

Flexible insulating sleeving —

Part 2: Methods of test

The European Standard EN 60684-2:1997, with the incorporation of amendments A1:2003 and A2:2005, has the status of a British Standard

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National foreword

This British Standard is the official English language version of EN 60684-2:1997 including amendments A1:2003 and A2:2005. It is identical with IEC 60684-2:1997 including amendments 1:2003 and 2:2005. It supersedes BS 6893-2:1987 which is withdrawn.

The start and finish of text introduced or altered by amendment is indicated in the text by tags **A1** **A1**. Tags indicating changes to CENELEC text carry the number of the CENELEC amendment. For example, text altered by CENELEC amendment 1 is indicated by **A1** **A1**.

The UK participation in its preparation was entrusted by Technical Committee GEL/15, Insulating materials, to Subcommittee GEL/15/3, Material specifications, which has the responsibility to:

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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 15C/657/FDIS, future edition 2 of IEC 60684-2, prepared by SC 15C, Specifications, of IEC TC 15, Insulating materials, was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as EN 60684-2 on 1997-07-01.

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Annexes designated “normative” are part of the body of the standard.

Annexes designated “informative” are given for information only. In this standard, Annex ZA is normative and Annex A is informative. Annex ZA has been added by CENELEC.

Endorsement notice

The text of the International Standard IEC 60684-2:1997 was approved by CENELEC as a European Standard without any modification.

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

IEC 60068-2	NOTE: Harmonized as HD 323.2 and EN 60068-2 series.
IEC 60068-2-10	NOTE: Harmonized as HD 323.2.10 S3:1988 (not modified).
IEC 60216-2	NOTE: Harmonized as HD 611.2 S1:1992 (not modified).
IEC 60304	NOTE: Harmonized as HD 402 S2:1984 (not modified).

Foreword to amendment A1

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Annexes designated “normative” are part of the body of the standard.

In this standard, annex ZA is normative. Annex ZA has been added by CENELEC.

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Endorsement notice

The text of amendment 2:2005 to the International Standard IEC 60684-2:1997 was approved by CENELEC as an amendment to the European Standard without any modification.

Contents

	Page	Page
Foreword	2	44 Toxicity index 37
Introduction	5	45 Halogen content 41
1 General	6	46 Acid gas generation 42
2 Test conditions	6	47 Hot elongation and hot set 42
3 Measurements of bore, wall thickness and concentricity	7	48 Tension set 43
4 Density	8	49 Tear propagation 43
5 Resistance to splitting after heating	8	50 Long term heat ageing (3 000 h) 44
6 Heat shock (resistance to heat)	9	51 Dynamic shear at ambient temperature 44
7 Resistance to soldering heat	9	52 Dynamic shear at elevated temperature 45
8 Loss in mass on heating of uncoated textile glass sleeving	10	53 Dynamic shear after heat shock and heat ageing 45
9 Longitudinal change	10	54 Rolling drum peel to aluminium 46
10 Deformation under load (resistance to pressure at elevated temperature)	11	55 Aluminium rod dynamic shear 47
11 Thermal stability of PVC sleeving	11	56 Sealing 47
12 Volatile content of silicone sleeving	12	57 Adhesive T peel strength of two bonded heat-shrinkable substrates 48
13 Bending after heating	12	Annex A (informative) Bibliography 70
14 Bending at low temperature	13	Annex ZA (normative) Normative references to international publications with their corresponding European publications 71
15 Brittleness temperature	13	Figure 1 — Specimen for test resistance to soldering heat 50
16 Dimensional stability on storage	13	Figure 2 — Examples of sleeving after being subjected to test for resistance to soldering heat 50
17 Hydrolysis of coating	14	Figure 3 — Arrangement for the test for resistance to pressure at elevated temperature 51
18 Flexibility	14	Figure 4 — Apparatus for flexibility test 52
19 Tensile strength, tensile stress at 100 % elongation, elongation at break and secant modulus at 2 % elongation	15	Figure 5 — Dumb-bell specimen for tensile strength test 53
20 Fraying resistance test	18	Figure 6 — Sketch of fray test arrangement 54
21 Breakdown voltage	18	Figure 7 — Schematic arrangement for shot bath breakdown voltage test 55
22 Insulation resistance	20	Figure 8 — Specimen for insulation resistance test 56
23 Volume resistivity	21	Figure 9 — Standard propane burner for flame propagation test (Sectional view) 57
24 Permittivity and dissipation factor	22	Figure 10 — Flame propagation test — Method A (Proportions exaggerated for clarity of detail) 58
25 Resistance to tracking	23	Figure 11 — Flame propagation test — Method B (Proportions exaggerated for clarity of detail) 59
26 Flame propagation tests	24	Figure 12 — Flame propagation test — Method C 60
27 Oxygen index	26	Figure 13 — Mandrel for restricted shrinkage test 61
28 Transparency	26	Figure 14 — Schematic details of burner for smoke index test 62
29 Ionic impurities test	27	Figure 15 — Schematic front view of smoke test sample holder, showing vertically mounted sleeving samples 63
30 Silver staining test	27	
31 Electrolytic corrosion resistance	28	
32 Corrosion resistance (tensile and elongation)	28	
33 Copper corrosion (presence of corrosive volatiles)	28	
34 Colour fastness to light	29	
35 Resistance to ozone	30	
36 Resistance to selected fluids	30	
37 Thermal endurance	31	
38 Mass per unit length	31	
39 Heat ageing	31	
40 Water absorption	32	
41 Restricted shrinkage	32	
42 Colour stability to heat	32	
43 Smoke index	33	

	Page
Figure 16 — Assembly and fixture for dynamic shear at ambient temperature	64
Figure 17 — Assembly for heat shock and heat ageing	65
Figure 18 — Schematic arrangement for rolling drum peel	66
Figure 19 — Assembly preparation for aluminium rod dynamic shear	67
Figure 20 — Test specimen for aluminium rod dynamic shear	67
Figure 21 — Assembly for sealing test	68
Figure 22 — Mandrel assembly	68
Figure 23 — Slab specimen	69
Figure 24 — T peel strength specimen	69

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: Specification requirements for individual types of sleeving (IEC 60684-3).*

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 normative documents contain provisions which, through reference in this text, constitute provisions of this part of IEC 60684. At the time of publication, the editions indicated were valid. All normative documents are subject to revision, and parties to agreements based on this part of IEC 60684 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

IEC 60068-2-20:1979, *Environmental testing — Part 2: Tests, Test T: Soldering.*

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

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

IEC 60216, *Guide for the determination of thermal endurance properties of electrical insulating materials.*

IEC 60216-4-1:1990, *Guide for the determination of thermal endurance properties of electrical insulating materials — Part 4: Ageing ovens — Section 1: Single-chamber ovens.*

IEC 60216-4-1:1990, *Guide for the determination of thermal endurance properties of electrical insulating materials — Part 4: Ageing ovens — Section 1: Single-chamber ovens.*

Ⓐ IEC 60216-4-2:2003, *Electrical insulating materials — Thermal endurance properties — Part-4-2: Ageing ovens — Precision ovens for use up to 300 °C.* Ⓐ

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 60426:1973, *Test methods for determining electrolytic corrosion with insulating materials.*

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

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

IEC 60684-3, *Flexible insulating sleeving — Part 3: Specification requirements for individual types of sleeving.*

IEC 60695-6-30:1996, *Fire hazard testing — Part 6: Guidance and test methods for 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.*

- IEC 60754-1:1994, *Tests on gases evolved during combustion of materials from cables — Part 1: Determination of the amount of halogen acid gas evolved during the combustion of polymeric materials taken from cables.*
- IEC 60754-2:1991, *Tests on gases evolved during combustion of materials from cables — Part 2: Determination of degree of acidity of gases evolved during the combustion of materials taken from electric cables by measuring pH and conductivity.*
- ISO 5-1:1984, *Photography — Density measurements — Part 1: Terms, symbols and notations.*
- ISO 5-2:1991, *Photography — Density measurements — Part 2: Geometric conditions for transmission density.*
- ISO 5-3:1995, *Photography — Density measurements — Part 3: Spectral conditions.*
- ISO 5-4:1995, *Photography — Density measurements — Part 4: Geometric conditions for reflection density.*
- ISO 37:1994, *Rubber, vulcanized or thermoplastic — Determination of tensile stress-strain properties.*
- ISO 62:1980, *Plastic — Determination of water absorption.*
- ISO 105, *Textiles — Tests for colour fastness.*
- ISO 105-A02:1993, *Textiles — Tests for colour fastness — Part A02: Grey scale for assessing change in colour.*
- ISO 105-B01:1994, *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 974:1980, *Plastics — Determination of the brittleness temperature by impact.*
- ISO 1431-1:1989, *Rubber, vulcanized or thermoplastic — Resistance to ozone cracking — Part 1: Static strain test.*
- ISO 2921:1982, *Rubber, vulcanized — Determination of low temperature characteristics — Temperature-retraction procedure (TR test).*
- ISO 3261:1975, *Fire tests — Vocabulary.*
- ISO 4589-2-2:1994, *Plastics — Determination of flammability — Part 2: Oxygen index (OI) at room temperature.*
- 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.

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 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.

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.

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 $70^\circ\text{C} \pm 2$ K unless another temperature is specified in IEC 60684-3, and then allowed to cool to $23^\circ\text{C} \pm 5$ 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 $23^\circ\text{C} \pm 5$ 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.

6.3 Procedure

The specimens shall be suspended vertically in an oven 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, cracking or flowing. In addition, when so specified in IEC 60684-3, the specimens shall be tested for tensile strength and/or elongation at break.

6.4 Result

Report all results from the visual examination. 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.

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 Appendix C of IEC 60068-2-20.)

7.3 Procedure

With the sleeving at a temperature of $23^\circ\text{C} \pm 5 \text{ K}$, 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 $260^\circ\text{C} \pm 5 \text{ K}$ 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 ± 1) g.

8.2 Procedure

The specimens shall be conditioned by heating at $105\text{ }^{\circ}\text{C} \pm 2\text{ K}$ for 1 h and then allowed to cool in a desiccator to room temperature. They shall then be weighed to the nearest 0,000 2 g (m_1) and then heated in a ventilated furnace at $600\text{ }^{\circ}\text{C} \pm 10\text{ K}$ 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:

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

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 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 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.

10.2 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.

10.3 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.

10.4 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.

10.5 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.

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 °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:

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

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.

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 $(336 \pm 2) \text{ h}$ at a temperature of $40^\circ\text{C} \pm 3 \text{ K}$ 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 $100\text{ }^{\circ}\text{C} \pm 2\text{ K}$ for $(72 \pm 1)\text{ h}$.

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

18.1 Number and length of test specimens

Three specimens shall be tested, each approximately 150 mm long.

18.2 Conditioning

The test specimen shall be left loose on a flat surface in an ambient temperature of $23\text{ }^{\circ}\text{C} \pm 5\text{ K}$ for approximately 24 h. Thereafter, the specimen should be handled as little as possible to avoid increasing its temperature.

18.3 Apparatus

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

A length of sewing thread shall be attached to the mandrel and passed through the sleeving. The specimen shall be attached to the mandrel by a screw clamp as shown in Figure 4.

NOTE A polyethylene terephthalate sewing thread is suitable for this purpose, but for 0,5 mm bore sleeving, it may be necessary to use suction or a pull-through to get the thread through the sleeving.

The mandrel shall be provided with a means of rotating it through 270° . The weight shall be attached to the thread. The weight to be attached is specified in IEC 60684-3 for the particular type of sleeving relative to the bore size.

The thread below the sleeving shall pass and almost touch a scale of deflection in millimetres. A plumb line shall be used to ensure that the zero of the scale is directly below the side of the mandrel.

18.4 Test temperature

The test shall be made with the sleeving and the apparatus at $23\text{ }^{\circ}\text{C} \pm 2\text{ K}$.

18.5 Procedure

The mandrel shall be rotated so that the screw clamp used to anchor the sleeving is above the zero mark on the deflection scale. The weight shall be applied with the mandrel in this position and the mandrel shall immediately be rotated smoothly through 270°, at such a rate that it reaches the position shown in Figure 4 in about 10 s. The deflection shall be recorded (30 ± 5) s after completion of the rotation. If there is any curvature, the test shall be carried out with the curvature and not against it. The true deflection is obtained by subtracting the wall thickness of the sleeving under test from the deflection recorded.

NOTE It may be necessary to use a guide to ensure that the sleeving remains in a vertical plane.

18.6 Result

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

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

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.

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

19.1.1 Number of test specimens

Five specimens shall be tested.

19.1.2 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.

19.1.3 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.

19.1.4 Test temperature

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

19.1.5 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.

19.1.6 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):

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

where

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

A is the original cross-sectional area (mm²).

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.

19.1.7 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.

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

The test shall be carried out as in 19.1 but with the following changes.

19.2.1 Specimens shall be cut to the dimensions and tolerances given in Figure 5, 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.

19.2.2 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.

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

19.3 Tensile strength of uncoated glass textile sleeving

The test shall be carried out as in 19.1 but with the following changes.

19.3.1 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.

19.3.2 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.

19.4 Secant modulus at 2 % elongation

19.4.1 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 19.2.2.

19.4.2 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 $(0,1 \pm 0,03)$ mm/min for each millimetre length between jaws (e.g. 25 mm/min for a 250 mm length between jaws).
- a) 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.
- b) 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.

19.4.3 Calculation

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

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

where

- A is the initial average cross-sectional area of the specimen (mm^2) (determined as specified in 19.2.2);
- F_1 is the force required to produce a 2 % extension (N);
- F is the force applied to produce the initial (straightening) stress (N).

19.4.4 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.

19.5 Tensile stress at 100 % elongation

The test shall be carried out as in 19.1 or 19.2 as appropriate and in addition, the load shall be recorded when the distance between the reference lines is increased by 100 %.

19.5.1 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).

19.5.2 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.

19.6 Tensile stress at 100 % elongation and at elevated temperature

The test shall be carried out as in 19.5 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 6). 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

Clause 2 describes three test methods for the determination of breakdown voltage:

- a) shot bath test (air only);
- b) straight mandrel test, 100 mm foil electrode;
- c) 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.

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

21.1.1 Number and form of test specimens

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

21.1.2 Conditioning

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

21.1.3 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.

21.1.4 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.

21.1.5 Result

The reporting requirement and result for all methods is described in 21.7.

21.2 Shot bath test (air only)

21.2.1 Test specimen

A length of approximately 200 mm of sleeving shall be fitted over a smooth straight round conductor to form the test specimen. The conductor shall be of a diameter approximately that of the bore of the sleeving (and not less than 75 % of it). To avoid damage to the sleeving, the conductor shall have all burrs removed. For heat-shrinkable sleeving, the specimen shall be shrunk onto a metal mandrel having a diameter approximately equal to but not smaller than the specified maximum recovered bore of the sleeving.

21.2.2 Apparatus

21.2.2.1 Container

The specimen shall be placed in a metallic container designed to hold the specimen so that 100 mm of its length is immersed in shot. The dimensions of the container are unimportant provided this is achieved. It is convenient to use a container designed so that the shot can be poured over the sleeving by tilting the container. A convenient arrangement is shown in Figure 7.

21.2.2.2 Shot

The shot shall be 0,75 mm to 2,0 mm in diameter and can be nickel, nickel-plated or stainless steel but any shot of the required dimensions is suitable, provided it does not damage the sleeving and provides a conducting medium such that breakdown occurs when a voltage of 20 V a.c. is applied between the test electrode inserted in the middle of the shot and the walls of the container as shown in Figure 7.

21.2.3 Procedure

The shot shall be poured into the container so that it surrounds the specimen around the central 100 mm of its length and separates the specimen from all sides of the container. Care is needed to avoid damage to the specimen by the shot.

The voltage shall be applied between the conductor and the shot as described in 21.1.3.

21.3 Straight mandrel test, 100 mm foil electrode

21.3.1 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.

21.3.2 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 21.1.4).

21.3.3 Procedure

The voltage shall be applied between the two electrodes as described in 21.1.3.

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

21.4.1 Test specimen

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

21.4.2 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.

21.4.3 Procedure

The voltage shall be applied between the two electrodes as described in 21.1.3.

21.5 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 21.1.3 while the specimen is at the specified temperature.

21.6 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.

21.7 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 $23 \text{ °C} \pm 2 \text{ K}$.

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 $23^\circ\text{C} \pm 2\text{ K}$ and $(50 \pm 5)\%$ 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

Not applicable to textile-based sleeving.

23.1 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 $(50 \pm 5)\%$ relative humidity at a temperature of $23^\circ\text{C} \pm 2\text{ K}$.

23.2 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.