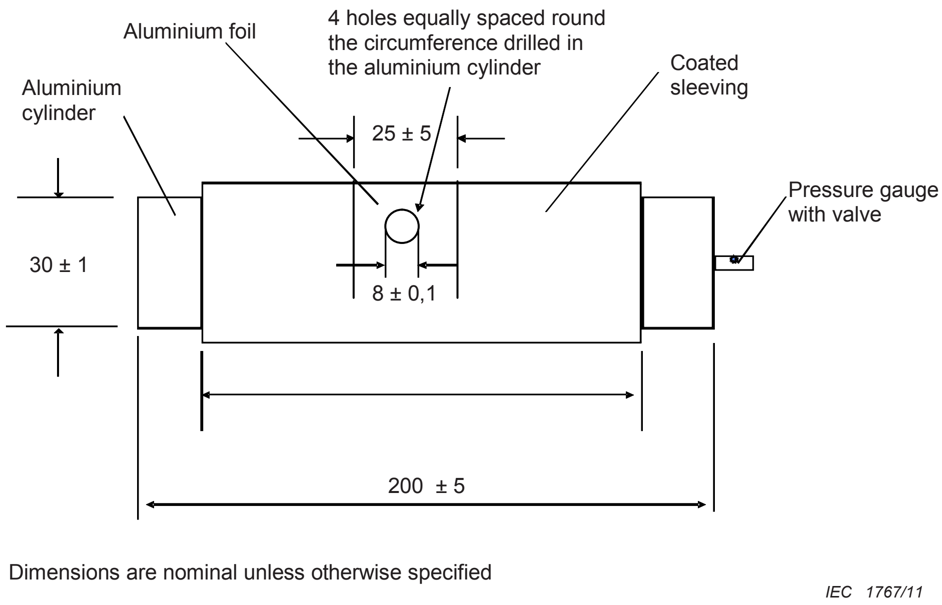


Dimensions are nominal unless otherwise specified

IEC 1766/11

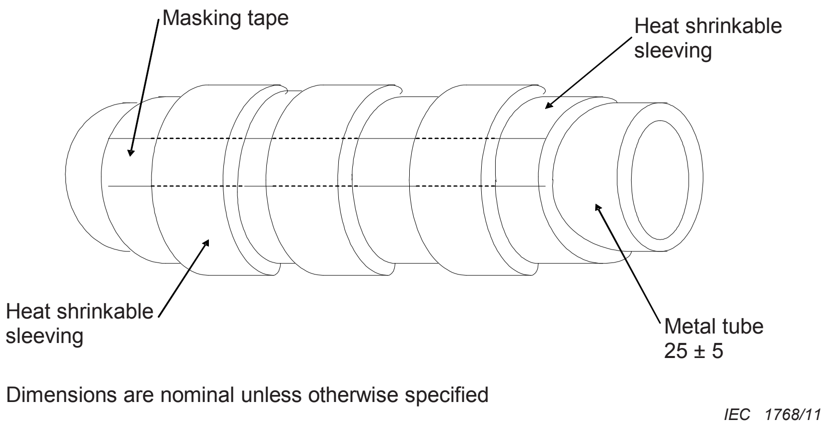
Dimensions in millimetres

Figure 20 – Test specimen for aluminium rod dynamic shear



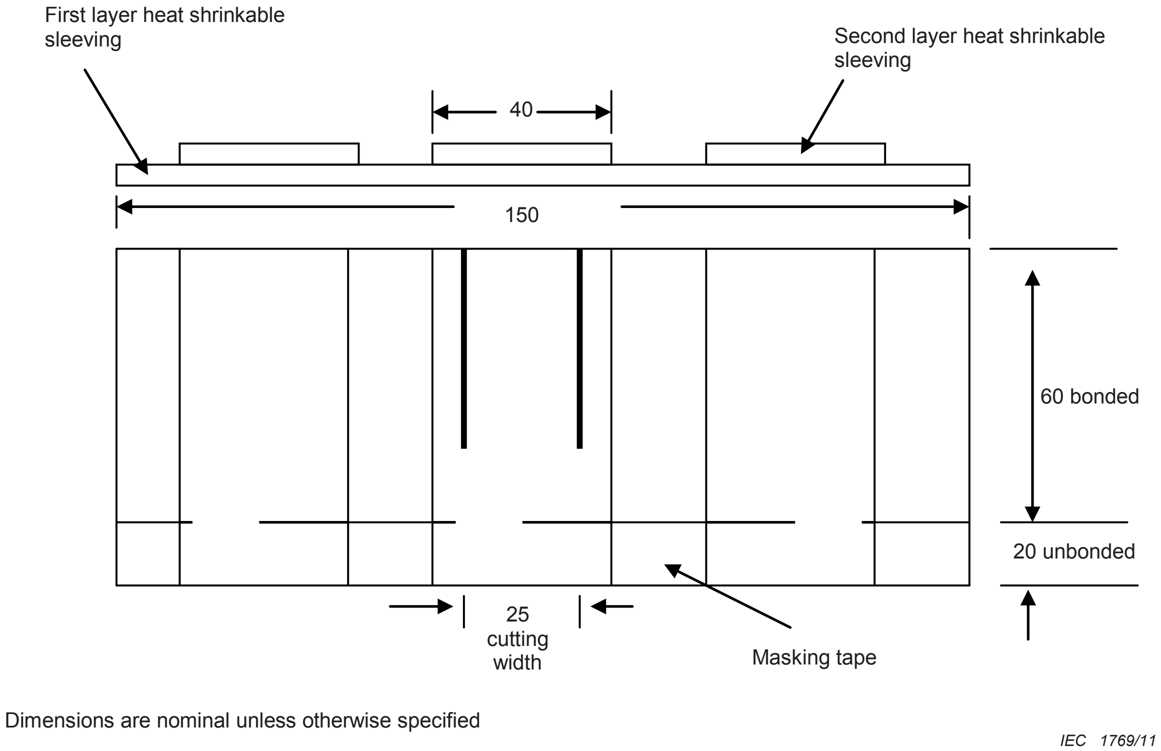
Dimensions in millimetres

Figure 21 – Assembly for sealing test



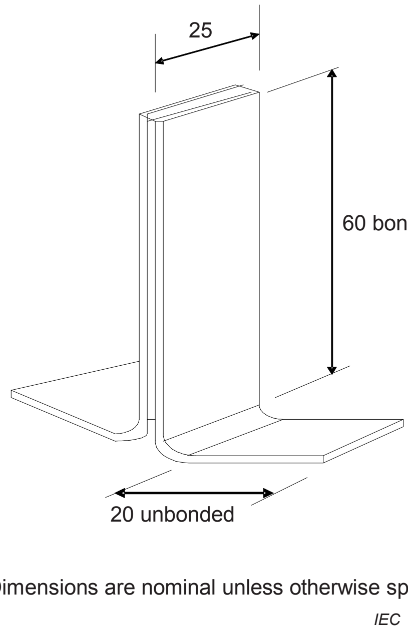
Dimensions in millimetres

Figure 22 – Mandrel assembly



Dimensions in millimetres

Figure 23 – Slab specimen



Dimensions in millimetres

Figure 24 – T peel strength specimen

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