

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)

bsi.

...making excellence a habit.
AVA Documents™
Document Sharing Hub

Publishing and copyright information

The BSI copyright notice displayed in this document indicates when the document was last issued.

© BSI 2011

ISBN 978 0 580 70007 1

ICS 29.060.20

The following BSI references relate to the work on this standard:

Committee reference GEL/20/16

Draft for comment 11/30214057 DC

Publication history

First published October 1996

Second edition, June 1999

Third (present) edition, December 2011

Amendments issued since publication

Date	Text affected
------	---------------

Contents

Foreword *iii*

Section 1 General 1

- 1.1 Scope 1
- 1.2 Normative references 1
- 1.3 Applicable tests 1
- 1.4 Sampling 1
- 1.5 Test conditions 2
- 1.6 Rounding of numbers 2

Section 2 Non-electrical tests 3

- 2.1 Dimensional measurements 3
- 2.2 Mechanical tests on non-metallic components 8
- 2.3 Mechanical tests on metallic components 11
- 2.4 Non-electrical tests on samples of complete cable 11
- 2.5 Physical and chemical tests 18

Section 3 Electrical tests 20

- 3.1 Electrical resistance 20
- 3.2 Voltage tests 21
- 3.3 Insulation resistance tests 22
- 3.4 N/A 24
- 3.5 N/A 24
- 3.6 Spark tests 24
- 3.7 N/A 25
- 3.8 Heating cycle test 25
- 3.9 Measurement of the electrical resistivity of the semi-conducting screens 25
- 3.10 Partial discharge test 28
- 3.11 Tan δ measurement 29
- 3.12 N/A 29
- 3.13 Adherence of screens at short circuit temperature 29
- 3.14 Resistivity test for water blocking tape 30
- 3.15 N/A 31
- 3.16 N/A 31
- 3.17 N/A 31
- 3.18 N/A 31
- 3.19 N/A 31

Section 4 N/A 31

Section 5 Long-term tests 31

- 5.1 N/A 31
- 5.2 N/A 31
- 5.3 N/A 31
- 5.4 Long-term voltage test 31
- 5.5 N/A 34
- 5.6 N/A 34

Annexes

- Annex A (normative) NA 35
- Annex B (normative) NA 35

Bibliography 36

List of figures

- Figure 2.1.10.5 – Dissociation, inclusions and penetration 7
- Figure 2.2.2.2 – Test piece for tear resistance test method 2 9
- Figure 2.4.5 – Abrasion test 13
- Figure 2.4.9.1 – Schematic diagram of apparatus for water penetration test 15
- Figure 2.5.9 – Details of test apparatus to determine the tape swell height 19
- Figure 3.3.1 – Height measurement of insulated sectoral shaped conductors 24

Figure 3.9.1a) – Measurement of the volume resistivity of the conductor screen 27

Figure 3.9.1b) – Measurement of the volume resistivity of the insulation screen 28

List of tables

Table 1.5.2 – Tolerances on temperature values 2

Table 2.4.5 – Vertical force on cable during abrasion test 14

Table 3.11.3.1 – Coefficients for correction of $\tan \delta$ values to 20 °C 29

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 appropriate 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 $(20 \pm 15) ^\circ\text{C}$.

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 $^\circ\text{C}$	Tolerance 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 $\pm 7\%$. 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:

- if the last figure to be retained is followed, before rounding, by 0, 1, 2, 3 or 4, it shall remain unchanged (rounding down);
- 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 $\approx$ 2.45 rounded to two decimal places

2.449 $\approx$ 2.4 rounded to one decimal place

25.0478 $\approx$ 25.048 rounded to three decimal places

25.0478 $\approx$ 25.05 rounded to two decimal places

25.0478 $\approx$ 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 $5D$ and $15D$, 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.

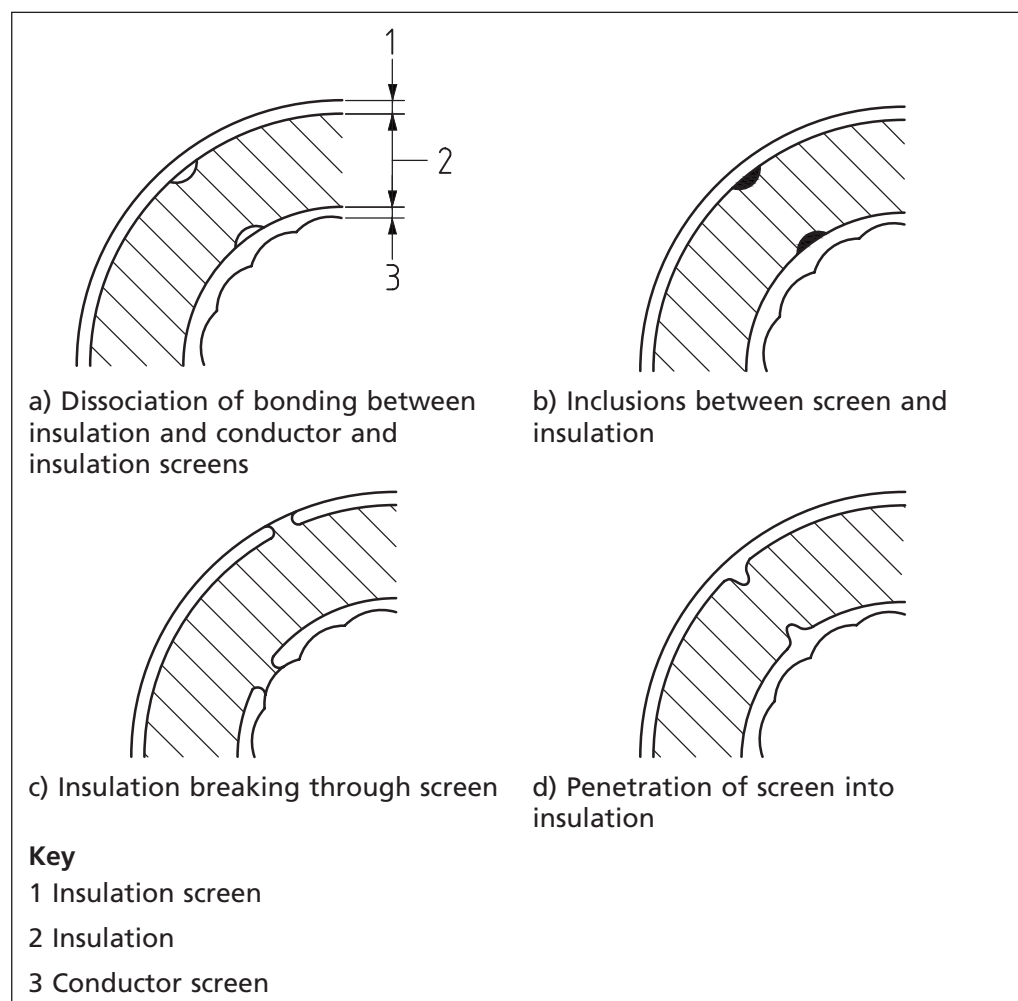
The interfaces shall be examined in a good light with normal or corrected vision without magnification.

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



c) Test method to determine contaminants and discoloured particles

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

At least 5 cm³ of insulation shall be examined using a microscope based measuring system at a minimum magnification of $\times 20$.

Requirements shall be as follows.

i) Contaminants

- 0.05 mm < largest dimension $\leq$ 0.15 mm: 1 per cm³ 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 $\times 10$ (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.