

BS EN 60684-2:2011



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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 It supersedes BS EN 60684-2:1997, which will be withdrawn on 14 September 2014.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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Gaines isolantes souples -
Partie 2: Méthodes d'essai
(CEI 60684-2:2011)

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

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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.

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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 (dop) 2012-06-14
national level by publication of an identical national
standard or by endorsement
- latest date by which the national standards conflicting with the (dow) 2014-09-14
document have to be withdrawn

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

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.

<u>Publication</u>	<u>Year</u>	<u>Title</u>	<u>EN/HD</u>	<u>Year</u>
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.

<u>Publication</u>	<u>Year</u>	<u>Title</u>	<u>EN/HD</u>	<u>Year</u>
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.

<u>Publication</u>	<u>Year</u>	<u>Title</u>	<u>EN/HD</u>	<u>Year</u>
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

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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/cm³.

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 $(15 \pm 1)^\circ$. The specimens shall be maintained for a period of (168 ± 2) h at a temperature of $70^\circ\text{C} \pm 2^\circ\text{K}$ unless another temperature is specified in IEC 60684-3, and then allowed to cool to $23^\circ\text{C} \pm 5^\circ\text{K}$. 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 $23^\circ\text{C} \pm 5^\circ\text{K}$ 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 $4\text{ h} \pm 10\text{ min}$ 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 $23\text{ °C} \pm 5\text{ K}$, 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 $(15 \pm 1)\text{ s}$ 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 $260\text{ °C} \pm 5\text{ K}$ 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 $(5 \pm 1)\text{ g}$.

8.2 Procedure

The specimens shall be conditioned by heating at $105\text{ °C} \pm 2\text{ K}$ 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 $600\text{ °C} \pm 10\text{ K}$ 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 $\pm 0,01$ mm with a rectangular indenter blade with an edge $(0,70 \pm 0,01)$ mm which applies a load to the specimen of $(1,2 \pm 0,05)$ N, unless otherwise specified in IEC 60684-3. The specimen is placed on a metal mandrel $(6,00 \pm 0,1)$ 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 $110\text{ }^{\circ}\text{C} \pm 2\text{ K}$ 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 $110\text{ }^{\circ}\text{C} \pm 2\text{ K}$, unless another temperature is specified in IEC 60684-3.

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

NOTE With small bore sleeveings 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 indenter blade shall then be recorded. Remove the specimen, allow the indenter 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 indenter 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
$\leq 1,6$	2,95
1,6 to 4,22	4,91
$\geq 4,22$	19,61

Pressure foot discs, ($9,5 \pm 0,1$ 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 mm² to 6 mm² 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 $200\text{ °C} \pm 3\text{ K}$ 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 $4 \text{ h} \pm 10 \text{ min}$ 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 $40\text{ °C} \pm 3\text{ K}$ 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 $100\text{ °C} \pm 2\text{ K}$ 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 $23\text{ °C} \pm 2\text{ K}$ for 1 h immediately before testing, or for a longer time to enable the specimen to reach a temperature of $23\text{ °C} \pm 2\text{ K}$.

19.2.4 Test temperature

The test shall be made at a temperature of $23\text{ °C} \pm 2\text{ K}$.

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

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

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 (mm²) 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.