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Interested committees:

Title: Draft BS EN IEC 60684-2 Flexible insulating sleeving. Part 2: Methods of test.

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- iii) requires additional national guidance or information

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Introduction

This draft standard is based on national and international discussions. Your comments on this draft are invited and will assist in the preparation of the consequent standard.

For international standards, comments will be reviewed by the relevant UK national committee before sending the consensus UK vote and comments to the international committee, which will then decide appropriate action. If the international standard is approved, it is usual for the text to be published as a British Standard.

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UK Vote

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Template for comments and secretariat observations

Date: xx/xx/20xx	Document: ISO/DIS xxxx
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1	2	(3)	4	5	(6)	7
MB	Clause No./ Subclause No./Annex (e.g. 3.1)	Paragraph/Figure/ Table/Note	Type of comment	Commend (justification for change) by the MB	Proposed change by the MB	Secretariat observations on each comment submitted
	3.1	Definition 1	ed	Definition is ambiguous and needs clarifying.	Amend to read '...so that the mains connector to which no connection...'	
	6.4	Paragraph 2	te	The use of the UV photometer as an alternative cannot be supported as serious problems have been encountered in its use in the UK.	Delete reference to UV photometer.	



15/921/CD

COMMITTEE DRAFT (CD)

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15/920/RR

IEC TC 15 : SOLID ELECTRICAL INSULATING MATERIALS

SECRETARIAT:

United States of America

SECRETARY:

Mr John Gauthier

OF INTEREST TO THE FOLLOWING COMMITTEES:

TC 112

PROPOSED HORIZONTAL STANDARD:

☐

Other TC/SCs are requested to indicate their interest, if any, in this CD to the secretary.

FUNCTIONS CONCERNED:

☐ EMC

☐ ENVIRONMENT

☐ QUALITY ASSURANCE

☐ SAFETY

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TITLE:

Flexible insulating sleeving - Part 2: Methods of test

NOTE FROM TC/SC OFFICERS:

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FLEXIBLE INSULATING SLEEVING –**Part 2: Methods of test****FOREWORD**

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- International Standard IEC 60684-2 has been prepared by IEC technical committee 15: Solid electrical insulating materials.

146

147 This fourth edition cancels and replaces the third edition published in 2011, and constitutes a
148 minor revision and technical updating. The main changes from the previous edition are as
149 follows:

150 **Major update of normative references**

151 **Revised clause 3, with amendment of methods for measurements of bore and wall**
152 **thickness.**

153 **Revised clause 9, to clarify that the longitudinal change test is done on expanded**
154 **sleeving.**

155 **Revised clause 26, additional method D for flame propagation testing.**

156 **Revised clause 54, additional method for preparation of samples for adhesive peel test.**

157 **Addition of clause 61, abrasion test method.**

158 **Addition of clause 62, volume resistivity for semi-conducting materials**

159 **Addition of Clause 63, outgassing**

160 **Addition of clause 64, resistance to weathering**

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

FDIS	Report on voting

162

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

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

166 A list of all the parts in the IEC 60684 series, under the general title *Flexible insulating*
167 *sleeving*, can be found on the IEC website.

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

- 171 • reconfirmed,
- 172 • withdrawn,
- 173 • replaced by a revised edition, or
- 174 • amended.

175

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176

177

178

INTRODUCTION

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

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

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

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

184

185

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 62631-3-1:2016 Dielectric and resistive properties of solid insulating materials - Part 3-1: Determination of resistive properties (DC methods) - Volume resistance - General method

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: **2013**, *Electrical strength of insulating materials – Test methods – Part 1: Tests at power frequencies*

IEC 62631-2-1:2018, Dielectric and resistive properties of solid insulating materials - Part 2-1: Relative permittivity and dissipation factor - Technical Frequencies (0,1 Hz - 10 MHz) - AC Methods

- 224 IEC 60426:2007, *Electrical insulating materials – Determination of electrolytic corrosion caused*
225 *by insulating materials – Test methods*
- 226 IEC 60587:2007, *Electrical insulating materials used under severe ambient conditions – Test*
227 *methods for evaluating resistance to tracking and erosion*
- 228 IEC 60589:1977, *Methods of test for the determination of ionic impurities in electrical insulating*
229 *materials by extraction with liquids*
- 230 IEC 60684-3 (all parts), *Flexible insulating sleeving – Part 3: Specifications for individual types*
231 *of sleeving*
- 232 IEC 60695-6-30:1996, *Fire hazard testing – Part 6: Guidance and test methods on the*
233 *assessment of obscuration hazards of vision caused by smoke opacity from electrotechnical*
234 *products involved in fires – Section 30: Small scale static method – Determination of smoke*
235 *opacity – Description of the apparatus*
- 236 ***This has been withdrawn, is there an alternative? What should we refer to in the body of***
237 ***the specification?***
- 238 IEC/TS 60695-11-21 2005, *Fire hazard testing - Part 11-21: Test flames - 500 W vertical flame*
239 *test method for tubular polymeric materials*
- 240 IEC 60754-1:1994-**2011**, *Tests on gases evolved during combustion of materials from cables –*
241 *Part 1: Determination of the amount of halogen acid gas*
- 242 IEC 60754-2:1994-**2011**, *Test on gases evolved during combustion of electric cables – Part 2:*
243 *Determination of degree of acidity of gases evolved during the combustion of materials taken*
244 *from electric cables by measuring pH and conductivity*
245 *Amendment 1 (1997)*
- 246 ISO 5-1:2009, *Photography and graphic technology – Density measurements – Part 1:*
247 *Geometry and functional notation*
- 248 ISO 5-2:2009, *Photography and graphic technology – Density measurements – Part 2:*
249 *Geometric conditions for transmittance density*
- 250 ISO 5-3:2009, *Photography and graphic technology – Density measurements – Part 3: Spectral*
251 *conditions*
- 252 ISO 5-4:2009, *Photography and graphic technology – Density measurements – Part 4:*
253 *Geometric conditions for reflection density*
- 254 ISO 37:2005, *Rubber, vulcanized or thermoplastic – Determination of tensile stress-strain*
255 *properties*
- 256 ISO 62:2008, *Plastics – Determination of water absorption*
- 257 ISO 105-A02, *Textiles – Tests for colour fastness – Part A02: Grey scale for assessing change*
258 *in colour*
- 259 ISO 105-B01, *Textiles – Tests for colour fastness – Part B01: Colour fastness to light: Daylight*
- 260 ISO 182-1:1990, *Plastics – Determination of the tendency of compounds and products based*
261 *on vinyl chloride homopolymers and copolymers to evolve hydrogen chloride and any other*
262 *acidic products at elevated temperature – Part 1: Congo red method*

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

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

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

269 ISO 13943: 2008, *Fire safety – Vocabulary*

270 ISO 4589-2:1996 **2017**, *Plastics – Determination of burning behaviour by oxygen index – Part*
271 *2: Ambient-temperature test*

272 ISO 4589-3:1996 **2017**, *Plastics – Determination of burning behaviour by oxygen index – Part*
273 *3: Elevated-temperature test*

274 **ASTM E595 15, Standard Test Method for Total Mass Loss and Collected Volatile**
275 **Condensable Materials from Outgassing in a Vacuum Environment**

276 **ISO 4892-3:2016, Plastics – Methods of exposure to laboratory light sources – Part 3:**
277 **Fluorescent UV lamps**

278 **2 Test conditions**

279 **2.1** Unless otherwise specified, all tests shall be made under standard ambient conditions
280 according to IEC 60212; i.e., at a temperature between 15 °C and 35 °C and at ambient relative
281 humidity.

282 In cases of dispute, the tests shall be carried out at a temperature of 23 °C ± 2 K and at
283 (50 ± 5) % relative humidity.

284 **2.2** When heating at elevated temperature is specified for a test procedure, the specimen
285 shall be maintained for the prescribed period in a uniformly heated oven complying with
286 IEC 60216-4-1.

287 **2.3** Where a test at low temperature is specified, the specification sheets of IEC 60684-3 may
288 require it to be carried out at $-t$ °C or lower. In such cases the operator may carry out the test
289 at the specified temperature or any lower temperature which is convenient. If, however, at a
290 temperature below that specified the specimen fails to meet the requirements, the test shall be
291 repeated at the specified temperature, subject to a tolerance of ± 3 K as specified in
292 IEC 60212. If the specimen then passes, it shall be considered to have met the requirements.

293 **3 Measurements of bore, wall thickness and concentricity**

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

295 **3.1 Bore**

296 **3.1.1 Number of test specimens**

297 Three specimens shall be tested.

298 **3.1.2 General method**

299 **Plug or taper gauges of appropriate diameter or an optical method shall be used to establish**
300 **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.

Measurements shall be made to the nearest 0,05 mm for sizes 10 mm and below and to the nearest 0,1 mm for sizes above 10 mm. For shrink sleeving use a tapered gauge to measure the unshrunk minimum diameter. For bore sizes 2 mm and below and inner coated sleeveings a micrometer microscope shall be used and measurements shall be made to the nearest 0,05 mm.

Cut short lengths between 2 mm and 20 mm and ensure the ends are cut square. If during the preparation of these short lengths for heat shrink sleeving they are distorted, re-condition for (5 ± 1) min at the temperature specified in the part 3 sheet for recovery.

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. **When using a pin micrometer care should be taken not to compress the wall.**

3.3.2.1 Wall correction for Heat Shrink sleeving

When specified in the part 3 sheet, use the following formula when the sleeving is fully shrunk.

S_{min} (corrected min wall thickness) = $(S_{min} \times d1) / d1_{max}$

S_{max} (corrected max wall thickness) = $(S_{max} \times d1) / d1_{max}$

Where :

$d1$ = measured recovered internal diameter

$d1_{max}$ = Specified maximum recovered internal diameter in part 3 sheet

S_{max} = measured maximum wall thickness

S_{min} = measured minimum wall thickness

3.3.3 Concentricity

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

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

380

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.

391

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 $70^\circ\text{C} \pm 2\text{ K}$ unless another temperature is specified in IEC 60684-3, and then allowed to cool to $23^\circ\text{C} \pm 5\text{ K}$. 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 $23^\circ\text{C} \pm 5\text{ K}$ 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 $105\text{ }^{\circ}\text{C} \pm 2\text{ K}$ for 1 h and then allowed to cool in a desiccator to room temperature. They shall then be weighed to the nearest 0,0002 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 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. **This test is carried out on expanded sleeve, do not shrink prior to test.**

9.2 Form of test specimen

Each specimen of **expanded** 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 **marked** 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 the **appropriate** IEC 60684-3 **sheets**.

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.

503 9.5 Result

504 Report all values for longitudinal change as the result.

505 10 Deformation under load (resistance to pressure at elevated temperature)**506 10.1 Method A****507 10.1.1 Number of test specimens**

508 Three specimens shall be tested.

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

510 10.1.2 Form of test specimen

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

515 10.1.3 Apparatus

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

521 The assembly shall be placed in an oven maintained at $110\text{ }^{\circ}\text{C} \pm 2\text{ K}$ during the heating period,
522 unless another temperature is specified in IEC 60684-3. To minimize vibration, a gravity-
523 circulated oven, mounted on suitable damping pads, shall be used.

524 10.1.4 Procedure

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

529 The assembly with mandrel but without the test specimen shall be conditioned for at least 2 h
530 before the test in the oven at $110\text{ }^{\circ}\text{C} \pm 2\text{ K}$, unless another temperature is specified in
531 IEC 60684-3.

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

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

537 The assembly and test specimen shall then remain in the oven at the specified temperature for
538 (60 ± 5) min.

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

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

544 10.1.5 Result

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

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

549 10.2 Method B

550 10.2.1 Number of test specimen

551 As method A.

552 10.2.2 Form of test specimen

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

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

559 10.2.3 Apparatus

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

561 Air circulating oven.

562 Weights as follows, mounted in the metal frame, so as to provide free vertical movement, as
563 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

564

565 Pressure foot discs, ($9,5 \pm 0,1$ mm), slightly rounded at the edges.

566 10.2.4 Procedure

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

571 $T_1 = (D_1 - d)/2$ where D is the diameter over the sleeving and d is the diameter of the metal
572 conductor.

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

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

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

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

583 Calculate the percentage deformation using the following formula:

584
$$\% \text{ deformation} = (T_1 - T_2)/T_1 \times 100$$

585 where

586 T_1 is the original thickness, and

587 T_2 is the thickness after conditioning.

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

590 **10.2.5 Result**

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

593 **11 Thermal stability of PVC sleeving**

594 **11.1 Principle**

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

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

600 **11.2 Form of test specimen**

601 **11.2.1 ISO 182-1 method**

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

605 **11.2.2 ISO 182-2 method**

606 To prepare specimens, cut pieces of sleeving approximately 5 mm² to 6 mm² in size and place
607 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 $200 \text{ }^\circ\text{C} \pm 3 \text{ K}$ 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.

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

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

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

651 **13.4 Result**

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

653 **14 Bending at low temperature**

654 **14.1 Number and form of test specimens**

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

661 **14.2 Procedure**

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

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

671 **14.3 Result**

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

673 **15 Brittleness temperature**

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

675 For sleeving of nominal bore up to 4 mm diameter, the specimen shall be cut in full section
676 40 mm long. For sleeving of bore larger than 4 mm, the specimen shall be 6 mm wide
677 and 40 mm long, with the longer dimension parallel to the longitudinal axis. The strip
678 specimens shall be mounted so that the hammer strikes the convex side of the specimen.

679 **16 Dimensional stability on storage** (applicable to heat-shrinkable sleeving only)

680 **16.1 Number and length of test specimens**

681 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.

722 18.2 Procedure

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

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

729 18.3 Report

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

733 19 Tensile strength, tensile stress at 100 % elongation, elongation at break 734 and secant modulus at 2 % elongation

735 19.1 General

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

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

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

747 19.2 Tensile strength and elongation at break for full-section sleeving

748 19.2.1 Number of test specimens

749 Five specimens shall be tested.

750 19.2.2 Form of test specimen

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

756 19.2.3 Conditioning

757 Unless otherwise specified in IEC 60684-3, the test specimen shall be kept at an ambient
758 temperature of $23\text{ °C} \pm 2\text{ K}$ for 1 h immediately before testing, or for a longer time to enable the
759 specimen to reach a temperature of $23\text{ °C} \pm 2\text{ K}$.

760 19.2.4 Test temperature

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

762 19.2.5 Procedure

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

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

766 The specimen shall be mounted in the tensile test machine in axial alignment with the direction
767 of pull. The jaws shall be separated at the uniform rate specified in IEC 60684-3 for a particular
768 material. The range of the testing machine shall be such that the maximum load is between
769 15 % and 85 % of the maximum scale reading.

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

772 The maximum load shall be measured to the nearest 2 %. The distance between the reference
773 lines at break shall be measured to within 2 mm.

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

776 19.2.6 Calculations

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

$$779 \quad \text{tensile strength (MPa)} = \frac{F_{\max.}}{A}$$

780 where

781 $F_{\max.}$ is the maximum load (N);

782 A is the original cross-sectional area (mm²) calculated using the following formula:

$$783 \quad A = (\pi/4) \times (D_o^2 - D_i^2) = 0,7854 (D_o^2 - D_i^2)$$

784 where

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

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

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

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

$$791 \quad \text{elongation at break (\%)} = \frac{L - L_0}{L_0} 100$$

792 where

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

794 L_0 is the original distance between the marks.

19.2.7 Result

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

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

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

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

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

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

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

19.4 Tensile strength of uncoated glass textile sleeving

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

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

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

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

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

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

19.5 Secant modulus at 2 % elongation**19.5.1 Number and form of test specimens**

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

19.5.2 Procedure

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

b) Depending on the method of measurement chosen, the length of specimen between the jaws or reference lines shall be not less than 100 mm nor greater than 250 mm.

- c) The extension may be measured by means of an extensometer or by jaw separation; the extension shall be measured to an accuracy of 2 %.
- d) The strain rate shall be $(0,1 \pm 0,03)$ mm/min for each millimetre length between jaws (e.g. 25 mm/min for a 250 mm length between jaws).
- e) An initial tensile force (F) may need to be applied to the specimen for the purpose of straightening it. This force shall not exceed 3 % of the final value.
- f) The force shall be increased until the extension between the jaws or reference lines reaches 2 %. The force (F_1) required to produce this extension shall be recorded.

19.5.3 Calculation

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

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

where

A is the initial average cross-sectional area of the specimen (mm²) (determined as specified in 19.3.3);

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

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

19.5.4 Result

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

19.6 Tensile stress at 100 % elongation

19.6.1 General

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

19.6.2 Calculation

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

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

where

A is the initial average cross-sectional area of the specimen (mm²);

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

19.6.3 Result

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

19.7 Tensile stress at 100 % elongation and at elevated temperature

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