BS 7870-2:2011

BSI Standards Publication

LV and MV polymeric insulated cables for use by distribution and generation utilities

Part 2: Methods of test

(Implementation of HD 605 S2:2008)

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Contents

List of tables

Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 36, an inside back cover and a back cover.

Foreword

Publishing information

This part of BS 7870 is published by BSI and came into effect on 31 December 2011. It was prepared by Subcommittee GEL/20/16, *Medium/High voltage cables*, under the authority of Technical Committee GEL/20, *Electric cables*. A list of organizations represented on these committees can be obtained on request to their secretary.

Supersession

This part of BS 7870 supersedes BS 7870-2:1999, which is withdrawn.

Relationship with other publications

BS 7870 implements the nationally applicable parts of Harmonization Documents HD 603, 605, 620, 626 and 627 published by the European Committee for Electrotechnical Standardization (CENELEC), in accordance with the decision of the CENELEC Technical Board.

BS 7870 applies to cables for fixed installation having rated voltage U_0/U up to and including 19/33 kV, and is published as a series of separate parts and sections, as listed in the table in the foreword of BS 7870-1.

This part of BS 7870 implements the nationally applicable parts of HD 605 S2:2008.

BS 7870-2:2011 should be read in conjunction with BS 7870-1:2011 and the appropropriate parts and sections of BS 7870, a number of which have been updated to 2011 editions.

Information about this document

This is a full revision of the standard, which brings the standard up to date in accordance with current practice in the industry.

Clause numbering system. The clause numbering system used in this part of BS 7870 aligns with HD 605 S2:2008 to facilitate cross-referencing, except for Section 1 and the annexes. However, where a particular test is not specified in the separate parts and sections of BS 7870, the relevant clauses and/or subclauses are marked "N/A" (not applicable).

Hazard warnings

WARNING. This British Standard calls for the use of substances and/or procedures that can be injurious to health if adequate precautions are not taken. It refers only to technical suitability and does not absolve the user from legal obligations relating to health and safety at any stage.

Use of this document

It has been assumed in the preparation of this British Standard that the execution of its provisions will be entrusted to appropriately qualified and experienced people, for whose use it has been produced.

Presentational conventions

The provisions of this standard are presented in roman (i.e. upright) type. Its methods are expressed as a set of instructions, a description, or in sentences in which the principal auxiliary verb is "shall".

Commentary, explanation and general informative material is presented in smaller italic type, and does not constitute a normative element.

Contractual and legal considerations

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a British Standard cannot confer immunity from legal obligations.

Section 1 General

1.1 Scope

BS 7870-2 collates and specifies the test methods to be used for testing polymeric insulated and sheathed electric cables, of rated voltage up to and including 19/33 kV, intended for public distribution systems, and for use in power generating plants and sub-stations.

The test methods in this part of BS 7870 are additional to those already harmonized, e.g. in the BS EN 60332 series and the BS EN 60811 series, and are for use for testing cable types specified in BS 7870-3, BS 7870-4 and BS 7870-5. In each case, these standards give complementary information needed for the practical application of the test method to each specific type of cable. Therefore BS 7870-2:2011, as such, is not sufficient for carrying out and evaluating the tests on electric cables.

Full test conditions (e.g. temperatures, durations) and/or requirements to be met are not specified in this standard. Such data needed to carry out the tests is given in the particular sections of BS 7870.

NOTE The words "particular section" refer throughout to the individual sections of BS 7870 in which particular cable types are specified.

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.

BS 5099, *Electric cables – Voltage levels for spark testing*

BS EN 10244-2:2009, *Steel and wire products – Non-ferrous metallic coatings on steel wire – Part 2: Zinc or zinc alloy coatings*

BS EN 60228, *Conductors of insulated cables*

BS EN 60230, *Impulse tests on cables and their accessories*

BS EN 60811-1-1, *Insulating and sheathing materials of electric and optical cables – Common test methods – Part 1-1: General application – Measurement of thickness and overall dimensions – Tests for determining the mechanical properties*

BS EN 60811-1-2, *Insulating and sheathing materials of electric cables – Common test methods – Part 1-2: General application – Thermal ageing methods*

BS EN 60885-3, *Electrical test methods for electric cables – Part 3: Test methods for partial discharge measurements on lengths of extruded power cables*

BS EN 62230, *Electric cables – Spark test method*

BS EN ISO 4892 (all parts), *Plastics – Methods of exposure to laboratory light sources*

1.3 Applicable tests

Tests applicable to each type of cable are given in the particular sections which, where applicable, also specify the test sequence, the frequency of testing, and the possibility of repeating failed tests.

1.4 Sampling

The size and number of samples are specified either in this standard or in the particular section of BS 7870.

If a marking is indented in the insulation or sheath surface, the samples used for the tests shall be taken so as to include such markings.

For multicore cables, except for the test specified in **2.1.1**, not more than three cores (of different colours, if available) shall be tested, unless otherwise specified for a particular test.

1.5 Test conditions

1.5.1 Ambient temperature

Unless otherwise specified in the details for the particular test, tests shall be carried out at an ambient temperature of (20 ±15) °C.

1.5.2 Tolerance on temperature values

Unless otherwise specified in the particular section, the tolerances on the temperature values quoted in the test methods shall be as given in Table 1.5.2.

Table 1.5.2 **Tolerances on temperature values**

Specified temperature, t	Tolerance
°C	K
$-40 \leq t \leq 0$	±2
$0 < t \leq 50$	according to relevant clause
$50 < t \leq 150$	±2
$t > 150$	±3

1.5.3 Frequency and waveform of power-frequency test voltages

Unless otherwise specified in the details for the particular test, the test voltage shall be in the range 49 Hz to 61 Hz, of approximately sine-wave form, the peak ratio value/r.m.s. value being equal to $\sqrt{2}$ with a tolerance of ±7%. The values given are r.m.s.

1.5.4 Pre-conditioning

Unless otherwise specified in the details for the particular test, the tests shall be carried out not less than 16 h after the extrusion or cross-linking, if any, of the insulating or sheathing compounds.

1.6 Rounding of numbers

It may be required that values are rounded to one or more decimal places. This may occur, for instance, in calculating the average value of several measurement results, or the minimum value by applying a percentage tolerance to a given nominal value. In these cases, rounding shall be carried out to the number of decimal places specified in the relevant clauses. The method of rounding shall then be as follows:

a) if the last figure to be retained is followed, before rounding, by 0, 1, 2, 3 or 4, it shall remain unchanged (rounding down);

b) if the last figure to be retained is followed, before rounding, by 9, 8, 7, 6 or 5, it shall be increased by one (rounding up).

EXAMPLES:

2.449 ≈2.45 rounded to two decimal places
2.449 ≈2.4 rounded to one decimal place

25.0478 ≈25.048 rounded to three decimal places
25.0478 ≈25.05 rounded to two decimal places
25.0478 ≈25.0 rounded to one decimal place

Section 2 Non-electrical tests

2.1 Dimensional measurements

2.1.1 Measurement of insulation thickness

2.1.1.1 Procedure

The thickness of the insulation shall be measured in accordance with BS EN 60811-1-1, **8.1**. Unless otherwise specified, one sample of cable shall be taken and measurements made at three places.

Conformity shall be checked on each core of cables having up to five cores, and on the number of cores stated in the particular section for cables with more than five cores.

If withdrawal of the conductor is difficult, it shall be stretched in a tensile testing machine, or the piece of core shall be immersed in an appropriate liquid until the insulation becomes loose.

2.1.1.2 Evaluation of results

Unless otherwise specified, the mean of the 18 values (expressed in millimetres) obtained from the three pieces of insulation from each core shall be calculated to two decimal places and rounded up or down as given below, and this shall be taken as the mean value of the thickness of the insulation.

If in the calculation the second decimal figure is 5 or more, the first decimal figure shall be raised to the next number; thus, for example, 1.74 shall be rounded to 1.7 and 1.75 to 1.8.

The lowest of all the values obtained shall be taken as the minimum thickness of the insulation at any place.

2.1.2 Measurement of non-metallic sheath thickness

2.1.2.1 Procedure

The thickness of the sheath shall be measured in accordance with BS EN 60811-1-1, **8.2**. Unless otherwise specified, one sample of cable shall be taken and measurements made at three places.

2.1.2.2 Evaluation of results

The mean of all the values (expressed in millimetres) obtained from the three pieces of sheath shall be calculated to two decimal places and rounded up or down as given below, and this shall be taken as the mean value of the thickness of the sheath.

If in the calculation the second decimal figure is 5 or more, the first decimal figure shall be raised to the next number; thus, for example, 1.74 shall be rounded to 1.7 and 1.75 to 1.8.

The lowest of all the values obtained shall be taken as the minimum thickness of the sheath at any place.

2.1.3 Measurement of cable dimensions

2.1.3.1 Measurement of overall dimensions

Unless otherwise specified, the three samples taken in accordance with **2.1.1** or **2.1.2** shall be used.

The measurement of the overall diameter of any circular cable and of the overall dimensions of flat cables with a major dimension not exceeding 15 mm shall be carried out in accordance with BS EN 60811-1-1, **8.3**.

For the measurement of flat cables with a major dimension exceeding 15 mm, a micrometer, a profile projector or similar equipment shall be used.

The mean of the values obtained shall be taken as the mean overall dimensions.

2.1.3.2 Measurement of ovality

For checking the ovality of circular sheathed cables, two measurements shall be made at the same cross-section of the cable, covering the maximum and minimum values.

2.1.4 Measurement of wires, strips and tapes

2.1.4.1 N/A

2.1.4.2 N/A

2.1.4.3 Wires, strips and tapes from armour

Measurement of wires, strips and tapes from armour shall be carried out as follows.

a) **Round wires**

Take at random 10 wires or 10% of the total number of wires, whichever is the lesser, from a sample of the completed cable.

Determine the diameter of each wire in this sample of wires by taking two measurements at right angles to each other using a micrometer with flat noses to an accuracy of ±0.01 mm.

Take the average value as the wire diameter.

b) **Flat wires or strips**

Take at random 10 flat wires or strips or 10% of the total number of flat wires or strips, whichever is the lesser, from a sample of the completed cable.

Determine the thickness and width of each flat wire or strip in this sample of flat wires or strips by using either a micrometer with flat noses to an accuracy of ±0.01 mm or a vernier calliper with flat noses to an accuracy of ±0.02 mm.

Take the average values as the wire or strip thickness and wire or strip width.

c) **Metallic tapes thickness**

Take and straighten a sample of each armour tape, remove the non-metallic coating, if any, and determine the tape thickness at six different places.

The measurement shall be made with either a micrometer or a vernier calliper, both with two flat noses of approximately 5 mm in diameter, to an accuracy of ±0.01 mm or ±0.02 mm, respectively. For tapes up to 40 mm in width the thickness shall be measured at the centre of the width. For wider tapes the measurements shall be made 20 mm from each edge of the tape and the average of the results taken as the thickness.

Take the smallest value to compare with the specified thickness and tolerance given in the particular section.

2.1.5 Measurement of thickness of metallic sheath

The thickness of lead sheaths shall be determined by one of the following methods, at the discretion of the manufacturer. (Methods of measuring thickness of other types of metallic sheath are under consideration.)

a) **Strip method**

The measurement shall be made on a test piece of sheath about 50 mm in length removed from the finished cable length. The test piece shall be taken a sufficient distance from the cable end to allow a proper measurement to be made.

The test piece shall be slit longitudinally and carefully flattened. After cleaning the test piece, a number of measurements shall be taken along the circumference of the sheath and not less than 10 mm away from the edge of the flattened test piece to ensure that the minimum thickness is measured. The measurement shall be made with a micrometer with plane faces of 2 mm to 8 mm diameter and an accuracy of ±0.01 mm.

b) **Ring method**

The measurements shall be made on a ring of the sheath carefully cut from the finished cable length. The thickness shall be determined at a sufficient number of points around the circumference of the ring to ensure that the minimum thickness is measured.

The measurements shall be made with a micrometer having either one flat nose and one ball nose, or one flat nose and one flat rectangular nose 0.8 mm wide and 2.4 mm long. The ball nose or the flat rectangular nose shall be applied to the inside of the ring. The accuracy of the micrometer shall be ±0.01 mm.

2.1.6 Check of application of screen or armour tapes, or wires

2.1.6.1 Method 1

Take a cable sample 300 mm long, at not less than 150 mm from the end of a factory length. Measure the gap between adjacent edges of the tape(s), and also the tape width. Measurements shall be made at 4 positions along the sample, with an accuracy better than 0.5 mm.

2.1.6.2 Method 2

Remove two rings of the oversheath each 50 mm in length, cut at a distance of 5*D* and 15*D*, respectively, (where *D* is the overall cable diameter) from one end of the cable length, so as to expose the metallic tapes or wires.

Make a visual examination of the exposed components and measure the largest gap between adjacent wires or tapes. The measurement shall be made with an accuracy better than 0.5 mm and the result shall be given to one decimal place.

2.1.7 N/A

2.1.8 Measurement of gap between non-metallic tapes of taped bedding

See **2.1.6.1**.

2.1.9 N/A

2.1.10 Irregularities of semi-conducting layers and insulation

2.1.10.1 N/A

2.1.10.2 N/A

2.1.10.3 N/A

2.1.10.4 N/A

2.1.10.5 Method 5 – Method for inspection for protrusions, contaminants and discoloured particles in XLPE insulation

This test method is to determine the presence of discontinuities at the semi-conducting screen/insulation interfaces and the presence of contaminants (opaque impurities) and discoloured particles in the insulation. Testing shall be carried out as follows.

a) **Sample preparation**

Test pieces shall be prepared from 300 mm lengths of core. Samples 25 mm long shall be cut from each end of the core to give samples A_1 and A_2.

The remaining portion shall be cut into two pieces of equal length to give samples B and C.

The insulation screen shall be removed from sample B and this shall be cut into further pieces to give samples B_1 and B_2.

b) **Test method to determine discontinuities**

Immerse samples A_1 and B_1 in glycerol or polyethylene glycol or similar liquid contained in a glass beaker and maintained at 130 °C to 150 °C, or alternatively heat up the samples in an air oven to a similar temperature. Allow the samples to attain the approximate liquid or air temperature such that the insulation becomes transparent.

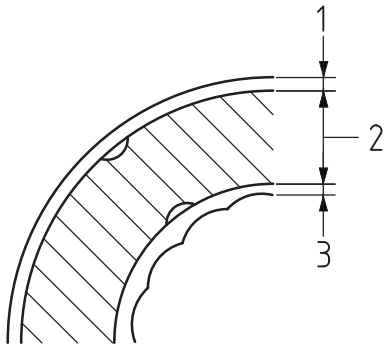
The interfaces shall be examined in a good light with normal or corrected vision without magnification.

Examine by viewing along the conductor axis the conductor screen/insulation and insulation screen/insulation interfaces and the insulation of sample A_1, and by viewing radially the conductor screen/insulation interface and the insulation of sample B_1.

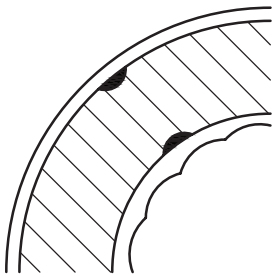
The conductor and insulation screens shall be bonded to the insulation with no traces of dissociation between them [see Figure 2.1.10.5a)]. There shall be no detectable traces of any inclusions between the screen and the insulation [see Figure 2.1.10.5b)]. The insulation material shall not have broken through the screen [see Figure 2.1.10.5c)] nor shall there be any penetration of the insulation by the screen material [see Figure 2.1.10.5d)].

Repeat on samples A_2 and B_2.

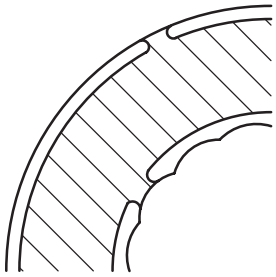
Figure 2.1.10.5 **Dissociation, inclusions and penetration**



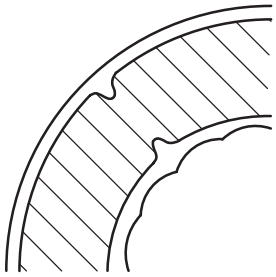
a) Dissociation of bonding between insulation and conductor and insulation screens



b) Inclusions between screen and insulation



c) Insulation breaking through screen



d) Penetration of screen into insulation

Key

1 Insulation screen

2 Insulation

3 Conductor screen

c) **Test method to determine contaminants and discoloured particles**

Samples for examination shall be produced by cutting wafers from sample C.

At least 5 cm^3 of insulation shall be examined using a microscope based measuring system at a minimum magnification of ×20.

Requirements shall be as follows.

i) **Contaminants**

- 0.05 mm < largest dimension ≤ 0.15 mm: 1 per cm^3 maximum;
- 0.15 mm < largest dimension: rejected.

ii) **Discoloured particles**

- 1.25 mm < largest dimension: rejected.

2.1.10.6 N/A

2.1.11 Dimensions of cores

2.1.11.1 N/A

2.1.11.2 N/A

2.1.11.3 Method 3 – Thickness of semi-conducting layers

From a sample of completed cable, remove very carefully the conductor and any external covering to the cable core without damaging the semi-conducting layers.

With a sharp knife or blade cut a thin slice of the semi-conducting layers perpendicular to the conductor axis.

By means of a microscope with a resolution of 0.01 mm or a projection enlarger, with a magnification of ×10 (but in case of doubt only the microscope is allowed), take a total of six radial measurements of the thickness of each of the semi-conducting layers, preferably equally spaced around the circumference of the slice.

In the case of the inner semi-conducting layer the six measurements shall be taken at the thinnest parts of the layer, over the wire impressions.

The readings, expressed in millimetres, shall be taken to two decimal places.

The average of the six measurements for each layer shall be taken as the thickness of the layer.

2.1.12 N/A

2.1.13 N/A

2.1.14 N/A

2.1.15 N/A

2.2 Mechanical tests on non-metallic components

2.2.1 N/A

2.2.2 Determination of tear resistance of the protective sheath

2.2.2.1 N/A

2.2.2.2 Method 2

This test method is to determine the tear resistance of sheathing materials.

Testing shall be carried out as follows.

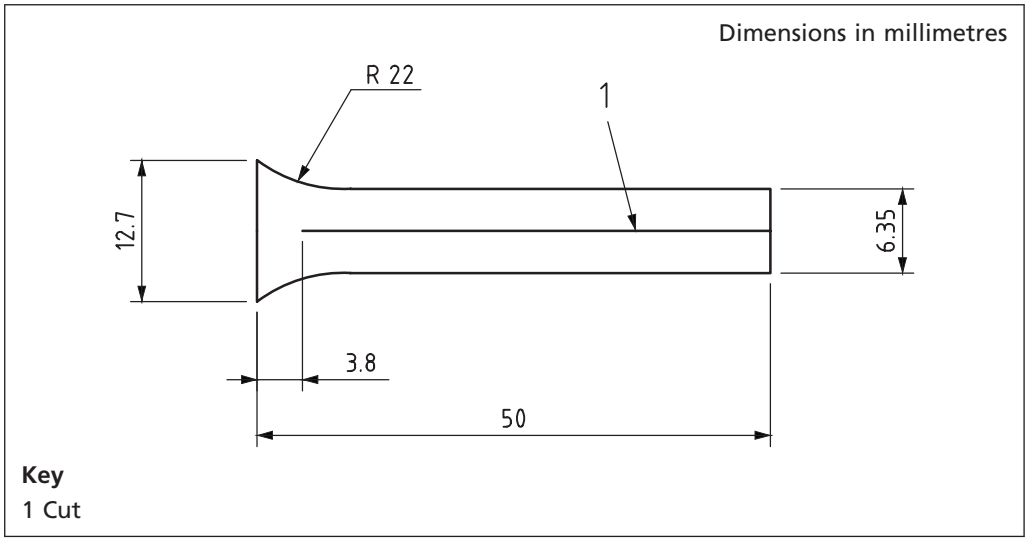
a) **General**

The tear resistance shall be measured along the direction of the cable axis and also, where possible, at right angles following the direction of the cable circumference.

b) **Preparation of test pieces**

Prepare six test pieces having dimensions as shown in Figure 2.2.2.2, with a thickness not greater than 4.0 mm and not less than 1.0 mm. Cut these, preferably along the direction of the cable axis, by means of a sharp knife or die from portions of the sheath from which all irregularities or corrugations, if present, have been removed by grinding or cutting. Make a central longitudinal cut, perpendicular to the width of the test piece, with a sharp razor blade to a point 3.8 mm from the wider end.

Figure 2.2.2.2 **Test piece for tear resistance test method 2**



c) **Conditioning of test pieces**

Before the start of the test, keep the test pieces for at least 3 h at the temperature at which the test is to be carried out, which shall be (20 ±5) °C, and commence testing within 5 min of removal from the conditioning chamber.

d) **Procedure**

Test each test piece in the following way. Place the halves of the split end in the jaws of a tensile testing machine and separate the jaws at a rate between 350 mm/min and 500 mm/min.

e) **Evaluation of results**

Determine the tear resistance by dividing the maximum load, in newtons, required to tear the uncut section, by the thickness of the test piece, in millimetres. Arrange the results in order of increasing value and take the average of the two middle values as the tear resistance.

2.2.3 N/A

2.2.4 N/A

2.2.5 N/A

2.2.6 N/A

2.2.7 (Spare)

2.2.8 Strippability test on extruded semi-conducting insulation screen

2.2.8.1 Method 1

This test shall be carried out when the manufacturer claims that the extruded semi-conducting insulation screen is strippable.

The test shall be performed three times, using either three separate pieces of cable or one piece of cable at three positions around the circumference, spaced at approximately 120°.

Core lengths of at least 250 mm shall be taken from the cable to be tested.

Two cuts shall be made in the extruded semi-conducting insulation screen of each sample, longitudinally from end to end and radially down to the insulation, the cuts being (10 ±1) mm apart and parallel to each other.

After removing approximately 50 mm length of the 10 mm strip by pulling it in a direction parallel to the core (i.e. a stripping angle of approximately 180°), the core shall be mounted vertically in a tensile testing machine with one end of the core held in one grip and the 10 mm strip in the other.

The force required to separate the 10 mm strip from the insulation, removing a length of at least 10 mm, shall be measured at a stripping angle of approximately 180° using a pulling speed of (250 ±50) mm/min.

The test shall be carried out a temperature of (20 ±5) °C.

For unaged and aged samples, the stripping force values shall be continuously recorded.

2.2.8.2 N/A

2.2.8.3 N/A

2.2.8.4 N/A

2.2.8.5 N/A

2.2.8.6 Method 6

See **2.2.8.1**.

2.2.8.7 N/A

2.2.8.8 Method 8

See **2.2.8.1**.

2.2.9 N/A

2.2.10 N/A

2.2.11 Insulation screen cutting test

The insulation screen at each end of the cable shall be cut horizontally for a distance of 100 mm, at its thinnest position as determined by visual examination, using a guarded knife with the blade set at a depth of 0.5 mm. The screen shall then be removed and the insulation examined. If there is no cut in the insulation the whole cable length shall be regarded as satisfactory.

2.2.12 Water immersion test on sheath

2.2.12.1 General

This test is to demonstrate the effect of water on the mechanical properties of sheath by determining the tensile strength and elongation at break of the sheathing material in the condition as manufactured and after immersion in water.

The tensile tests on the conditioned and unconditioned test pieces shall be made in immediate succession.

2.2.12.2 Sampling and preparation of test pieces

Test pieces shall be prepared in accordance with BS EN 60811-1-1, **9.2.3**.

2.2.12.3 Procedure

The dumb-bell test pieces shall be immersed in approximately 1 L of de-ionized water for the time and at the temperature given in the particular section. Following immersion the test pieces shall be allowed to cool to a temperature of (20 ±5) °C before removing them from the water. The test pieces shall then be dried with absorbent paper and within 60 min of drying both the tensile strength and elongation at break shall be measured in accordance with BS EN 60811-1-1, **9.2**.

2.2.12.4 Evaluation of results

The tensile strength and elongation at break shall be calculated in accordance with BS EN 60811-1-1, **9.2.8**.

2.2.13 N/A

2.3 Mechanical tests on metallic components

2.3.1 N/A

2.3.2 Wrapping test for galvanized steel wire

Take at random 10% of the total number of wires from one sample of completed cable. Wrap each wire round a cylindrical mandrel for one complete turn. The mandrel shall have a diameter of approximately four times the specified diameter of the wire under test.

2.3.3 N/A

2.3.4 N/A

2.4 Non-electrical tests on samples of complete cable

2.4.1 Bend tests for complete cable

2.4.1.1 Standard bend test for complete cable

A sample of cable of sufficient length shall be bent around a test cylinder for one complete turn unless otherwise specified. It shall then be unwound and the process repeated, except that the sample shall be bent in the reverse direction. This cycle of operations shall be carried out three times.

Instead of turning the sample, it is permissible to reverse the direction of rotation around the test cylinder, the sample being positioned either above or below the cylinder depending on the direction of rotation. Bending shall be carried out at a reasonably uniform speed, each half cycle taking between 0.5 s and 1.0 s per millimetre diameter of cable.

If the test is to be carried out at other than ambient temperature then it shall be performed immediately after conditioning.

The test temperature and test cylinder diameter shall be as given in the particular section.

2.4.1.2 N/A

2.4.1.3 N/A

2.4.1.4 N/A

2.4.1.5 N/A

2.4.1.6 N/A

2.4.1.7 Method B

Bend a cable sample around a test cylinder at ambient temperature for at least one complete turn. Unwind and repeat the process but this time bend the sample in the reverse direction.

Perform this cycle of operations a total of three times and examine the sample with normal or corrected vision without magnification.

The diameter of the test cylinder shall be not greater than the following unless otherwise stated in the particular section:

- for single-core unarmoured cables: 20(D + d);
- for single-core armoured cables: 15(D + d);
- for three-core unarmoured cables: 15(D + d);
- for three-core armoured cables: 12(D + d);

where:

D is the measured overall diameter of the cable in millimetres (mm);

d is the measured diameter of the conductor, in millimetres (mm).

NOTE If the conductor is not circular, $d = 1.13\sqrt{S}$, where S is the nominal cross-section in millimetres squared (mm^2).

After completion of the bending test, visually examine the sample and subject it to a partial discharge test as specified in the particular section.

2.4.1.8 Cold bend test

A sample of the cable with a length of at least five times the test cylinder diameter shall be subjected to a partial discharge test in accordance with BS EN 60885-3. The sample shall then be cooled to 0 °C for at least 4 h.

The sample shall then, without delay, be bent around a test cylinder, for at least one complete turn. It shall then be unwound and the process repeated after rotating the sample through 180° about its axis.

The sample shall be bent at a reasonably uniform speed, each half cycle of the test taking approximately 1.0 s per millimetre of overall cable diameter.

The diameter of the test cylinder shall be not greater than 20(D + d) mm, where D and d are as defined in **2.4.1.7**.

The sample shall then again be subjected to the partial discharge test in accordance with BS EN 60885-3.

The cable components, as applicable, shall then be visually examined.

2.4.1.9 N/A

2.4.2 N/A

2.4.3 N/A

2.4.4 N/A

2.4.5 Abrasion test

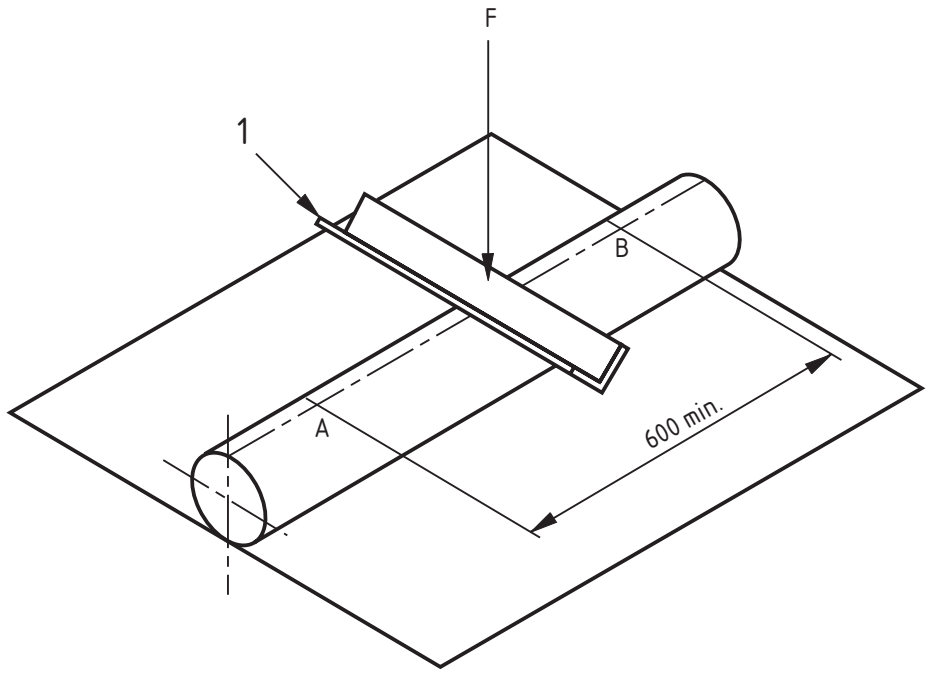
Lay a sample of cable out straight and horizontal on a firm base. In the middle part of the sample and perpendicular to it, place a length of low carbon steel (mild steel) angle horizontally, at right angles to the cable, with its angle edge resting on the cable and with its arm symmetrical about the vertical plane through the longitudinal axis of the cable. Ensure that the outer radius of curvature of the angle edge is not less than 1 mm and not greater than 2 mm (see Figure 2.4.5).

Vertically load the steel angle, above the point of contact, to give a force in accordance with Table 2.4.5.

Drag the steel angle horizontally along the cable for a distance not less than 600 mm at a speed of between 150 mm/s and 300 mm/s. Reverse the direction of movement at the end of each pass to give 50 passes, 25 in each direction, over the 600 mm test path.

Figure 2.4.5 **Abrasion test**

Dimensions in millimetres



Key

F Force (see Table 2.4.5)

1 Low carbon steel (mild steel) angle

A Start/finish position

B Finish/start position

A – B Test path length

Table 2.4.5 **Vertical force on cable during abrasion test**

1	2	3
Overall measured diameter of cable		**Force**
Greater than or equal to	**Less than**	
mm	mm	N
10	20	15
20	30	35
30	40	65
40	50	105
50	60	155
60	70	210
70	80	270

2.4.6 N/A

2.4.7 N/A

2.4.8 N/A

2.4.9 Water penetration test

The water penetration test shall be performed as follows.

a) **General**

The water penetration test shall be applied to those designs of cable where the manufacturer claims that barriers to longitudinal water penetration have been included.

The test is designed to meet the requirements for buried cables and is not intended to apply to cables which are constructed for use as submarine cables.

The test is applicable to the following cable designs:

i) where a barrier is included which prevents longitudinal water penetration in the region of the metallic screen layers;

ii) where a barrier is included which prevents longitudinal water penetration along the conductor.

b) **Sample**

A sample of completed cable at least 6 m in length, which has not been subjected to any other tests, shall be subjected to a bending test described in **2.4.1.5** unless otherwise specified, without the additional partial discharge test.

A 3 m length of cable shall be cut from the length which has been subjected to the bending test and placed horizontally. A ring approximately 50 mm wide shall be removed from the centre of the length. This ring shall comprise all the layers external to the insulation screen. Where the conductor is also claimed to contain a barrier, the ring shall comprise all layers external to the conductor.

If the cable contains intermittent barriers to longitudinal water penetration then the sample shall contain at least two of these barriers, the ring being removed from between the barriers. In this case, the average distance between the barriers should be stated and the length of the cable sample shall be determined accordingly.

The surfaces shall be cut so that the relevant interstices can be readily exposed to the water.

NOTE 1 If the design incorporates a conductor barrier only, then the relevant cut surfaces may be sealed with a suitable material or the outer coverings may be removed.

Arrange a suitable device (see Figure 2.4.9.1) to allow a tube having a diameter of at least 10 mm to be placed vertically over the exposed ring and sealed to the surface of the oversheath. The seals where the cable exits the apparatus shall not exert mechanical stress on the cable.

NOTE 2 The response of certain barriers to longitudinal water penetration can be dependent on the composition of the water (e.g. pH, ion concentration). Normal tap water should be used for the test unless otherwise specified.

c) **Test**

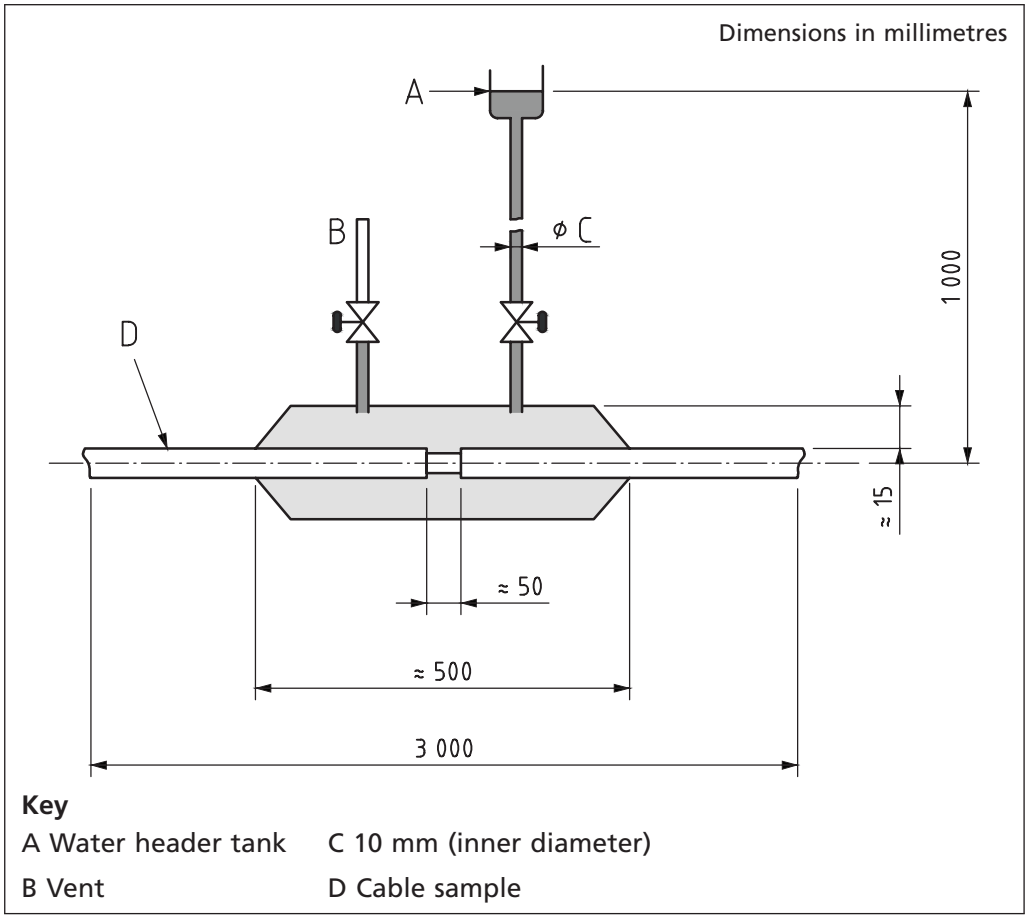
The tube shall be filled within 5 min with water at an ambient temperature of (20 ±10) °C so that the height of the water in the tube is 1 m above the cable centre (see Figure 2.4.9.1). The sample shall be allowed to stand for 24 h.

The sample shall then be subjected to 10 heating cycles, unless otherwise specified in the particular section, by passing a current through the conductor, until the conductor reaches a steady temperature which is 5 °C to 10 °C above the maximum conductor temperature for which the cable is suitable in normal operation and which shall not reach 100 °C.

The heating cycle shall be of 8 h duration. The conductor temperature shall be maintained within the stated temperature limits for at least 2 h of each heating period. This shall be followed by at least 3 h of natural cooling.

The water head shall be maintained at 1 m.

Figure 2.4.9.1 **Schematic diagram of apparatus for water penetration test**



NOTE No voltage is applied throughout the test therefore it is advisable to connect a dummy cable in series with the cable to be tested, the temperature being measured directly on the conductor of this cable.

d) **Inspection of tested cable samples**

Unless otherwise specified in the particular section, no water shall emerge at the ends of the sample.

2.4.9.1 N/A

2.4.9.2 N/A

2.4.9.3 a N/A

2.4.9.3 b N/A

2.4.9.3 c N/A

2.4.9.3 d N/A

2.4.9.3 e N/A

2.4.9.3 f N/A

2.4.9.3 g N/A

2.4.9.3 h N/A

2.4.9.4 N/A

2.4.10 N/A

2.4.11 N/A

2.4.12 Special compatibility tests

2.4.12.1 N/A

2.4.12.2 Method 2

The test method shall conform to BS EN 60811-1-2, **8.1.4** using the temperature and duration given in the particular section.

A sheet of clean white blotting paper shall be placed under each test piece in the oven to detect any exudation which might drip from the cable. At the end of the test period in the oven the blotting paper shall be inspected and any stains reported.

2.4.12.3 (Spare)

2.4.12.4 N/A

2.4.12.5 N/A

2.4.13 N/A

2.4.14 N/A

2.4.15 N/A

2.4.16 N/A

2.4.17 N/A

2.4.18 (Spare)

2.4.19 N/A

2.4.20 Determination of UV stability of MDPE sheath

This test is to determine the UV stability of the sheathing material of the cable in the condition as manufactured, by means of measuring elongation at break in the condition as manufactured and after exposure to ultraviolet light.

Testing and requirements to be met shall be as follows.

a) **General**

Samples shall be selected, prepared and tested in accordance with BS EN 60811-1-1, **9.2**.

b) **Method of exposure to UV**

Samples shall be exposed to UV light in accordance with the requirements of BS EN ISO 4892, using either of the following specific conditions:

i) Xenon arc lamp

Lamp characteristic:	Borosilicate inner and outer filter system (daylight simulation) and irradiance of 0.34 W/m^2 at 340 nm;
Test temperature:	(60 ±3) °C;
Spray cycle:	18 min of spraying with 102 min dry interval between periods of spraying.

ii) Fluorescent tube lamp

Lamp characteristic:	Type E;
Test temperature:	(60 ±3) °C during UV exposure;
	(50 ±3) °C during condensation exposure;
Cycle:	600 min of UV with 120 min of condensation.

c) **Requirements**

Both of the following requirements shall be met after (500 ±5) h exposure to UV light.

i) The difference between the median value of elongation at break after UV light exposure and the median value without such exposure, expressed as a percentage of the latter shall be less than ±30%.

ii) The median value of elongation at break after UV light exposure shall be not less than that specified for unaged test pieces in the particular section.

2.4.21 NA

2.4.22 N/A

2.4.23 N/A

2.4.24 N/A

2.5 Physical and chemical tests

2.5.1 Zinc coating

2.5.1.1 Measurement of the mass of zinc coating

2.5.1.1.1 N/A

2.5.1.1.2 N/A

2.5.1.1.3 N/A

2.5.1.1.4 Description of gravimetric method

See BS EN 10244-2:2009, **5.2**.

2.5.1.2 N/A

2.5.2 N/A

2.5.3 N/A

2.5.4 Checking durability of colours and marking

Conformity to this requirement shall be checked by trying to remove the marking of the manufacturer's name or trade mark and the colours of cores or numerals by rubbing lightly ten times with a piece of cotton wool or cloth soaked in water.

2.5.5 N/A

2.5.6 N/A

2.5.7 N/A

2.5.8 N/A

2.5.9 Swell height of water blocking tape

A polyamide (e.g. nylon) measuring apparatus, consisting of a cup in which a perforated ram can sit shall be used. The ram shall be free to move vertically (see Figure 2.5.9).

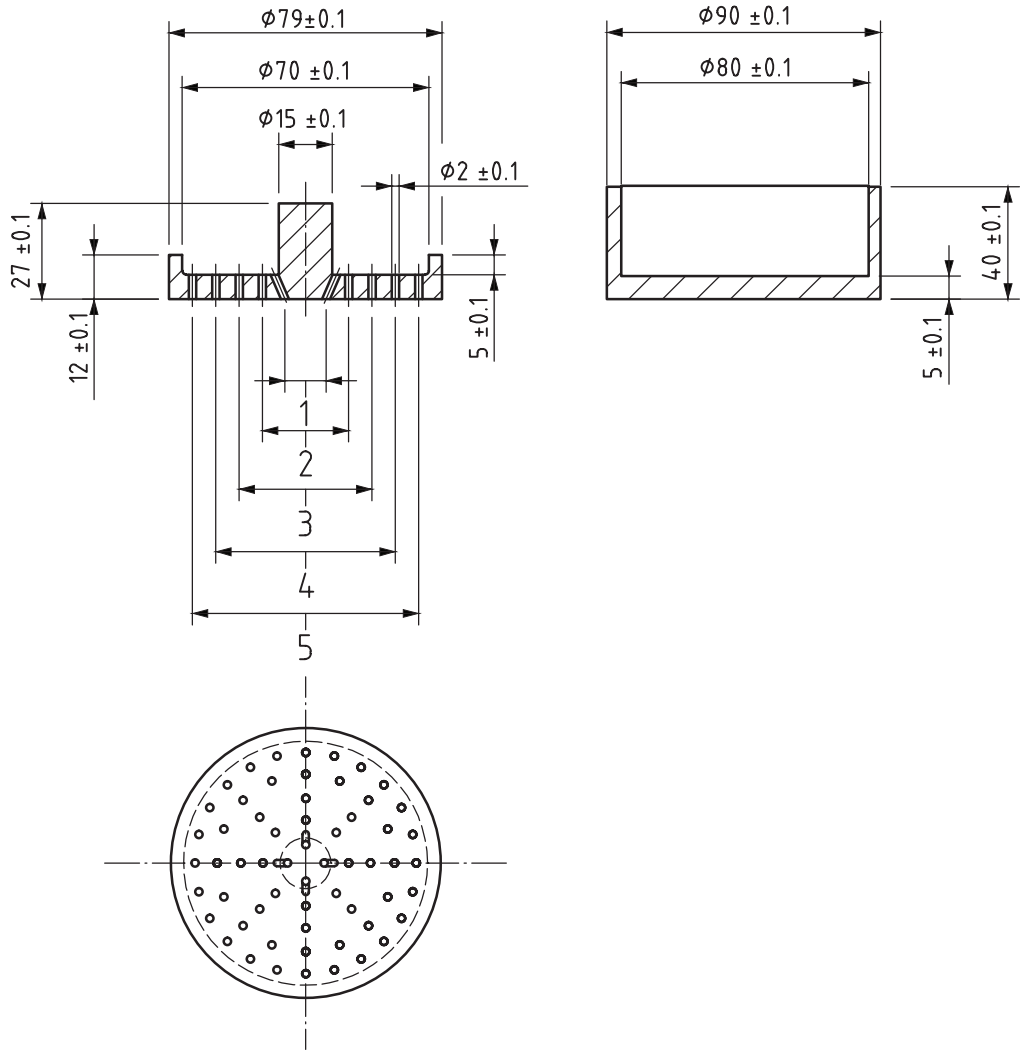
The tape shall be so cut as to completely fill the base of the cup without any overlaps. The tape shall be placed with the swellable side (white side) uppermost. Cover the tape with a thin circular tissue before placing the ram on top of the sample.

Measure the height of the apparatus. Pour a quantity of de-ionized water at (20 ±1) °C into the cup on top of the ram. Leave for 10 min topping up with de-ionized water as required to keep the perforations in the ram full.

At the end of 10 min, measure again the height of the apparatus. The difference in the two measured heights shall be taken as the swell height.

Figure 2.5.9 **Details of test apparatus to determine the tape swell height**

Dimensions in millimetres



a) Ram b) Cup

Key

1 4 holes on 10 p.c.d. (pitch circle diameter)
2 8 holes on 25 p.c.d. (pitch circle diameter)
3 8 holes on 40 p.c.d. (pitch circle diameter)
4 16 holes on 55 p.c.d. (pitch circle diameter)
5 24 holes on 65 p.c.d. (pitch circle diameter)

2.5.10 Measurement of water content of insulation

The water content of insulation shall be measured as follows.

a) **Equipment calibration**

The equipment shall have been calibrated within the previous 12 months, by using sodium tungstate dihydrate or a suitable alternative; the results of the calibration tests shall be within 5% of the calculated value.

b) **Test procedure**

A sample of completed cable approximately 300 mm long shall be taken from the appropriate cable length. Three samples of insulation shall be taken from positions equally spaced along this length. Each sample shall be cut so as to contain at least 80% of the radial thickness but shall not include any screen material.

NOTE Care should be exercised when cutting the samples to avoid handling and to avoid the samples absorbing moisture from other sources.

The moisture content measurement shall be commenced within 15 min of cutting the samples.

The mass of the sample shall be in line with the particular moisture determination method adopted. The following method is recommended. A glass oven containing the sample shall be maintained at (130 ±10) °C and dry nitrogen used to transport the water vapour into an automatic Karl Fischer titration equipment.

The recorded value shall be the average of the readings on the three samples.

2.5.11 N/A

2.5.12 N/A

2.5.13 N/A

2.5.14 N/A

2.5.15 N/A

Section 3 Electrical tests

3.1 Electrical resistance

3.1.1 Conductors

The measurement of electrical resistance shall be made on all conductors making up the cable, including the concentric conductor, if any.

The complete cable length, or a sample therefrom, shall be in the test room, which shall be maintained at a reasonably constant temperature, for at least 12 h before the test. If it is doubtful whether the conductor temperature is the same as the room temperature the resistance shall be measured after the cable has been in the test room for 24 h. Alternatively, the resistance shall be measured on a sample of conductor conditioned for at least 1 h in a temperature-controlled liquid bath.

The measured value of resistance shall be corrected to a temperature of 20 °C and 1 km length in accordance with the equations and factors given in BS EN 60228.

The d.c. resistance of each conductor at 20 °C shall not exceed the appropriate maximum value specified in BS EN 60228 where relevant, and the value specified in the particular section in other cases. For concentric conductors, the resistance value shall conform to the particular section.

3.1.2 N/A

3.1.3 N/A

3.1.4 N/A

3.2 Voltage tests

The voltage and test duration shall be as given in the particular section. The test value shall be achieved within 1 min and the duration shall be taken from when the specified voltage is reached. Unless otherwise specified, voltage tests shall be carried out at ambient temperature.

3.2.1 Tests on complete cable

3.2.1.1 Single core cables

Testing shall be carried out as follows.

a) On single core screened or armoured cables, the test voltage shall be applied between the conductors and the metallic screen/armour, which shall be earthed.

b) Single core unscreened or unarmoured cables shall be immersed in water at room temperature for 1 h and the test voltage then applied between the conductor and the water.

NOTE Alternatively, where permitted by the particular section, this test may be replaced by a spark test using the method and voltage given in the particular section.

3.2.1.2 Multicore cables

On multicore cables, the test voltage shall be applied in succession between each insulated conductor and all the other conductors, and the metal covering, if any, connected together.

NOTE The conductors may be suitably connected for successive application of the test voltage to limit the total testing time, provided that the sequence of connections ensures that the voltage is applied for the time given in the particular section without interruption between each conductor and each of the other conductors, and between each conductor and the metallic covering, if any, which is earthed.

3.2.2 N/A

3.2.3 Tests on oversheath

3.2.3.1 Method 1

The oversheath of a screened cable shall either be tested by applying an a.c. or a d.c. voltage between the screen or a concentric conductor and a conductive coating, which may be a water immersion bath or, alternatively, where permitted by the particular section this test may be replaced by a spark test using the method and voltage given in the particular section.

3.2.3.2 (Spare)

3.2.3.3 Method 3

See **3.2.3.1**.

3.2.4 Impulse voltage test

3.2.4.1 Method 1

See **3.2.4.2**.

3.2.4.2 Method 2 – Impulse voltage test followed by a.c. voltage test

The sample shall be heated by a suitable method so that the conductor is kept within the temperature limits given in the particular section during the test.

The impulse voltage test shall be carried out as specified in BS EN 60230.

The sample shall be subjected to 10 positive and 10 negative voltage impulses at the level given in the particular section.

On completion of the impulse voltage test the sample shall be subjected to an a.c. voltage test for 15 min at ambient temperature with a test voltage as given in the particular section, without breakdown of the insulation.

3.2.5 Special four-hour voltage test

NOTE This test is applicable to cables for rated voltages above 3.8/6.6 kV.

Subject a piece of cable not less than 5 m long between terminations to an alternating power frequency voltage applied between each conductor and the screen(s), which shall be earthed.

Carry out the test at the relevant test voltage as given in the particular section.

Increase the voltage gradually to the specified value and maintain it for 4 h. Apply the voltage continuously, but if there are any unavoidable interruptions during the 4 h period, increase that period by the time of the interruptions. Ensure that the total of such interruptions does not exceed 1 h, otherwise restart the test.

3.2.6 N/A

3.2.7 N/A

3.2.8 N/A

3.3 Insulation resistance tests

3.3.1 Insulation resistance test on insulated cores

The measurement shall be made on a cable sample of at least 5 m before any other electrical test. All outer coverings shall be removed and the cores shall be immersed in water at the temperature given in the particular section for at least 1 h before the test. The measurement shall be made between the conductor(s) and the water.

The d.c. test voltage shall be 80 V to 500 V and shall be applied for a sufficient time to reach a reasonably steady measurement, but for not less than 1 min and not more than 5 min.

a) **Calculation**

The volume resistivity shall be calculated from the measured insulation resistance by the following equation:

$$\rho = \frac{2 \times \pi \times l \times R}{\ln \frac{D}{d}}$$

where:

ρ is the volume resistivity in ohm centimetres (Ω·cm);

R is the measured insulation resistance in ohms (Ω);

l is the measured length of the core or cable in the water, as appropriate, in centimetres (cm);

D is the measured outer diameter of the insulation or oversheath, as appropriate, in millimetres (mm);

d is the measured inner diameter of the insulation or oversheath, as appropriate, in millimetres (mm).

Also the insulation resistance constant K_i, in megohm kilometres (MΩ·km), may be calculated using the equation:

$$K_i = \frac{IR \times 10^{-11}}{\ln \frac{D}{d}} = 10^{-11} \times \rho \times 0.367$$

NOTE For the cores of shaped conductors, the ratio D/d is the ratio of the perimeter over the insulation to the perimeter over the conductor.

b) **Calculation** (alternative method for shaped conductors)

Alternatively, the volume resistivity for cores with shaped conductors may be calculated from the measured insulation resistance by the following equation:

$$\rho = \frac{2 \times \pi \times l \times R}{\ln \frac{h_a}{h_i}}$$

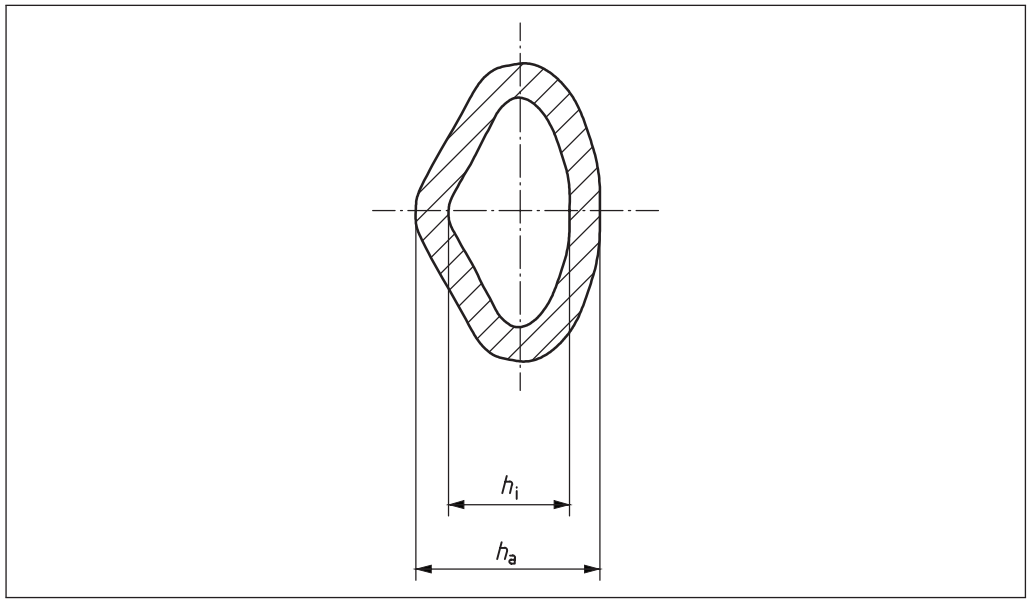
where:

h_a is the height of the core with the shaped conductor as indicated in Figure 3.3.1;

h_i is the height of the shaped conductor as indicated in Figure 3.3.1.

NOTE For cores with shaped conductors the ratio h_a/h_i may be used instead of the ratio D/d also for the calculation of the insulation resistance constant K_i.

Figure 3.3.1 **Height measurement of insulated sectoral shaped conductors**



3.3.2 Insulation resistance test on screened or armoured complete cable

Measure the insulation resistance, at ambient temperature unless otherwise specified, after electrification with direct current for at least 1 min and not more than 5 min at not less than 500 V. For single core cables the measurement shall be made between the conductor and the screen or armour and for multicore cables between the conductor under test and the remaining conductors which shall also be connected to the screen or armour.

Calculate the insulation resistance constant (K_i) in megohm kilometres (MΩ·km) from the equation given in **3.3.1**.

NOTE For multicore auxiliary cables, the cores may be connected in groups so that the insulation of each conductor is proved with respect to all the others.

3.3.3 N/A

3.3.4 Oversheath resistance test on screened or armoured complete cable

Immerse a length of at least 5 m of completed cable for at least 2 h in water at (20 ±5) °C, leaving a length of about 250 mm at each end projecting above the water. Maintain the temperature of the water at (20 ±5) °C for the 30 min immediately preceding the test. Apply a voltage of between 80 V and 500 V d.c. between the armour or screen and the water. Measure the insulation resistance 1 min after the application of the voltage.

Calculate the insulation resistance constant (K_i value) in megohm kilometres (MΩ·km) from the equation given in **3.3.1**.

3.3.5 N/A

3.4 N/A

3.5 N/A

3.6 Spark tests

Test in accordance with the a.c. or d.c. test methods specified in BS EN 62230, using the test voltages specified in BS 5099.

3.6.1 Method 1

See **3.6**.

3.6.2 N/A

3.6.3 N/A

3.6.4 N/A

3.7 N/A

3.8 Heating cycle test

3.8.1 Method 1

Install the cable sample indoors in a draught-free environment at a steady ambient temperature and away from direct sunlight.

Place thermocouples at intervals not exceeding 2 m along the length of the cable in order to measure the temperature of the metallic screen.

The heating cycle shall be of 8 h duration. The conductor temperature shall be maintained between 95 °C and 100 °C for at least 2 h of the heating period. This shall be followed by at least 3 h of natural cooling in air. This cycle shall be carried out 20 times. Confirm that the screen temperature accurately reflects the required conductor temperature by making suitable measurements of phase conductor resistance, or by other means. During the heating cycles, take at least four measurements of partial discharge in accordance with BS EN 60885-3 at approximately equal intervals at the end of a cooling cycle, including one measurement at the completion of the test (i.e. after the last heating cycle).

3.8.2 N/A

3.8.3 N/A

3.8.4 N/A

3.8.5 N/A

3.8.6 N/A

3.9 Measurement of the electrical resistivity of the semi-conducting screens

3.9.1 Method 1

The resistivity of the extruded semi-conducting screens applied over the conductor and over the insulation shall be determined by measurements on test pieces taken from the core of a sample of cable.

Each test piece shall be prepared from a 150 mm sample of completed cable.

The conductor screen test piece shall be prepared by cutting a sample of core in half longitudinally and removing the conductor and separator if any [see Figure 3.9.1a)]. The insulation screen test piece shall be prepared by removing all the coverings, including any sealing product, from the sample of core [see Figure 3.9.1b)].

The procedure for determining the volume resistivity of the screens shall be as follows.

Four silver-painted electrodes A, B, C and D [see Figures 3.9.1a) and 3.9.1b)] shall be applied to the semi-conducting surfaces. The two potential electrodes, B and C, shall be 50 mm apart and the two current electrodes, A and D, shall each be placed at least 25 mm beyond the potential electrodes.

Connections shall be made to the electrodes by means of suitable clips. In making connections to the conductor screen electrodes it shall be ensured that the clips are insulated from the insulation screen on the outer surface of the test piece.

The assembly shall be placed in an oven preheated to (90 ±2) °C and, after an interval of at least 30 min, the resistance between the electrodes shall be measured by means of a circuit, the power of which shall not exceed 100 mW.

After the electrical measurements, the diameters over the conductor screen and insulation screen and the thicknesses of the conductor screen and insulation screen shall be measured at ambient temperature, each value recorded being the average of six measurements made on the sample shown in Figure 3.9.1b).

The volume resistivity, ρ, in ohm metres (Ω·m), shall be calculated as follows:

a) conductor screen:

$$\rho_c = \frac{R_c \times \pi \times (D_c - T_c) \times T_c}{2L_c}$$

where:

ρ_c is the volume resistivity of the conductor screen, in ohm metres (Ω·m);

R_c is the measured resistance, in ohms (Ω);

L_c is the distance between the potential electrodes, in metres (m);

D_c is the outer diameter over the conductor screen, in metres (m);

T_c is the average thickness of the conductor screen, in metres (m).

b) insulation screen

$$\rho_i = \frac{R_i \times \pi \times (D_i - T_i) \times T_i}{L_i}$$

where:

ρ_i is the volume resistivity of the insulation screen, in ohm metres (Ω·m);

R_i is the measured resistance, in ohms (Ω);

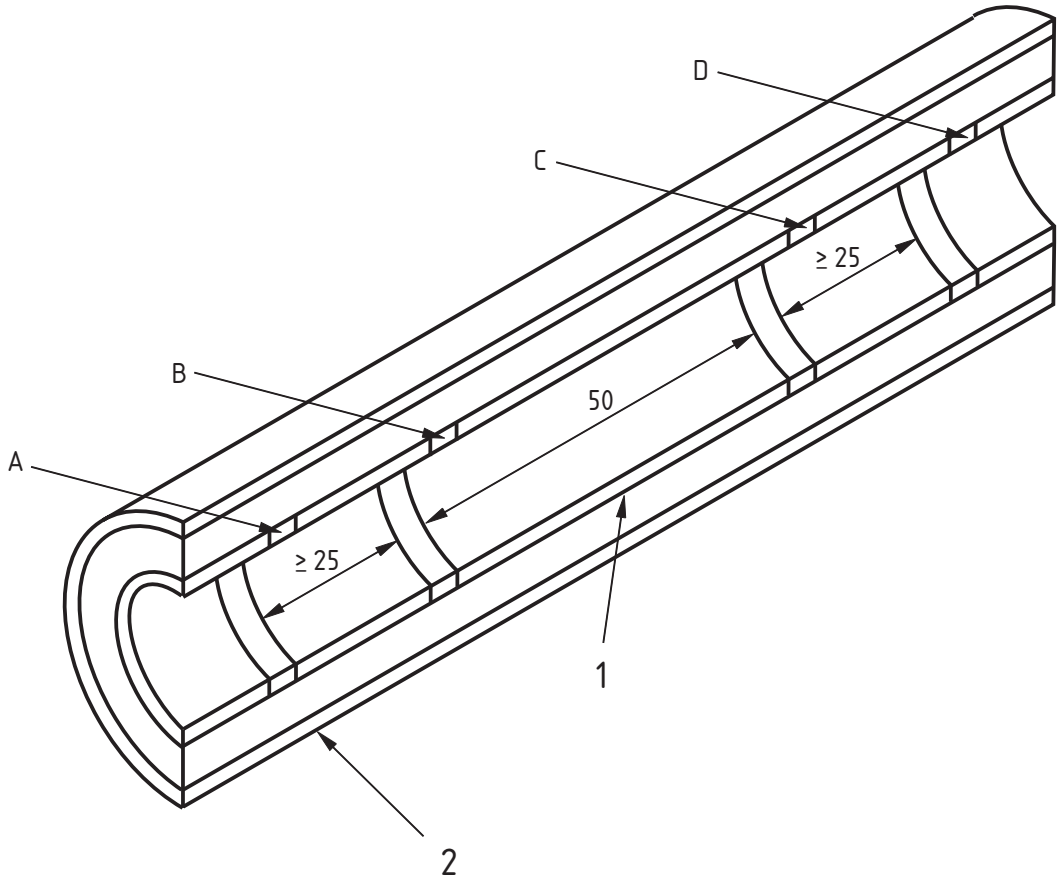
L_i is the distance between the potential electrodes, in metres (m);

D_i is the outer diameter over the insulation screen, in metres (m);

T_i is the average thickness of the insulation screen, in metres (m).

Figure 3.9.1a) **Measurement of the volume resistivity of the conductor screen**

Dimensions in millimetres



Key

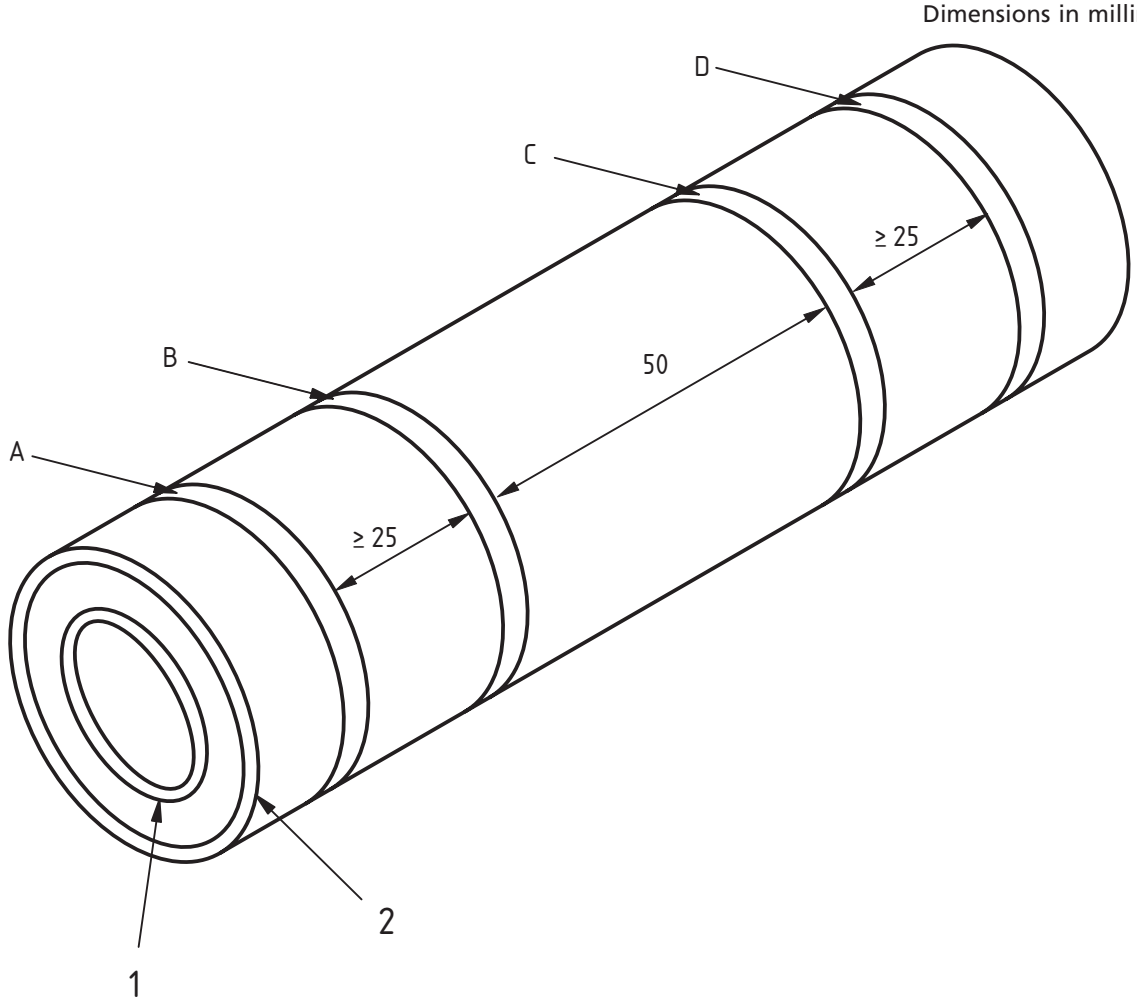
1 Conductor screen

2 Insulation screen

B and C Potential electrodes

A and D Current electrodes

Figure 3.9.1b) **Measurement of the volume resistivity of the insulation screen**



Key
1 Conductor screen
2 Insulation screen
B and C Potential electrodes
A and D Current electrodes

3.9.2 N/A

3.9.3 Method 3

See **3.9.1**.

3.9.4 N/A

3.10 Partial discharge test

3.10.1 Method 1

The partial discharge test shall be carried out in accordance with BS EN 60885-3.

3.10.2 N/A

3.10.3 Method 3

See **3.10.1**.

3.10.4 N/A

3.10.5 N/A

3.11 Tan δ measurement

3.11.1 Method 1 – Tan δ test in relation to temperature

A sample of completed cable shall be heated by one of the following methods: the sample shall be placed either in a tank of liquid or in an oven, or a heating current shall be passed through either the metallic screen or the conductor or both.

The sample shall be heated until the conductor reaches a temperature which is 5 °C to 10 °C above the maximum conductor temperature for which the cable is suitable in normal operation.

In each method, the temperature of the conductor shall be determined either by measuring the conductor resistance or by a suitable temperature measuring device in the bath or oven or on the surface of the screen or on an identically heated reference cable.

The tan δ value shall be measured with an alternating voltage of at least 2 kV at the temperature specified above.

3.11.2 N/A

3.11.3 Method 3 – Tan δ test

3.11.3.1 Tan δ test as a function of voltage

The test shall be performed at room temperature, with an a.c. voltage. The test voltage shall be applied between the conductor and the relevant metallic screen or sheath, and the loss angles measured respectively at $0.5U_0$, U_0 and $2U_0$.

The value measured at U_0 and the difference between the measurements at $2U_0$ and $0.5U_0$ (tan δ at $2U_0$ minus tan δ at $0.5U_0$) shall be recorded; they shall not exceed the values specified in the particular section.

To correct to 20 °C the tan δ values measured at different room temperatures, they shall be multiplied by the appropriate coefficient as given in Table 3.11.3.1.

Table 3.11.3.1 **Coefficients for correction of tan δ values to 20 °C**

Room temperature (°C)	10	12	14	16	18	20	22	24	26	28	30
Multiplying coefficient	1.05	1.06	1.07	1.06	1.04	1.00	0.94	0.86	0.80	0.79	0.79

3.11.3.2 Tan δ test as a function of temperature

See **3.11.1**.

3.11.4 N/A

3.12 N/A

3.13 Adherence of screens at short circuit temperature

The requirement and test method for the adherence of screens at short circuit temperature shall be as follows.

a) **Requirement**

The discharge magnitude (q) for both tests shall not exceed 5 pC at $1.5U_0$ when tested as follows.

b) **Method**

Subject a separate sample of cable having a conductor cross-sectional area not greater than 185 mm^2 and at least 5 m in length to the partial discharge test specified in the particular section, and then subject one core to a current with a magnitude as derived from the relevant equation as given below. Upon completion of the test allow the sample to cool to ambient temperature and subject it to the discharge test specified in **3.10.1**.

Subject one core of the 5 m length of cable to a current with a magnitude as derived from the relevant equation, as follows:

$$I^2t = 5.04 \times 10^4 A^2 \log_{10} \frac{(228 + T_2)}{(228 + T_1)} \qquad \text{for aluminium conductors}$$

$$I^2t = 11.77 \times 10^4 A^2 \log_{10} \frac{(234.5 + T_2)}{(234.5 + T_1)} \qquad \text{for copper conductors}$$

where:

I is the r.m.s. value of the short circuit current, in amps (A);

t is the duration of the short circuit current, in seconds (s), maximum 3 s;

A is the conductor cross-sectional area, in millimetres squared (mm^2);

T_2 is the final conductor temperature, in degrees Celsius (°C) = 250 °C;

T_1 is the initial conductor temperature in degrees Celsius (°C).

NOTE An acceptable alternative procedure for this test is to use the facilities of a short circuit testing station. If this alternative is used, a signed certificate from the testing station is considered to be acceptable in lieu of a witness.

3.14 Resistivity test for water blocking tape

Prepare three samples of tape 10 mm × 150 mm.

Condition them for 24 h in an environment at (23 ±5) °C and relative humidity of (50 ±5)%.

While still in the environment, place a tape sample in a jig having two parallel electrical contact clamping bars with a separation distance between them of 100 mm. Measure the resistance of each tape sample using a Wheatstone bridge.

The value of the resistivity of the tape in ohms/square shall be taken as the average of the three values obtained, divided by 10.

3.15 **N/A**

3.16 **N/A**

3.17 **N/A**

3.18 **N/A**

3.19 **N/A**

Section 4 N/A

Section 5 Long-term tests

5.1 **N/A**

5.2 **N/A**

5.3 **N/A**

5.4 Long-term voltage test

5.4.1 **N/A**

5.4.2 **N/A**

5.4.3 **N/A**

5.4.4 **N/A**

5.4.5 **N/A**

5.4.6 **N/A**

5.4.7 **N/A**

5.4.8 Method 8 – Test for resistance to water

The test shall be carried out in accordance with **5.4.15**.

As an alternative to ageing at power-frequency voltage, one 60 m active test length shall be energized at 500 Hz frequency for not less than 3 000 h. Apart from that, the conditioning, ageing procedure and ageing assessment shall be in accordance with **5.4.15**.

5.4.9 N/A

5.4.10 N/A

5.4.11 N/A

5.4.12 N/A

5.4.13 N/A

5.4.14 N/A

5.4.15 Harmonized long duration test

5.4.15.1 General

This test method is intended to assess the resistance to water of cables with extruded insulation of rated voltages from 3.6/6 (7.2) kV to 20.8/36 (42) kV.

The test shall be performed on production cable cores, with either XLPE or EPR insulation and having extruded semi-conducting conductor and insulation screens.

NOTE Cable cores submitted for testing may incorporate any conductor construction, including circular or shaped, solid or stranded, with or without water blocking.

5.4.15.2 Approval

Satisfactory completion of tests on one conductor construction with a cross-section in the range 95 mm^2 to 400 mm^2, copper or aluminium, shall provide approval for all conductor constructions and cross-sections.

Satisfactory completion of tests on cable cores having a nominal insulation thickness of either 3.4 mm, 4.5 mm or 5.5 mm shall provide approval for all cables rated from 3.6/6 (7.2) kV to 20.8/36 (42) kV with the same combination of insulating and semi-conducting screening materials.

5.4.15.3 Test method

5.4.15.3.1 Cable core length

Two 60 m active lengths of cable core (excluding extra cable core required for terminations both for ageing and breakdown tests) shall be tested, using semi-conducting screened core with or without metallic screen wires.

5.4.15.3.2 Conditioning

The cable core shall be conditioned to remove remaining by-products of cross-linking and at the same time to allow the insulation and screens to absorb moisture. Conditioning shall be as follows.

Cable cores with a nominal insulation thickness of either 3.4 mm, 4.5 mm or 5.5 mm shall be conditioned in a bath of tap water at a temperature of (55 ±5) °C for at least 500 h, with the ends of the cable core protruding from the water.

NOTE 1 Before commencing the ageing test, the cable core may be subjected to a power frequency voltage withstand test at (60 ±3) kV, (90 ±3) kV or (120 ±5) kV for at least 1 min for 3.4 mm, 4.5 mm and 5.5 mm nominal insulation thicknesses respectively. If failure occurs, the sample may be replaced in order to exclude failures not related to water treeing, and the test repeated.

WARNING. The water used for conditioning and for the ageing test might contain a number of *Legionnella* bacteria per unit of volume. These could grow to high levels, resulting in serious contamination of the water. It is advisable that laboratories carrying out this test perform a health and safety risk assessment.

NOTE 2 Possible methods to control the level without affecting the conditioning or ageing are under consideration.

5.4.15.3.3 Ageing procedure

The cable core shall be placed in a water bath at a temperature of (40 ±5) °C with the ends of the cable core protruding from the water. The water in the bath shall be tap water and the water level in the bath shall be maintained, if necessary, with tap water.

NOTE 1 Cable cores may be aged in single or multiple lengths.

A minimum surface area of water of 0.5 m² per cubic metre of water in the water bath shall be open to the atmosphere to ensure oxygenation of the water.

Suitable terminations shall be provided and the cable core energized at a power-frequency voltage of (18 ±3) kV, (27 ±3) kV or (36 ±3) kV for 3.4 mm, 4.5 mm and 5.5 mm nominal insulation thicknesses, respectively.

The water in the bath shall be earthed by means of a metallic electrode. The outer semi-conducting screen of the cable core shall be fully earthed.

NOTE 2 Copper wires may be wrapped around the cores or NaCl may be added to the water to provide adequate conductivity.

Both the voltage and the water temperature shall be checked and recorded periodically.

One 60 m active test length of cable core shall be aged for not less than 8 750 h and the other 60 m for not less than 17 500 h. The cable core shall not lose contact with water for more than 24 h on any occasion, for more than a total of 60 h during the 8 750 h ageing period or for more that a total of 120 h during the 17 500 h ageing period.

5.4.15.3.4 Ageing assessment

a) **Sample preparation**

At the end of both ageing periods, the cable core shall be removed and the active length cut into 6 x 10 m lengths (the additional cable core lengths required for terminating the samples having been cut off) which shall be stored under water temporarily. Suitable terminations shall be used to test each sample individually at a temperature of (20 ±15) °C. Metallic wires or tapes shall be wound on to cores to provide a testing electrode. Core sample preparation shall be completed within 72 h. Samples shall be returned to a water bath if testing is to be delayed by more than 48 h.

NOTE It is advisable not to include in the step tests either the ends of core protruding from the water during the ageing procedure or the small length of core (e.g. 150 mm) immediately below the water surface, as ageing of this section will not have been under controlled conditions.

b) **Power-frequency voltage step test**

A step test regime shall be used for the power-frequency voltage test. The test voltage shall be raised in 6 kV, 9 kV or 12 kV steps every 5 min, commencing at 18 kV, 27 kV or 36 kV for 3.4 mm, 4.5 mm and 5.5 mm nominal insulation thicknesses, respectively, until breakdown occurs. The breakdown voltage values shall be recorded. If failure occurs between steps, the value of the voltage level corresponding to the next step up shall be recorded as the breakdown voltage. If failure occurs at a test piece termination, the test shall be restarted from the beginning.

The core dimensions of each tested length shall be measured in accordance with **2.1**. The mean values of the core dimensions and respective breakdown voltage values shall be used to calculate the conductor screen breakdown stresses.

c) **Cable and termination failures**

One failure of the active test length of a cable core during ageing may be accepted.

Terminations which fail either during ageing or in the voltage step test may be reterminated.

Results shall be obtained on at least five aged samples with a minimum total active length of 40 m for both ageing periods.

5.4.15.4 N/A

5.5 N/A

5.6 N/A

Annex A (normative) **NA**

Annex B (normative) **NA**

Bibliography

For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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