BRITISH STANDARD

Electric cables – Armoured cables with thermosetting insulation for rated voltages from 3.8/6.6 kV to 19/33 kV – Requirements and test methods

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British Standards

Publishing and copyright information

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Contents

List of tables

Summary of pages

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Foreword

Publishing information

This British Standard was published by BSI and came into effect on 30 March 2007. 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 this committee can be obtained on request to its secretary.

Supersession

This British Standard supersedes BS 6622:1999, which is withdrawn.

Information about this document

This revision of BS 6622 has been prepared to bring the requirements up to date in accordance with current practice in the industry and to align with the methods used for calculating cable component dimensions given in IEC 60502-2.

This revision of BS 6622 specifies armoured cables. Unarmoured cables, which were specified in the previous edition or BS 6622, are no longer included. Unarmoured cables with a copper wire screen, which were specified in BS 6622:1999, are generally for use by the utilities and are now specified in BS 7870-4.

This standard specifies requirements for cables in the rated voltage range from 3.8/6.6 kV up to 19/33 kV which are insulated with cross-linked polyethylene (XLPE) or ethylene propylene rubber compound (EPR). Cables with improved performance under fire conditions are specified in BS 7835.

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 requirements are expressed 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 necessary provisions of a contract. Users are responsible for its correct application.

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

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1 Scope

This British Standard specifies requirements and test methods for the construction, dimensions and mechanical and electrical properties of armoured cables with thermosetting insulation for rated voltages from 3.8/6.6 (7.2) kV up to 19/33 (36) kV inclusive, designed for a maximum continuous conductor operating temperature of 90 °C and for a maximum short circuit conductor temperature of 250 °C, for use in fixed installations such as networks or industrial installations.

This British Standard specifies single-core and three-core cables for voltages in the range 3.8/6.6 (7.2) kV up to 19/33 (36) kV, with:

- a stranded copper, stranded aluminium or solid aluminium conductor or conductors;
- cross-linked polyethylene or cross-linked ethylene propylene rubber insulation;
- a metallic screening layer of copper wire or copper tape and/or a metallic armour of aluminium or galvanized steel wire;
- a polyvinyl chloride compound (PVC) or polyethylene (PE) oversheath.

NOTE Guidance on the selection of cables is given in Annex A. Information to be supplied by the purchaser, and items to be agreed between the purchaser and the manufacturer, at the time of enquiry and/or order, are given in Annex B. Recommendations for the installation of cables are given in Annex C. Guidance on the use of cables is given in Annex D.

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 4727-2: Group 08, *Glossary of electrotechnical, power, telecommunication, electronics, lighting and colour terms – Part 2: Terms particular to power engineering – Group 08: Electric cables*

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

BS 7655-1.2, *Specification for insulating and sheathing materials for cables – Part 1: Cross-linked elastomeric insulating compounds – Section 1.2: General 90 °C application*

BS 7655-1.3, *Specification for insulating and sheathing materials for cables – Part 1: Cross-linked elastomeric insulating compounds – Section 1.3: XLPE*

BS 7655-4.2, *Specification for insulating and sheathing materials for cables – Part 4: PVC sheathing compounds – Section 4.2: General application*

BS 7655-10.1, *Specification for insulating and sheathing materials for cables – Part 10: Polyethylene sheathing compounds – Section 10.1: Thermoplastic medium density polyethylene (MDPE) sheathing compound*

BS EN 10002-1, *Metallic materials – Tensile testing – Part 1: Method of test at ambient temperature*

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

BS EN 50356, *Method for spark testing of cables*

BS EN 60228, *Conductors of insulated cables*

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

BS EN 60332-1-2:2004, *Tests on electric and optical fibre cables under fire conditions – Part 1-2: Test for vertical flame propagation for a single insulated wire or cable – Procedure for 1 kW pre-mixed flame*

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, *Common test methods for insulating and sheathing materials of electric and optical cables – Part 1-2: General application – Thermal ageing methods*

BS EN 60811-1-3, *Insulating and sheathing materials of electric and optical cables – Common test methods – Part 1-3: General application – Methods for determining the density – Water absorption tests – Shrinkage test*

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

3 Terms and definitions

For the purposes of this British Standard the terms and definitions given in BS 4727-2: Group 08 and the following apply.

3.1 rated voltage
reference voltage for which the cable is designed

NOTE This is expressed as a combination of the values U_0, U and U_m.

3.2 rated voltage U_0
nominal power-frequency voltage between any conductor and earth or metallic screen for which the cable is suitable

3.3 rated voltage U
nominal power-frequency voltage between phase conductors for which the cable is suitable

3.4 maximum voltage U_m
maximum sustained power-frequency voltage between phase conductors for which the cable is suitable

3.5 cross-linked polyethylene (XLPE)
thermosetting material formed by the cross-linking of thermoplastic polyethylene compound

3.6 ethylene propylene rubber compound (EPR)
thermosetting material comprising a cross-linked compound in which the elastomer is ethylene propylene

3.7 polyvinyl chloride compound (PVC)
combination of materials of which polyvinyl chloride is the characteristic constituent

3.8 polyethylene (PE)
thermoplastic compound based on polyethylene

3.9 nominal value
value, often used in tables, by which a quantity is designated

NOTE In this standard, actual values to be checked by measurement, and on which tolerances are given, are usually specified in relation to particular nominal values.

3.10 approximate value
value which is only indicative

NOTE In this standard, values described as "approximate" do not constitute requirements to be checked by measurements.

3.11 fictitious value
value calculated in accordance with the "fictitious method" described in Annex E [IEC 60502-2:2005, **3.1.4**]

NOTE The fictitious values referred to in the present standard are "fictitious diameters".

3.12 routine tests
tests performed by the manufacturer on each manufactured length of cable to check whether the whole of each length meets the specified requirements

3.13 sample tests
tests performed by the manufacturer on samples of completed cable, or components taken from a completed cable, at a specified frequency, to determine whether the finished product meets the specified requirements

3.14 type tests
tests made before supplying a particular type of cable on a general commercial basis, to determine whether the cable has satisfactory performance characteristics to be suitable for the intended application

NOTE Type tests are of such a nature that, after they have been performed, they need not be repeated unless changes are made in the cable materials or design or manufacturing process which might change the performance characteristics.

4 Voltage designation

Cables shall be designated by the voltages U_0, U and U_m expressed in the form U_0/U (U_m).

NOTE The voltage designations of cables specified in this standard are as follows:

- *3.8/6.6 (7.2) kV;*
- *6.35/11 (12) kV;*
- *8.7/15 (17.5) kV;*
- *12.7/22 (24) kV;*
- *19/33 (36) kV.*

5 Conductors

Conductors shall be either plain annealed copper or aluminium, circular, and shall conform to BS EN 60228. Copper conductors shall be stranded (class 2) and aluminium conductors shall be either solid (class 1) or stranded (class 2). Conductors shall be compacted or uncompacted and be between 70 mm^2 and 1 000 mm^2 for copper or aluminium stranded conductors (class 2) and 70 mm^2 to 300 mm^2 for solid aluminium conductors (class 1).

6 Conductor screen

A conductor screen consisting of an extruded layer of a cross-linkable semi-conducting compound shall be applied over the conductor and shall cover the surface of the conductor completely.

NOTE A semi-conducting tape may be applied prior to the extruded layer, at the discretion of the manufacturer.

The conductor screen shall be applied in the same operation as the insulation and shall be fully bonded to the insulation.

7 Insulation

The insulation shall be either XLPE (type GP 8) conforming to BS 7655-1.3 or EPR (type GP 7) conforming to BS 7655-1.2.

The insulation shall be applied by extrusion and cross-linked to form a compact and homogeneous layer.

NOTE The colour of the insulation should be such that it is easily distinguishable from the screening materials.

The nominal thickness of the insulation shall be as specified in Table 1.

Table 1 **Nominal thickness of insulation**

Nominal cross-sectional area of conductor	**Nominal thickness of insulation for cables of rated voltage U_0/U (U_m)**				
mm²	**3.8/6.6 (7.2) kV** mm	**6.35/11 (12) kV** mm	**8.7/15 (17.5) kV** mm	**12.7/22 (24) kV** mm	**19/33 (36) kV** mm
70 to 185	2.5	3.4	4.5	5.5	8.0
240	2.6	3.4	4.5	5.5	8.0
300	2.8	3.4	4.5	5.5	8.0
400	3.0	3.4	4.5	5.5	8.0
⩾500	3.2	3.4	4.5	5.5	8.0

8 Insulation screen

8.1 General

An insulation screen shall be applied to all cables and shall consist of a cross-linkable extruded semi-conducting layer as specified in **8.2**, in combination with a metallic layer (see **9.3** and **9.4** and Clause **10**). This screen shall be in contact with the metallic layer either directly or through a semi-conducting layer.

8.2 Extruded semi-conducting layer

The extruded semi-conducting layer shall consist of a bonded or cold strippable semi-conducting compound capable of removal for jointing and terminating (see **C.4** and Annex B). It shall be applied in the same operation as the insulation, and shall cover the surface of the insulation completely.

NOTE At the discretion of the manufacturer, a semi-conducting tape may be applied over the extruded semi-conducting layer as a bedding for the metallic layer.

9 Assembly of three-core cables, including inner coverings and fillers

9.1 General

Three-core cables shall be constructed with conductor sizes up to a maximum of 400 mm². Assembly of three-core cables shall be as specified in **9.2**, **9.3** or **9.4**, as applicable.

9.2 Inner coverings and fillers

The inner covering shall be extruded or lapped.

For cables with circular cores, if a lapped inner covering is to be used the interstices between the cores shall be filled.

NOTE 1 Before application of an extruded inner covering, a binder may be applied to the cores, at the manufacturer's discretion.

NOTE 2 The approximate thickness of an extruded inner covering should be as given in Table 2.

Table 2 **Thickness of extruded inner covering**

Fictitious diameter over laid-up cores, D_f *		**Approximate thickness of extruded inner covering**
Above mm	**Up to and including** mm	mm
—	25	1.0
25	35	1.2
35	45	1.4
45	60	1.6
60	80	1.8
80	—	2.0

* Calculated in accordance with Annex E.

NOTE 3 The approximate thickness of a lapped inner covering should be 0.6 mm.

9.3 Cables with a collective metallic layer

Cables with a collective metallic layer shall have an inner covering, and fillers if applicable, conforming to **9.2**, over the laid-up cores. The inner covering and fillers shall be of non-hygroscopic material, except if the cable is to be made longitudinally watertight.

The inner covering shall be semi-conducting.

NOTE The fillers may also be semi-conducting.

9.4 Cables with a metallic layer over each individual core

In cables with a metallic layer over each individual core, the metallic layers over the individual cores shall be in contact with each other.

Cables which have an additional collective metallic layer of the same material as the underlying individual metallic layers shall have an inner covering, and fillers, if applicable, conforming to **9.2**, over the laid-up cores. The inner covering and fillers shall be of non-hygroscopic material except if the cable is to be made longitudinally watertight.

NOTE 1 The inner covering and fillers may be semi-conducting.

For cables which have an additional collective metallic layer of a different material to the underlying individual metallic layers, the two shall be separated by an extruded sheath of a material conforming to **19.7** which is compatible with other materials in the cable construction in accordance with **19.13**.

NOTE 2 For cables without a collective metallic layer, the inner covering and fillers may be omitted provided the outer shape of the cable is still approximately circular.

10 Metallic layer

10.1 General

The metallic layer shall be applied around each core and/or as a collective screen. For cables with rated voltages above 8.7/15 (17.5) kV, a metallic insulation screen shall be applied around each core.

The metallic layer applied to a single-core cable or to the individual cores of a three-core cable shall be non-magnetic.

NOTE 1 Measures may be taken to achieve longitudinal watertightness in the region of the metallic layer, for example by the use of water swellable tapes.

NOTE 2 When choosing the material for the metallic layer, special consideration should be given to the possibility of corrosion, not only with regard to mechanical safety but also with regard to electrical safety.

If a copper wire screen is used, the d.c. resistance of the screen shall be as specified in **19.4**.

10.2 Metallic screen on each core

A metallic screen applied directly over the core of single-core cables or each core in three-core cables, shall consist of either metallic tape(s) or a concentric layer of metallic wires or a combination of wires and tapes.

The metallic wires shall be spaced with a mean gap width not greater than 4 mm. No gap shall exceed 8 mm.

10.3 Collective metallic screen

Three-core cables not having a metallic screen over each individual core shall have a collective screen of steel wire armour conforming to Clause **11** applied after the cores have been laid up together and over the lapped inner covering.

11 Metallic armour

11.1 Construction

11.1.1 General

The armour shall consist of round wires. The nominal diameter of the armour wires shall be as given in Table 3.

Table 3 **Nominal diameter of round armour wires**

Fictitious diameter under the armour, D_A *		**Nominal diameter of armour wires**
Above mm	**Up to and including** mm	mm
—	25	1.6
25	35	2.0
35	60	2.5
60	—	3.15

* See Annex E.

NOTE An open helix consisting of galvanized steel tape with an approximate thickness of 0.3 mm may be applied over the armour.

11.1.2 Material

The wires shall be of galvanized steel, aluminium or aluminium alloy.

NOTE In those cases where the purchaser specifies a minimum conductance for the steel wire armour layer (see Annex B) it is permissible to include sufficient copper or tinned copper wires in the armour layer to ensure conformity.

Armour of single-core cables for use on a.c. systems, unless provision of an armour layer with a special construction which requires the armour to be made of magnetic material has been specified by the purchaser at the time of enquiry and/or order (see Annex B), shall consist of non-magnetic material.

11.1.3 Application of armour

11.1.3.1 Single-core cables

In the case of single-core cables with no metallic layer under the armour, aluminium wire armour shall be applied over an extruded or lapped semi-conducting inner covering.

*NOTE The approximate thickness of the inner covering should be in accordance with **9.2** Note 2 or Note 3, as applicable.*

11.1.3.2 Three-core cables

In the case of three-core cables, galvanized steel wire armour shall be applied over the inner covering specified in Clause **9**.

11.2 Separation sheath

11.2.1 In cables with a metallic layer under the armour, if the underlying metallic layer and the armour are of different materials, unless measures have been taken to achieve longitudinal watertightness in the region of these metallic layers they shall be separated by an extruded separation sheath comprising material conforming to **19.7** which is compatible with other materials in the cable construction in accordance with **19.13**.

11.2.2 The nominal thickness of the separation sheath shall be not less than 1.2 mm.

12 Oversheath

12.1 General

Cables shall have an extruded oversheath which shall be either PVC Type 9 conforming to BS 7655-4.2 or medium density polyethylene (MDPE) Type TS 2 conforming to BS 7655-10.1.

NOTE Oversheaths are normally black, but colours other than black may be provided by agreement between the manufacturer and the purchaser (see Annex B), subject to their suitability for the particular conditions under which the cables are to be used.

12.2 Thickness of oversheath

12.2.1 Unless otherwise specified by the purchaser at the time of enquiry or order (see Annex B) the nominal thickness of the oversheath, t_s, in millimetres (mm), shall be as specified in **12.2.2** or **12.2.3**, as applicable, or as calculated by the following formula, and rounded to the nearest 0.1 mm in accordance with Annex F, whichever is larger:

$$t_s = 0.035D + 1.0$$

where:

D is the fictitious diameter immediately under the oversheath, in millimetres (mm) (see Annex E).

12.2.2 For cables with the oversheath not applied directly over the armour, the nominal thickness of the oversheath shall be not less than 1.4 mm for single-core cables and not less than 1.8 mm for three-core cables.

12.2.3 For cables with the oversheath applied directly over the armour, the nominal thickness of the oversheath shall be not less than 1.8 mm.

12.3 Semi-conducting layer

If the purchaser specifies at the time of enquiry and/or order that a d.c. voltage test is to be performed on the oversheath (see **A.5** and Annex B), a semi-conducting layer shall be applied over the surface of the oversheath.

13 Marking

13.1 External marking

The external surface of all cables shall be legibly marked with the following elements:

Element	Example of marking
a) Electric cable	ELECTRIC CABLE
b) Voltage designation	
3.8/6.6 (7.2) kV	6 600 V
6.35/11 (12) kV	11 000 V
8.7/15 (17.5) kV	15 000 V
12.7/22 (24) kV	22 000 V
19/33 (36) kV	33 000 V
c) British Standard number [1]	BS 6622
d) Manufacturer's identification	XYZ
e) The number of cores, and type and nominal cross-sectional area of conductors e.g.	
single-core cable with a 70 mm^2 copper conductor	1 × 70
three-core cable with 70 mm^2 aluminium conductors	3 × 70 AL

The marking of elements a) to d) shall be by embossing or indenting on the oversheath.

Elements a), b) and c) shall appear on two or more primary lines along the axis of the cable, approximately equally spaced around the circumference of the cable.

Elements d) and e) shall appear on at least one line.

NOTE They may be on one of the primary lines or on a secondary line or lines and need not be on the same line.

The letters and figures shall consist of upright block characters. The characters shall have a minimum height of 3 mm.

The distance between the end of one element of marking and the beginning of the next identical element shall be not greater than 550 mm for items a), b) and c), and not greater than 1 100 mm for items d) and e).

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[1] Marking BS 6622 on or in relation to a product represents a manufacturer's declaration of conformity, i.e. a claim by or on behalf of the manufacturer that the product meets the requirements of the standard. The accuracy of the claim is solely the claimant's responsibility. Such a declaration is not to be confused with third party certification of conformity.

13.2 Identification of year of manufacture

A means of identifying the year of manufacture of the cable shall be provided throughout the length of the cable, either internally or by marking on the surface of the cable.

If the identification is internal, the distance between the end of one mark and the beginning of the next mark shall be not greater than 550 mm.

NOTE An identification thread may be used as an alternative to internal marking.

If the identification is by marking on the surface, the maximum distance between marks shall be 1 100 mm.

13.3 The mark of an approval organization

If the mark of an approval organization is used it shall be provided throughout the length of the cable, either as a mark on the surface of the cable, or as an identification thread, as specified by the approval organization.

If the mark is applied to the surface of the cable, it shall be in the form of the symbol(s) specified by the approval organization and the distance between the end of one mark and the beginning of the next shall be not greater than 1 100 mm.

13.4 Additional marking

Where additional marking is made, it shall be throughout the length of the cable, either on the external surface of the cable, or by means of a tape or thread within the cable, or by combination of these methods. If the additional marking is applied to the surface of the cable, it shall not render illegible the marking specified in **13.1**, **13.2** and **13.3**.

The additional marking, however made, shall be repeated at intervals not exceeding 1 100 mm.

14 End sealing

Before despatch, the manufacturer shall cap the ends of all cable in order to form a seal to prevent the ingress of water during transportation and storage.

15 Schedule of tests

Testing shall be performed in accordance with the schedule of tests given in Table 4.

NOTE 1 Tests listed in Table 4 as routine tests or sample tests may be required as part of a type approval scheme.

NOTE 2 Guidance on type testing is given in Annex G.

NOTE 3 Unless otherwise stated for particular tests, the tests need not be carried out in any particular sequence.

Table 4 **Schedule of tests**

Test	Test method and requirements given in clause
Routine tests (see **3.12**)	
Spark test on oversheath	**17.2**
Conductor resistance	**17.3**
Copper wire screen resistance	**17.4**
Partial discharge test	**17.5**
Voltage test on complete cable	**17.6**
Cable markings	**17.7**
D.C. voltage test on oversheath [A)]	**17.8**
Sample tests (see **3.13**)	
Conductor material and construction	**18.4**
Conductor screen application	**18.5**
Insulation, hot set test	**18.6**
Insulation, thickness	**18.7.1**
Insulation, concentricity	**18.7.2**
Circularity of cores	**18.8**
Insulation screen	
• application	**18.9.1**
• cold strippability	**18.9.2**
Metallic screen, application	**18.10**
Assembly of three-core cables	**18.11**
Separation sheath, thickness	**18.12**
Semi-conducting lapped inner covering, application	**18.13**
Measurement of armour wires	**18.14**
Oversheath thickness	**18.15**
Four-hour voltage test	**18.16**

A) If requested by the purchaser at the time of enquiry and/or order (see Annex B).

Table 4 **Schedule of tests** *(continued)*

Test		**Test method and requirements given in clause**
Type tests (see **3.14**)		
Material tests		
Conductor screen resistivity		**19.2**
Insulation material		**19.3**
Insulation screen resistivity		**19.4**
Insulation screen cold strippability		**19.5**
Semi-conducting lapped inner covering resistivity		**19.6**
Separation sheath material		**19.7**
Armour		
• galvanized steel wires	• mass of zinc coating	**19.8**
	• wrapping test	**19.9**
	• wet compatibility test	**19.10**
• aluminium wires	• tensile test	**19.11**
Oversheath – material		
• material		**19.12.1**
• shrinkage		**19.12.2**
Compatibility test		**19.13**
Test under fire conditions		**19.14**
Electrical tests		
Sequential tests (see **20.1**)		
• partial discharge test		**20.2**
• bending test		**20.3**
• tan δ in relation to voltage		**20.4**
• tan δ in relation to temperature		**20.5**
• heating cycle test		**20.6**
• impulse voltage test		**20.7**
• four-hour voltage test		**20.8**
Adherence of screens at short circuit temperature		**20.9**

16 Test conditions

16.1 Ambient temperature

Unless otherwise specified for a particular test, tests shall be performed at an ambient temperature within the range 5 °C to 35 °C.

16.2 Tolerances on temperature values

Unless otherwise specified for a particular test, the tolerances on the temperature values given in the test methods shall be as specified in Table 5.

Table 5 **Tolerances on temperature values**

Specified temperature, t °C	**Tolerance** °C
$-40 \leqslant t \leqslant 0$	±2
$0 < t \leqslant 50$	As specified for the particular test
$50 < t \leqslant 150$	±2
$t > 150$	±3

16.3 Frequency and waveform of power-frequency test voltages

Unless otherwise specified for a particular test, alternating test voltages shall have a frequency between 49 Hz and 61 Hz. The waveform shall be substantially sinusoidal.

17 Routine tests

17.1 General

Routine tests shall be as specified in Table 4.

17.2 Spark test on oversheath

The oversheath shall be tested in accordance with BS EN 50356 with the voltages specified in BS 5099. No breakdown of the oversheath shall occur.

17.3 Conductor resistance

When measured, and corrected to 20 °C, in accordance with BS EN 60228, the d.c. resistance of each conductor shall be not less than the relevant value specified in BS EN 60228.

17.4 Copper wire screen resistance

17.4.1 Method

For cables with a copper wire screen, the d.c. resistance of the screen shall be measured on the complete cable with the wires of the screen bunched together at the ends of the cable, and the resistance value corrected to 20 °C, in accordance with BS EN 60228.

17.4.2 Requirement

The d.c. resistance of the copper wire screen shall not exceed the relevant value specified in Table 6.

Table 6 **D.C. resistance of copper wire screen**

Nominal cross-sectional area of screen	**Maximum d.c. resistance at 20 °C**
mm^2	Ω/km
16	1.190
25	0.759
35	0.542
50	0.379
70	0.271
95	0.200

17.5 Partial discharge test

The cable shall be tested in accordance with BS EN 60885-3, except that the sensitivity, as defined in BS EN 60885-3, shall be 10 pC or better. The magnitude of the discharge on each core shall not exceed 10 pC, at the voltage specified in Table 7.

Table 7 **Voltage for partial discharge test**

Rated voltage, U_0	**Test voltage r.m.s.**
kV	kV
3.8	7.5
6.35	12.5
8.7	17.5
12.7	25.5
19.0	38.0

17.6 Voltage test on complete cable

The cable shall be subjected to a power frequency voltage as specified in Table 8, applied between the conductor(s) and the metallic screen(s) with the metallic screen(s) earthed. The voltage shall be raised gradually and shall be maintained at the specified value for 15 min. No breakdown of the insulation shall occur.

Table 8 **Voltage for test on complete cable**

Rated voltage, U_0 kV	**Test voltage r.m.s.** kV
3.8	15.0
6.35	25.5
8.7	35.0
12.7	51.0
19.0	76.0

17.7 Cable markings

The cable markings shall be checked by visual examination and measurement and shall conform to Clause **13**.

17.8 D.C. voltage test on oversheath

17.8.1 General

If specified by the purchaser at the time of enquiry or order (see Annex B), a d.c. voltage test shall be carried out on the oversheath.

17.8.2 Method

A d.c. voltage shall be applied for a period of 1 min between the metallic layer underlying the oversheath and the semi-conducting layer applied over the oversheath. The voltage applied shall be equal to 8 kV per millimetre of nominal thickness of oversheath, with a maximum of 25 kV.

17.8.3 Requirement

No breakdown of the oversheath shall occur.

18 Sample tests

18.1 General

Sample tests shall be as specified in Table 4.

18.2 Sampling frequency

Unless otherwise agreed between the purchaser and the manufacturer (see Annex B), the sampling frequency for sample tests shall be as follows.

Where the total length of cable in the order exceeds 2 km of three-core cable or 4 km of single-core cable, the numbers of samples for the four-hour voltage test and the hot set test on the insulation shall be as specified in Table 9.

Table 9 **Number of samples for the four-hour voltage test and the hot set test on the insulation**

Three-core cables		**Single-core cables**		**Number of samples**
Above	**Up to and including**	**Above**	**Up to and including**	
km	km	km	km	
2	10	4	20	1
10	20	20	40	2
20	30	40	60	3
30	—	60	—	1 additional sample for every additional 10 km of three-core cable or for every additional 20 km of single-core cable

For all other sample tests, samples shall be taken from one length from each manufacturing series of the same type and nominal cross-section of cable, but shall be limited to not more than 10% of the number of lengths in any order.

18.3 Repetition of sample tests

If any sample fails any of the tests specified in **18.1**, two further samples shall be taken from a different length from the same manufacturing series and submitted to the same test or tests which the original sample failed. If both additional samples pass the test(s), all the cables in the manufacturing series from which they were taken shall be deemed to conform to the standard. If either of the additional samples fails, the manufacturing series from which they were taken shall be deemed not to conform to the standard.

18.4 Conductor material and construction

The conductor material and construction shall be checked by visual examination and shall conform to Clause **5**.

18.5 Conductor screen

The application of the conductor screen shall be checked by visual examination. The conductor screen shall be continuous and shall cover the surface of the conductor completely.

18.6 Hot set test on insulation

XLPE insulation shall be subjected to a hot set test as specified in BS 7655-1.3 and shall conform to the requirements specified in BS 7655-1.3 for type GP 8.

EPR insulation shall be subjected to a hot set test as specified in BS 7655-1.2 and shall conform to the requirements specified in BS 7655-1.2 for type GP 7.

18.7 Dimensions

18.7.1 Thickness of insulation

The thickness of the insulation shall be measured in accordance with Annex H. The thickness of extruded conductor and insulation screens shall not be included in the measured insulation thickness. The smallest measured value shall not fall below 90% the nominal value given in Table 1 by more than 0.1 mm i.e.:

$$t_{min} \geqslant 0.9t_n - 0.1$$

where:

t_{min} is the minimum insulation thickness, in millimetres (mm);

t_n is the nominal insulation thickness, in millimetres (mm).

18.7.2 Concentricity of insulation

The difference between the maximum and minimum measured values of the insulation thickness divided by the maximum measured value shall be not greater than 0.15 i.e.:

$$\frac{t_{max} - t_{min}}{t_{max}} \leqslant 0.15$$

where:

t_{max} is the maximum insulation thickness, in millimetres (mm);

t_{min} is the minimum insulation thickness, in millimetres (mm).

18.8 Circularity of cores

18.8.1 Method

The diameter across the insulation at the insulation/screen interface shall be measured by an optical method with an accuracy of at least ±0.025 mm. The maximum and minimum diameters shall be recorded.

18.8.2 Requirement

The difference between the minimum and maximum measured diameters shall not exceed 0.5 mm.

18.9 Insulation screen

18.9.1 Application

The application of the insulation screen shall be checked by visual examination. The insulation screen shall be continuous and shall cover the surface of the insulation completely, as specified in **8.2**.

18.9.2 Cold strippability

If the insulation screen is cold strippable from the underlying insulation, this shall be tested in accordance with Annex I. The force required to remove the insulation screen shall be not less than 8 N and not more than 45 N.

18.10 Metallic screen (wires only)

The gaps between adjacent wires shall be measured and shall conform to the requirements specified in **10.2**.

18.11 Assembly of three-core cables

The laid-up cores shall be checked by visual examination and shall conform to the requirements specified in Clause **9**.

18.12 Separation sheath

The thickness of the separation sheath shall be measured in accordance with Annex H.

The smallest measured value shall not fall below 80% of the nominal value specified in **11.2.2** by more than 0.2 mm, i.e.:

$$t_{min} \geqslant 0.8t_n - 0.2$$

where:

t_{min} is the minimum separation sheath thickness, in millimetres (mm);

t_n is the nominal separation sheath thickness, in millimetres (mm).

18.13 Semi-conducting lapped inner covering

The application of the semi-conducting lapped inner covering shall be checked by visual examination and shall conform to the requirements specified in Clause **9**.

18.14 Measurement of armour wires

Ten percent of the total number of wires shall be taken at random from one sample of completed cable and the diameter of each wire shall be determined using a micrometer by taking two measurements at right angles to each other. The mean of all the measurements shall be taken as the wire diameter.

The wire diameter shall not fall below the relevant nominal value specified in Table 3 by more than 5%.

18.15 Oversheath thickness

18.15.1 The thickness of the oversheath shall be measured in accordance with Annex H and shall conform to **18.15.2** or **18.15.3**, as applicable.

18.15.2 For cables with an oversheath not applied directly over the armour, the smallest measured value shall not fall below 85% of the nominal value, as specified the purchaser or calculated in accordance with **12.2**, by more than 0.1 mm, i.e.:

$$t_{min} \geqslant 0.85t_n - 0.1$$

where:

t_{min} is the minimum oversheath thickness, in millimetres (mm);

t_n is the nominal oversheath thickness, in millimetres (mm).

18.15.3 For cables with an oversheath applied directly over the armour, the smallest measured value measured shall not fall below 80% of the nominal value, as specified by the purchaser or calculated in accordance with **12.2**, by more than 0.2 mm, i.e.:

$$t_{min} \geqslant 0.8t_n - 0.2$$

where:

t_{min} is the minimum oversheath thickness, in millimetres (mm);

t_n is the nominal oversheath thickness, in millimetres (mm).

18.16 Four-hour voltage test

18.16.1 Method

Earth the screen(s) of a piece of cable not less than 5 m in length between terminations. Subject the cable to an alternating power frequency voltage, as specified in Table 10, applied, in turn, between each conductor and the screen(s).

Increase the voltage gradually to the specified value and maintain it at that value for 4 h. Apply the voltage continuously, but if there are any unavoidable interruptions during the 4 h period, increase that period by a length of time equal to the duration of the interruptions, provided that the total duration of the interruptions does not exceed 1 h. If the total duration of the interruptions exceeds 1 h, restart the test.

18.16.2 Requirement

No breakdown of the insulation shall occur.

Table 10 **Voltages for four-hour voltage test**

Rated voltage, U_0 kV	**Test voltage r.m.s.** kV
3.8	15.0
6.35	25.5
8.7	35.0
12.7	51.0
19.0	76.0

19 Type tests – Materials

19.1 General

Type tests on materials shall be as specified in Table 4.

19.2 Conductor screen resistivity

The resistivity of the conductor screen shall be measured in accordance with Annex J and shall not exceed 500 Ω·m at 90 °C.

19.3 Insulation material

XLPE insulation shall be subjected to the tests specified in BS 7655-1.3, except for the insulation resistance test, and shall conform to the requirements specified in BS 7655-1.3 for type GP 8, with the exception of the insulation resistance constant.

EPR insulation shall be subjected to the tests specified in BS 7655-1.2, except for the insulation resistance test, and shall conform to the requirements specified in BS 7655-1.2 for type GP 7, with the exception of the insulation resistance constant.

NOTE Insulation resistance testing is not applicable to cables which have an insulation screen.

19.4 Insulation screen resistivity

The resistivity of the insulation screen shall be measured in accordance with Annex J and shall not exceed 500 Ω·m at 90 °C.

19.5 Insulation screen cold strippability

If the insulation screen is cold strippable, this shall be tested in accordance with Annex I and shall conform to **18.9.2**.

19.6 Semi-conducting lapped inner covering resistivity

Where a semi-conducting lapped inner covering is used, the resistivity of this inner covering, when measured in accordance with Annex K, shall not exceed 1 500 Ω/square.

19.7 Separation sheath material

The separation sheath material, when tested in accordance with BS EN 60811-1-1, shall have a tensile strength of not less than 4 N/mm^2 and an elongation at break of not less than 50%.

19.8 Mass of zinc coating of galvanized steel wires

19.8.1 Method

Take, at random, 10% of the total number of wires from one sample of completed cable and determine the mass by either the gravimetric or the gas volumetric method specified in BS EN 10244-2.

Take the mean of all the measurements as the mass of zinc coating.

19.8.2 Requirement

The mass of zinc coating of galvanized steel wires shall conform to Table 11.

Table 11 **Mass of zinc coating**

Nominal diameter of armour wire	Minimum mass of zinc coating
mm	g/m^2
1.6	172
2.0	180
2.5	195
3.15	206

19.9 Wrapping test for galvanized steel wires

19.9.1 Method

Take, at random, 10% of the total number of wires from one sample of completed cable. Using a cylindrical mandrel with a diameter of approximately four times the nominal diameter of the wires under test, wrap each wire round the mandrel for one complete turn.

19.9.2 Requirement

None of the wires shall break.

19.10 Wet compatibility test for galvanized steel wires and semi-conducting tape layers

19.10.1 Method

Galvanized steel wires in contact with semi-conducting tape layers shall be subjected to a wet compatibility test in accordance with Annex L.

19.10.2 Requirements

After 7 days the d.c. potential developed across the resistor shall not exceed 0.7 mV. In addition, when viewed with normal or corrected vision, without magnification, there shall be no visible evidence of rusting on the surface of the immersed portion of the wire or red/brown discoloration of the solution.

19.11 Tensile test for aluminium wires

19.11.1 Method

Take, at random, 10% of the total number of wires from one sample of completed cable. Measure the tensile strength of each wire in accordance with BS EN 10002-1. Determine the original cross-sectional area (S_o), to an accuracy of ±1%, from the mass of a known length of wire, assuming a density of 2.703 g/cm^3.

Take the mean of all the measurements as the tensile strength.

19.11.2 Requirement

The mean tensile strength shall be not less than 125 N/mm^2.

19.12 Oversheath

19.12.1 Material

The oversheath material shall conform to the requirements specified in BS 7655-4.2 for Type 9 or to the requirements specified in BS 7655-10.1 for Type TS 2, as applicable.

19.12.2 Shrinkage (type TS 2 only)

When subjected to the shrinkage test for polyethylene sheaths specified in BS EN 60811-1-3, under the conditions specified in Table 12, the shrinkage shall be not greater than 3%.

Table 12 **Conditions for oversheath shrinkage test**

Parameter	Value
Temperature	80 °C
Heating duration	5 h
Number of heating cycles	5

19.13 Compatibility test

The compatibility of the materials used in the cable shall be tested by ageing a sample of cable in an air oven at 100 °C for 7 days in accordance with the procedure for thermal ageing of pieces of complete cable given in BS EN 60811-1-2. Then the properties of the components shall be measured in accordance with the test methods listed in Table 13 and shall conform to the requirements specified in Table 13.

Table 13 **Compatibility requirements**

Component	Property	Test method	Requirements	
Extruded PE oversheath	Minimum tensile strength	BS EN 60811-1-1	12.5 N/mm^2	
	Minimum elongation at break		300%	
Extruded PVC oversheath	Minimum tensile strength	BS EN 60811-1-1	12.5 N/mm^2	
	Minimum elongation at break		150%	
	Maximum variation of tensile strength A)		25%	
	Maximum variation of elongation at break A)		25%	
Extruded inner covering	Minimum tensile strength	BS EN 60811-1-1	4 N/mm^2	
	Minimum elongation at break		50%	
Extruded separation sheath	Minimum tensile strength	BS EN 60811-1-1	4 N/mm^2	
	Minimum elongation at break		50%	
Insulation screen	Maximum resistivity at 90 °C	Annex J	1 000 Ω·m	
	Force to remove cold strippable insulation screen	Annex I	8 N to 45 N	
Insulation			XLPE	EPR
	Maximum variation of tensile strength A)	BS EN 60811-1-1	25%	30%
	Maximum variation of elongation at break A)		25%	30%
Conductor screen	Maximum resistivity at 90 °C	Annex J	1 000 Ω·m	
Semi-conducting lapped inner covering	Maximum resistivity at (23 ± 5) °C	Annex K	1 500 Ω/square	

A) The variation is the difference between the values obtained prior to and after heat treatment, respectively, expressed as a percentage of the former.

19.14 Test under fire conditions for PVC sheathed cables

The finished cable shall be tested in accordance with BS EN 60332-1-2:2004. After the test the cable shall conform to the performance criteria recommended in BS EN 60332-1-2:2004, Annex A.

20 Type tests – Electrical

20.1 General

Electrical type tests shall be as specified in Table 4. The tests specified in **20.2** to **20.8** shall be performed on a sample of cable not less than 10 m in length between terminations (excluding accessories, if any) in the sequence given in Table 4. The test specified in **20.9** shall be performed on a separate sample of cable.

20.2 Partial discharge test

The cable shall be tested in accordance with **17.5** and shall conform to the requirements specified in **17.5**.

20.3 Bending test

20.3.1 Method

The bending test shall be carried out using a cylinder with a diameter not greater than the following:

- for single-core cables: $15(D + d)$;
- for three-core 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-sectional area of the conductor in square millimetres (mm^2).

Perform the bending at ambient temperature. Bend the cable sample around the relevant test cylinder 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.

After completion of the bending, visually examine the oversheath with normal or corrected vision without magnification. Finally, subject the sample to a partial discharge test in accordance with **17.5**.

20.3.2 Requirements

The oversheath shall show no visible evidence of cracking.

The performance of the cable sample in the partial discharge test shall be as specified in **17.5**.

20.4 Tan δ in relation to voltage

The tan δ value of each core of the sample shall be measured at ambient temperature with a.c. voltages equal to $0.5U_0$, $1.0U_0$ and $2.0U_0$ and shall not exceed the relevant limits given in Table 14.

Table 14 **Tan δ in relation to voltage**

Property	**XLPE insulation**	**EPR insulation**
Maximum tan δ at U_0	40×10^{-4}	200×10^{-4}
Maximum increase in tan δ ($0.5U_0$ to $2.0U_0$)	20×10^{-4}	25×10^{-4}

20.5 Tan δ in relation to temperature

20.5.1 Method

Heat the sample of cable by external means or by passing current through the metallic screen or by current loading of the conductor(s).

Measure the tan δ value with an a.c. voltage of not less than 2 kV, at power frequency, at ambient temperature and at a conductor temperature of not less than 95 °C and not greater than 100 °C.

*NOTE At the discretion of the manufacturer, these measurements may be performed during the heating cycle test specified in **20.6.1**.*

20.5.2 Requirements

The tan δ values shall not exceed the relevant limits given in Table 15.

Table 15 **Tan δ in relation to temperature**

Property	Cables with XLPE insulation	Cables with EPR insulation
Maximum tan δ at ambient temperature	40×10^{-4}	200×10^{-4}
Maximum tan δ at elevated temperature (i.e. 95 °C to 100 °C)	80×10^{-4}	400×10^{-4}

20.6 Heating cycle test

20.6.1 Method

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 or armour.

Subject the cable sample to a heating cycle of 8 h duration. Maintain the conductor temperature between 95 °C and 100 °C for at least 2 h during the heating period, followed by at least 3 h of natural cooling in air. Perform this cycle 20 times. Confirm that the screen or armour temperature accurately reflects the required conductor temperature by making measurements of the phase conductor resistance.

During the heating cycles, take at least four measurements of partial discharge in accordance with **17.5**, at approximately equal intervals, each measurement being taken at the end of a cooling period, including one measurement at the completion of the test (i.e. after the last heating cycle).

20.6.2 Requirement

The discharge magnitude for each of the measurements shall not exceed 5 pC at a test voltage of $2U_0$.

20.7 Impulse voltage test

When the cable sample is tested in accordance with BS EN 60230, at the appropriate voltage specified in Table 16, each core of the cable shall withstand 10 positive and 10 negative voltage impulses without breakdown of the insulation.

Table 16 **Voltage for impulse voltage test**

Rated voltage, U_0 kV	Impulse withstand voltage (peak) kV
3.8	75
6.35	95
8.7	112
12.7	144
19.0	194

20.8 Four-hour voltage test

The cable sample shall be tested in accordance with the method given in **18.16.1**. No breakdown of the insulation shall occur.

20.9 Adherence of screens at short circuit temperature

20.9.1 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 a partial discharge test in accordance with **17.5**.

Then subject one core of the cable sample to a short circuit current, I, with an r.m.s. value in amperes (A) calculated in accordance with one of the following equations, as appropriate, and with a maximum duration of 3 s:

For copper conductors:

$$I^2t = 11.77 \times 10^4 A^2 \log_{10}\frac{(234 + T_2)}{(234 + T_1)}$$

For aluminium conductors:

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

where:

- t is the duration of the short circuit current in seconds (s);
- A is the conductor cross-sectional area in millimetres squared (mm^2);
- T_2 is the final conductor temperature = 250 °C;
- T_1 is the initial conductor temperature in degrees centigrade (°C).

Then allow the cable sample to cool to ambient temperature and subject it to a further partial discharge test in accordance with **17.5**.

20.9.2 Requirement

The discharge magnitude in each of the partial discharge tests shall not exceed 5 pC at a test voltage of $2U_0$.

Annex A (informative) Recommendations for the selection of cables

A.1 General

The cables specified in this standard are designed to be installed in air or to be buried in free draining soil.

Where cables are to be laid in other environments, the cable manufacturer should be consulted. Subclause **D.3** gives details of the limitations of the cables specified in this standard.

A.2 Voltage ratings

The rated voltage of the cable for a given application should be suitable for the operating conditions in the system in which the cable is used. To facilitate the selection of the cable, systems are divided into three categories as follows:

a) *Category A*. This category comprises those systems in which any phase conductor that comes in contact with earth or an earth conductor is disconnected from the system within 1 min.

b) *Category B*. This category comprises those systems which, under fault conditions, are operated for a short time with one phase earthed. IEC 60183 recommends that this period should not exceed 1 h. For cables specified in this standard, a longer period, not exceeding 8 h on any occasion, can be tolerated. The total duration of earth faults in any year should not exceed 125 h.

c) *Category C*. This category comprises all systems which do not fall into categories A or B.

NOTE In a system in which an earth fault is not automatically and promptly isolated, the extra stresses on the insulation of cables during the earth fault might reduce the life of the cables. If the system is expected to be operated fairly often with a permanent earth fault, it might be advisable to classify the system as category C.

Table A.1 gives the lowest rated voltage of cable that should be used according to the system voltage and category.

Table A.1 **Selection of cables for three-phase a.c. systems**

System voltage		System category	Minimum rated voltage of cable, U_0/U
Nominal voltage, *U*	**Maximum sustained voltage, U_m**		
kV	kV		kV
6.6 or 6	7.2	A or B	3.8/6.6
6.6 or 6	7.2	C	6.35/11
11 or 10	12	A or B	6.35/11
11 or 10	12	C	8.7/15
15	17.5	A or B	8.7/15
15	17.5	C	12.7/22
22 or 20	24	A or B	12.7/22
22 or 20	24	C	19/33
33 or 30	36	A or B	19/33

NOTE For a 33 kV or 30 kV system of category C, the cable manufacturer should be consulted.

The nominal system voltage, U, given in Table A.1 is the nominal voltage between phases.

The maximum sustained system voltage, U_m, is the highest voltage between phases that can be sustained under normal operating conditions at any time and at any point in the system. It excludes transient voltage variations, due, for example, to lightning impulses, fault conditions and rapid disconnection of loads.

The nominal system voltages shown in Table A.1 are generally in accordance with series 1 as given in IEC 60038:2002. For system voltages intermediate between the values in Table A.1, the cable should be selected with a rated voltage not less than the next highest value (e.g. for a 13.8 kV system of category A or B, the cable should have a rated voltage not less than 8.7/15 kV and for a 13.8 kV system of category C, not less than 12.7/22 kV).

A.3 Metallic coverings

All the cable designs in this standard include metallic coverings surrounding the cores, either individually or collectively, which are intended to be earthed when the cables are in use.

A.4 Selection of metallic coverings in relation to earth fault capacity

The metallic coverings are usually required to carry earth fault current.

Under the conditions of an earth fault in the cable itself, due, for example, to spiking, the local heating at the fault position, caused by contact resistance or resistance in the fault, is more intense than in the metallic screen as a whole. This causes fusing of the screen locally and the current which the screen will sustain for a given time under these conditions is less than that for which it is suitable under through-fault conditions.

Advice on the most suitable type and cross-sectional area of metallic screen for a particular application should be sought from the manufacturer.

A.5 Semi-conducting layer on the oversheath

The purchaser has the option to specify a d.c. voltage test on the oversheath of the cable, and if this is specified, the cable is required to have a semi-conducting layer applied over the oversheath (see **12.3**). The test, which is a routine test, and the requirement that has to be met, are specified in **17.8**.

It is not envisaged that such a test would be needed unless it was also intended to apply a voltage test to the oversheath after the cable had been laid, to confirm that the oversheath had not been substantially damaged during installation or to detect such damage as might have occurred in order to enable repairs to be made.

A d.c. voltage test on the oversheath might be necessary in the following situations:

a) when the oversheath is required to perform an insulating function during the operation of the cable. This applies when the method of bonding of the metallic screens of single-core cables is designed to eliminate induced circulating currents, but gives rise to standing voltages between the metallic screens of the cables of the different phases, e.g. bonding at one position only and cross bonding (see **C.6**);

b) when damage to the oversheath is likely to lead to corrosion of an essential metallic layer which it protects, due to an environment aggressive to the particular metal.

A.6 Current carrying capacity

The cable that is selected should have a sustained current rating under the conditions of installation not less than the maximum current that it will be required to carry during normal operation. It should also have a short-circuit current rating adequate for the prospective short-circuit current and the time for which it can persist.

Standardized current rating data for the cables specified in this standard have not been published. Reference should be made to the manufacturer's recommendations.

NOTE 1 A limitation on the temperature of the cables might be needed if the cables are to be installed in situations where people might come into direct contact with them.

NOTE 2 Owing to the relatively high conductor temperature, there is a risk of buried cables drying out the surrounding soil causing an increase in thermal resistivity which in turn would lead to the cable temperature rising to a higher value than anticipated. For cable to be laid directly in the ground, a de-rating factor should be applied or a lower maximum sustained conductor operating temperature should be assumed, to take into account the possible effect of soil drying out.

NOTE 3 The performance of accessories should be taken into account in deciding the operating temperature of the cable.

Annex B (normative) Information to be supplied and items to be agreed

B.1 Information to be supplied by the purchaser at the time of enquiry and/or order

The following information shall be supplied by the purchaser at the time of enquiry and/or order:

a) length of cable required, and individual drum lengths, if particular drum lengths are required;

b) voltage designation (see Clause **4**);

c) number of cores;

d) size of phase conductor;

e) conductor material (i.e. copper or aluminium) (see Clause **5**);

f) type of conductor (i.e. stranded or solid) (see Clause **5**);

g) type of insulation (i.e. XLPE or EPR) and limiting dimensions (if any) of the cores;

h) whether the insulation screen is required to be cold strippable (see **8.2**);

i) type of metallic insulation screen (see Clause **10**);

j) cross-sectional area of metallic insulation screen;

k) if an armour layer with a special construction is required which requires the armour to be made of magnetic material (see **11.1.2**);

l) if a steel armour layer with a specific minimum conductance is required (see **11.1.2** Note);

m) type of oversheath (i.e. PVC or PE);

n) nominal thickness of oversheath if a thickness other than that specified in **12.2** is required;

o) if a d.c. voltage test on the oversheath is required (see **12.3** and **17.8**).

NOTE See Annex A and Annex D for recommendations on the selection and use of cables.

B.2 Items to be agreed between the purchaser and the manufacturer

The following items shall be agreed between the purchaser and the manufacturer at the time of enquiry and/or order:

a) colour of the oversheath if a colour other than black is required (see **12.1** Note);

b) sampling frequency for sample tests if different from that specified in **18.2**.

Annex C (informative) Recommendations for the installation of cables

C.1 Minimum temperature during installation

It is recommended that the cables specified in this standard be installed only when both the cable and ambient temperatures are above 0 °C and have been so for the previous 24 h, or where special precautions have been taken to maintain the cable above this temperature.

C.2 Minimum installation radius

Except where bends in the cables are positioned adjacent to joints or terminations, none of the cables specified in this standard should be bent during installation to a radius smaller than that given in Table C.1. Wherever possible, larger installation radii should be used.

Table C.1 **Bending radius during installation**

Type of cable	Minimum radius
Single-core	15*D*
Three-core	12*D*
NOTE D is the overall diameter of the cable.	

Where bends in the cables are positioned adjacent to joints or terminations the minimum bending radius may be reduced to that given in Table C.2 provided that the bending is carefully controlled, e.g. by the use of a former.

Table C.2 **Bending radius during installation for cables adjacent to joints or terminations**

Type of cable	Minimum bending radius
Single-core	12*D*
Three-core	10*D*
NOTE D is the overall diameter of the cable.	

C.3 Prevention of moisture ingress

Care should be exercised during installation to avoid any damage to cable coverings. This is important in wet or other aggressive environments, especially for cables that do not have an extruded inner covering or separation layer. The protective cap should not be removed from the ends of the cable until immediately prior to termination or jointing. When the caps have been removed the unprotected ends of the cable should not be exposed to moisture.

The possibility of damage to moisture seals during handling and installation or during storage of the cable should be borne in mind. Where such damage might have occurred, the seals should be inspected and remade if necessary.

C.4 Joints and terminations

In the absence of a metal sheath, all earth fault currents return through the armour and/or screens unless there is a parallel bonding connection to relieve them of some of the fault current. In either case it is necessary to ensure that there is no discontinuity in the return circuit via the armour and/or screens and no local spot of high resistance. Careful attention, therefore, should be paid to the design of all bonding clamps in joints and terminations to ensure that each tape, wire or strip contributes equally to the conductance of the bonding connection and that the resistance across a connector is not higher than that of the equivalent length of connected armour and/or screens of the cable.

It is also important to ensure that all tapes, strips or wires and all faces of clamps or connectors making contact with them are thoroughly cleaned during installation and that the clamps are adequately tightened to ensure good electrical contact. Bonding clamps in joints should be electrically connected with a bond having a conductance at least equivalent to that of an equal length of the complete armour and/or screens of the cable, and with adequate thermal capacity to avoid excessive overheating under short circuit conditions.

With all the cables specified in this standard it is important to ensure that the semi-conducting insulation screen (see **8.2**) is removed from the core(s) and any remaining semi-conducting coating or semi-conducting particles are thoroughly removed before application of the stress control components, which may be made up of:

a) moulded components;

b) various tapes;

c) heat shrinkable tubes.

A similar procedure should be followed for joints.

Insulation screens should be removed using the methods recommended by the cable manufacturer. It is also recommended that the advice of the cable and/or accessory manufacturer be sought on suitable methods of jointing and terminating all cables specified in this standard.

C.5 Compound filling

For compound filled joints, the design of the box and the composition of the filling compound should be such as to provide an effective seal to prevent moisture gaining access to the conductor ferrules and armour connections. The filling compound should be compatible with the materials of the cable components with which it comes into contact. Account should be taken of the pouring temperatures and the temperatures resulting from any exothermic reactions.

For terminations, provided that adequate clearances are maintained between phases and between each phase and earth, compound filling is not necessary. The minimum clearances should be related to the voltage and category of the system and to the environmental conditions. Guidance on minimum clearances can be obtained from the relevant equipment standards. Where the required clearances cannot be achieved, some other effective means of insulation should be provided.

C.6 Earthing of armour and screen(s)

Provision should be made for earthing the armour and screen(s) to the main earth system at the supply end by means of a metallic bond of adequate conductance, the bonding connection being as short and straight as possible. It is also desirable to earth the armour and screens at additional accessible positions, unless single-point bonding is being employed.

Special precautions may be necessary to eliminate the risk of corrosion, especially corrosion due to the use of dissimilar metals.

Care should be taken with single-core cables to ensure that the bonding and earthing arrangements are adequate to cater for circulating currents in the armour and screen(s).

In special circumstances it may be necessary to employ cross bonding or single-point bonding and in these cases recommendations should be sought from the manufacturer. With single-point bonded systems, attention is drawn to the fact that induced voltages can arise in the armour and screen(s).

C.7 Tests after installation

C.7.1 Tests on insulation

C.7.1.1 General

If agreed between the purchaser and the installer, the cable may be subjected to an a.c. voltage test at power frequency in accordance with **C.7.1.2** or to a d.c. voltage test in accordance with **C.7.1.3**.

C.7.1.2 A.C. testing

If an a.c. voltage test at power frequency has been agreed, this should be performed using one of the following methods.

a) The cable should be tested for 5 min with the phase-to-phase voltage of the system applied between the conductor and the metallic screen or sheath.

b) The cable should be tested for 24 h with the normal operating voltage.

No breakdown of the insulation should occur.

C.7.1.3 D.C. testing

If a d.c. voltage test has been agreed, a d.c. test voltage equal to $4U_0$ should be applied for 15 min.

No breakdown of the insulation should occur.

NOTE 1 A d.c. test can endanger the insulation system under test. Other methods are under consideration.

NOTE 2 For installations which have been in use, lower voltages and/or shorter durations may be used. Values should be negotiated, taking into account the age, environment, history of breakdowns and the purpose of carrying out the test.

C.7.2 D.C. voltage test on oversheath

When a semi-conducting layer has been applied to the oversheath in accordance with **12.3** a d.c. voltage test can be performed after installation. This d.c. voltage test should only be performed on the installed system if the joints are suitably insulated from earth; otherwise the test should be performed on the cable prior to jointing.

A d.c. voltage of 8 kV should be applied for 1 min between the semi-conducting layer and the oversheath. No breakdown of the oversheath should occur.

Annex D (informative) Guide to use of cables

D.1 General

The aim of this annex is to inform users of characteristics and limitations of the electric cables specified in this British Standard and thereby to minimize their misuse.

It has been assumed that the design of installations and the specification, purchase and installation of the cables specified in this British Standard will be entrusted to suitable skilled and competent people.

In cases of doubt as to the suitability of cables specified in this British Standard for a particular use, further specific information should be obtained from the manufacturer.

D.2 Cable selection in relation to installation design

D.2.1 The cables specified in this British Standard are intended to be used for the supply of electrical energy up to the rated voltage indicated on the cable. The voltage ratings of the cables specified in this standard are listed in Table A.1. These voltages should not be exceeded.

D.2.2 These cables are intended for use at a nominal power frequency range of 49 Hz to 61 Hz.

D.2.3 There are several aspects which need to be taken into account relating to the ability of the cable to withstand the worst anticipated fault condition of the system, as follows (see also **A.4**).

a) In a solidly or directly earthed system, in general the earth fault current is at least equal to the three-phase or phase-to-phase fault current.

b) When an earth fault current is specified for a system, it is necessary to ensure that the phase conductor of the cable selected has a corresponding earth fault capacity.

c) Some work on spiking of cables has been undertaken by the British cable industry and it has shown that, in general, the spiking capability of the screen(s) is less than their through fault capacity.

d) This standard specifies different forms of metallic screen having different earth fault capacities. In general, copper tape screen has a lower earth fault current capacity than standard copper wire screen. For high earth fault values, where a three-core cable is to be used, a cable with a collective wire screen or armour is recommended.

e) It is essential that connections at joints between, and terminations onto, metallic elements carrying fault currents to earth have an earth fault capacity at least equal to that of the metallic elements.

D.2.4 The possible effects of transient over-voltages should be recognized as they can be detrimental to cables.

D.3 Environmental factors

D.3.1 Cables should be provided with protection against mechanical damage appropriate to the type of cable and the installation conditions.

D.3.2 Cables specified in this British Standard, when installed in vertical bunches, can propagate fire, and when exposed to fire can produce harmful smoke and effluents. Cables with improved performance under fire conditions are specified in BS 7835.

D.3.3 Cables can be damaged by exposure to corrosive substances or solvents, including petroleum based vapours.

D.3.4 Cables specified in this British Standard are not specifically designed for the following:

a) for use as self supporting aerial cables;

b) for use as submarine cable or for laying in waterlogged conditions;

c) for use in situations where subsidence is likely, unless special precautions are taken to minimize damage if subsidence should occur;

d) for use in situations where they could be exposed to excessive heat.

D.3.5 If the cables specified in this standard are exposed to localized heat, solar radiation or high temperature ambient conditions, this reduces the current carrying capacity.

D.3.6 The cable sheathing components specified in this standard do not provide protection against damage by rodents, termites, etc.

D.3.7 Loaded cables can have a high surface temperature which requires protection to be provided against accidental contact.

D.4 Installation

D.4.1 Precautions should be taken to avoid mechanical damage to the cables before and during installation (see Annex C).

D.4.2 Exceeding the manufacturer's recommended maximum pulling tensions should be avoided as this can result in damage to the cable.

D.4.3 If cables are to be installed in ducts, the correct size of duct should be used.

D.4.4 The type of jointing and filling compounds employed should be chemically compatible with the cable materials (see **C.5**).

D.4.5 The cable support system should be such as to avoid damage to the cables.

D.4.6 Cables specified in this British Standard are designed for fixed installations only; they are not intended for use as, for example, trailing or reeling cables.

D.4.7 Repeated over-voltage testing can lead to premature failure of the cable, see **C.7.1**.

D.4.8 The selection of cable glands, accessories and any associated tools should take account of all aspects of intended use. Any semi-conducting coating present on the oversheath should be removed for a suitable distance from joints and terminations.

D.4.9 Care should be exercised with single-core cables to ensure that the bonding and earthing arrangements are adequate to cater for circulating currents in the armour and screen(s).

D.5 Storage and handling of drums

D.5.1 Cable drums should be regularly inspected during storage to assess their physical condition.

D.5.2 Battens, where applied, should not be removed from the drums until the cable is about to be installed.

D.5.3 When handling drums, precautions should be taken to avoid injury. Due regard should be given to the weight of the drums, the method and direction of rolling, the method of lifting, and any protruding nails or splinters.

D.5.4 Drums should be protected from the weather so as to avoid deterioration. Care should be taken that drums are not left anywhere where they could be a hazard to the public.

D.5.5 The cable manufacturer should be consulted for detailed guidance on the safe handling of cable drums.

D.6 Incineration of scrap cable

Incineration of scrap cable should only be undertaken by a licensed contractor. For further information, the Environment Agency should be contacted.

Annex E (normative) Fictitious calculation method for determination of dimensions of protective coverings

COMMENTARY ON ANNEX E

This annex reproduces verbatim the relevant parts of IEC 60502-2:2005, Annex A.

This annex is intended for use in the calculation of "fictitious diameters" (see ***3.11****).*

The thickness of cable coverings, such as sheaths and armour, has usually been related to nominal cable diameters by means of "step-tables".

This sometimes causes problems. The calculated nominal diameters are not necessarily the same as the actual values achieved in production. In borderline cases, queries can arise if the thickness of a covering does not correspond to the actual diameter because the calculated diameter is slightly different. Variations in shaped conductor dimensions between manufacturers and different methods of calculation cause differences in nominal diameters and may therefore lead to variations in the thicknesses of coverings used on the same basic design of cable.

To avoid these difficulties, the fictitious calculation method shall be used. The idea is to ignore the shape and degree of compaction of conductors and to calculate fictitious diameters from formulae based on the cross-sectional area of conductors, nominal insulation thickness and number of cores. Thicknesses of sheath and other coverings are then related to the fictitious diameters by formulae or by tables. The method of calculating fictitious diameters is precisely specified and there is no ambiguity about the thicknesses of coverings to be used, which are independent of slight differences in manufacturing practices. This standardizes cable designs, thicknesses being pre-calculated and specified for each conductor cross-section.

The fictitious calculation is used only to determine dimensions of sheaths and cable coverings. It is not a replacement for the calculation of actual diameters required for practical purposes, which should be calculated separately.

E.1 General

The following fictitious method of calculating thicknesses of various coverings in a cable has been adopted to ensure that any differences which can arise in independent calculations, for example due to the assumption of conductor dimensions and the unavoidable differences between nominal and actually achieved diameters, are eliminated.

All thickness values and diameters shall be rounded according to the rules in Annex F to the first decimal figure.

Holding strips, for example counter helix over armour, if not thicker than 0.3 mm, are neglected in this calculation method.

E.2 Method

E.2.1 Conductors

The fictitious diameter (d_L) of a conductor, irrespective of shape and compactness, is given for each nominal cross-section in Table E.1.

Table E.1 **Fictitious diameter of conductor**

Nominal cross-section of conductor mm^2	d_L mm	**Nominal cross-section of conductor** mm^2	d_L mm
10	3.6	240	17.5
16	4.5	300	19.5
25	5.6	400	22.6
35	6.7	500	25.2
50	8.0	630	28.3
70	9.4	800	31.9
95	11.0	1 000	35.7
120	12.4		
150	13.8		
185	15.3		

E.2.2 Cores

The fictitious diameter D_c of any core is given by:

$$D_c = d_L + 2t_i + 3.0$$

where:

t_i is the nominal thickness of insulation, in millimetres (see Table 1).

If a metallic screen or a concentric conductor is applied, a further addition shall be made in accordance with **E.2.5**.

E.2.3 Diameter over laid-up cores

The fictitious diameter over laid-up cores (D_f) is given by:

$$D_f = kD_c$$

where the assembly coefficient k is 2.16 for a three-core cable.

E.2.4 Inner coverings

The fictitious diameter over the inner covering (D_B) is given by:

$$D_B = D_f + 1.2$$

These fictitious values apply to:

a) three-core cables:

- whether an inner covering is applied or not;
- whether the inner covering is extruded or lapped;

  unless a separation sheath complying with **11.2** is used in place of or in addition to the inner covering, when **E.2.6** applies instead;

b) single-core cables:

- when an inner covering is applied whether it is extruded or lapped.

E.2.5 Concentric conductors and metallic screens

The increase in diameter due to the concentric conductor or metallic screen is given in Table E.2.

Table E.2 **Increase of diameter for concentric conductors and metallic screens**

Nominal cross-section of concentric conductor or metallic screen mm²	Increase in diameter mm	Nominal cross-section of concentric conductor or metallic screen mm²	Increase in diameter mm
16	1.1	120	2.7
25	1.2	150	3.0
35	1.4	185	4.0
50	1.7	240	5.0
70	2.0	300	6.0
95	2.4		

If the cross-section of the concentric conductor or metallic screen lies between two of the values given in the table above, then the increase in diameter is that given for the larger of the two cross-sections.

If a metallic screen is applied, the cross-sectional area of the screen to be used in the table above shall be calculated in the following manner:

a) tape screen

cross-sectional area = $n_t \times t_t \times w_t$

where

n_t is the number of tapes;

t_t is the nominal thickness of an individual tape, in millimetres;

w_t is the nominal width of an individual tape, in millimetres.

Where the total thickness of the screen is less than 0.15 mm then the increase in diameter shall be zero:

- for a lapped tape screen made of either two tapes or one tape with overlap, the total thickness is twice the thickness of one tape;
- for a longitudinally applied tape screen:
  - if the overlap is below 30%, the total thickness is the thickness of the tape;
  - if the overlap is greater than or equal to 30%, the total thickness is twice the thickness of the tape.

b) wire screen (with a counter helix, if any)

$$\text{cross-sectional area} = \frac{n_w \times d_w^2 \times \pi}{4} + n_h \times t_h \times w_h$$

where:

n_w is the number of wires;

d_w is the diameter of an individual wire, in millimetres;

n_h is the number of a counter helix;

t_h is the thickness of a counter helix, in millimetres, if greater than 0.3 mm;

w_h is the width of a counter helix, in millimetres.

E.2.6 Separation sheath

The fictitious diameter over the separation sheath (D_s) is given by:

$$D_s = D_u + 2t_s$$

where:

D_u is the fictitious diameter under the separation sheath, in millimetres;

t_s is the thickness in accordance with **12.2.1**, in millimetres.

E.2.7 Armour

The fictitious diameter over the armour (D_x) is given for round wire armour by:

$$D_x = D_A + 2t_A + 2t_w$$

where:

D_A is the diameter under the armour, in millimetres;

t_A is the thickness or diameter of the armour wire, in millimetres;

t_w is the thickness of the counter helix, if any, in millimetres.

Annex F (normative) Rounding of numbers

NOTE This annex is based on IEC 60502-2:2005, Annex C.

F.1 Rounding of numbers for the purpose of the fictitious calculation method

The following rules shall be applied when rounding numbers in the calculation of fictitious diameters and determination of dimensions of component layers in accordance with Annex E.

When the calculated value at any stage has more than one decimal place, the value shall be rounded to one decimal place, i.e. to the nearest 0.1 mm. The fictitious diameter at each stage shall be rounded to the nearest 0.1 mm and, when used to determine the thickness or dimension of an overlying layer, it shall be rounded before being used in the appropriate formula or table. The thickness calculated from the rounded value of the fictitious diameter shall in turn be rounded to the nearest 0.1 mm as required in Annex E.

Values shall be rounded according to the following rules.

a) When the figure in the second decimal place, before rounding, is 0, 1, 2, 3 or 4, then the figure retained in the first decimal place shall remain unchanged (i.e. the value shall be rounded down).

   EXAMPLES:

   2.12 would be rounded to 2.1

   2.449 would be rounded to 2.4

   25.0478 would be rounded to 25.0

b) When the figure in the second decimal place, before rounding, is 5, 6, 7, 8 or 9, then the figure in the first decimal place shall be increased by one (i.e. the value shall be rounded up).

EXAMPLES:

2.17 would be rounded to 2.2

2.453 would be rounded to 2.5

30.05 would be rounded to 30.1

F.2 Rounding of numbers for other purposes

For purposes other than those given in **F.1**, values shall be rounded to the number of decimal places given in the relevant clause of the standard according to the following rules.

a) If the last figure to be retained is followed, before rounding, by 0, 1, 2, 3 or 4, it shall remain unchanged (i.e. the value shall be rounded down);

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

EXAMPLES:

2.449 rounded to two decimal places would give 2.45

2.449 rounded to one decimal place would give 2.4

25.0478 rounded to three decimal places would give 25.048

25.0478 rounded to two decimal places would give 25.05

25.0478 rounded to one decimal place would give 25.0.

Annex G (informative) Guidance on the scope of type tests

G.1 General

Type tests, after they have been successfully completed, need not be repeated unless changes are made which might affect conformity to the requirements. Thus type tests should not normally be required for individual orders if the tests have already been successfully performed by the manufacturer on similar items.

If the type tests discussed in **G.3** have already been successfully performed by the manufacturer for conformity to BS 7835, repetition of the type tests is not necessary on account of differences in the protective layers applied over the screened cores, unless these would be likely to have a significant effect on the results, taking into account that the prime purpose of the type test is to test the electrical performance of the insulating system.

Guidance for each type test on the extent to which the results of the test on one or more cables can be taken as typical for a range of cables or for similar components used in other cables is given in **G.3**, **G.4** and **G.5**.

G.2 Invoking of type tests

When type testing, or evidence of relevant type testing previously carried out, is required for cables to be ordered, this should be stated at the enquiry stage.

Because of the possible variations in the cable designs, it should not be assumed that full type test information will automatically be available for the particular cables which are the subject of a particular enquiry. Moreover, **G.3**, **G.4** and **G.5** give only guidelines as to the amount of type testing or type test evidence it may be reasonable to require and these guidelines are open to interpretation.

When type testing or evidence of type testing is required, the details are finally the subject of agreement between the purchaser and the manufacturer.

G.3 Sequential electrical type tests

The sequential electrical type tests are intended to assess the performance of the type of cable. Cables are generally regarded as being of the same type if they are of the same voltage rating and of similar construction.

For the purposes of the sequential electrical type tests, cables of similar construction are generally regarded as those having the same number of cores (single-core or three-core), the same form of conductor (stranded or solid), the same insulating material (XLPE or EPR), and the same form of semi-conducting screens.

One type of cable embraces a range of different conductor sizes and, if the sequential electrical type tests have been performed successfully on cable(s) of particular conductor size(s), the results should be regarded as valid for cables of the same type having other conductor sizes. The results of tests on cable of one conductor size in the range 70 mm^2 to 300 mm^2 should be accepted as valid for cables of other conductor sizes in that range. For cables of conductor sizes outside that range, successful tests on cables of two conductor sizes should be accepted as valid for the same type of cable of the two next standard smaller sizes below the smaller size tested, and the two next standard larger sizes above the larger size tested.

The results of tests on cables with stranded copper conductors should be accepted as valid for similar cables with stranded aluminium conductors, and vice versa.

Successful tests on three-core cables should be accepted as valid for single-core cables, otherwise of the same type, for the same range of conductor size. However, as the manufacture of three-core cable can impose greater demands on the insulating system than that of single-core cable, tests on single-core cable are generally not regarded as demonstrating the performance of three-core cable.

Tests performed successfully on cables of one voltage rating should be accepted as demonstrating the manufacturer’s ability to produce satisfactory cables of lower voltage rating utilizing the same materials and processing methods, without additional type testing.

G.4 Compatibility test (see **19.13**)

The object of the compatibility test is to check that different materials forming the components of the cable do not have an unduly adverse effect on each other. It is a test for a type of construction and is largely independent of cable voltage and conductor size or form. A successful test on one cable having a particular construction should be accepted as demonstrating the suitability of the construction, in terms of the manufacturer's selection of materials and processing of the components, for other cables of any rated voltage and size or form of conductor.

G.5 Type tests on components

The type tests on cable components, embracing the physical and chemical tests on insulation and sheathing and the measurement of resistivity on semi-conducting screens, are tests for the type of component, not for the type of cable. The properties of the components covered by these type tests are independent of the rated voltage or the size of the cable, unless materials or methods of application and processing are varied according to the cable type.

Successful tests on components from one cable should therefore be accepted as demonstrating the satisfactory performance of an identical component when used in other cables of different rated voltage and/or size.

G.6 Evidence of type testing

A certificate of type testing signed by the representative of a competent witnessing body, or a report by the manufacturer giving the test results and signed by the appropriate personnel in his organization should be accepted as evidence of type testing.

Annex H (normative) Thickness measurements

H.1 Sampling

Measurement of the thickness of the insulation, separation sheath (if any) and non-metallic oversheath, as specified in **18.7**, **18.12** and **18.15**, respectively, shall be made on a sample taken from one end of each drum length of cable selected for the test, after having discarded any portion which might have suffered damage.

If any of the thicknesses measured does not conform to **18.7**, **18.12** or **18.15**, as applicable two further samples shall be measured for the non-conforming parameter(s). If both of the further samples meet the specified requirements, the cable shall be deemed to conform to the requirements of this British Standard, but if either does not meet the requirements, the cable shall be deemed not to conform.

H.2 Procedure

Make measurements on each component in accordance with the method given in BS EN 60811-1-1, using either the equipment specified in BS EN 60811-1-1 or a calibrated hand lens.

In the event of a dispute, the equipment specified in BS EN 60811-1-1, shall be used.

Measure and record the following:

a) for the insulation: the minimum thickness and the maximum thickness;

b) for the separation sheath: the minimum thickness;

c) for the oversheath: the minimum thickness.

For three-core cables, measure the insulation thickness on each core.

Annex I (normative) Test method for cold strippability of the extruded semi-conducting layer of an insulation screen

The test shall be performed three times, either on three separate pieces of cable or at three positions equally spaced around the circumference of a single piece of cable.

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

Two cuts shall be made in the semi-conducting layer of the insulation screen of each piece of cable, or at each test position, as applicable, running longitudinally from end to end and radially down to the insulation, the cuts being (10 ± 1) mm apart and parallel to each other.

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

After removing an approximately 50 mm length of the 10 mm wide strip by pulling it in a direction parallel to the core (i.e. at 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 wide strip in the other.

The force to required to separate the 10 mm wide strip from the insulation, shall be measured at a stripping angle of approximately 180° using a pulling speed of (250 ± 50) mm/min and separating a length of at least 100 mm. The stripping force values shall be continuously recorded.

Annex J (normative) Method for measurement of resistivity of extruded semi-conducting conductor screen and insulation screen

J.1 Preparation of test pieces

Prepare test pieces from 150 mm lengths of core taken from completed cable.

Prepare a conductor screen test piece by cutting a length of core in half longitudinally and then removing the conductor (see Figure J.1). Prepare an insulation screen test piece by removing all the coverings from a length of core (see Figure J.2).

J.2 Procedure

Apply four silver painted electrodes, A, B, C and D, to the semi-conducting surfaces (see Figure J.1 and Figure J.2). Ensure that the two potential electrodes, B and C, are approximately 50 mm apart and each of the two current electrodes, A and D, is placed at least 25 mm beyond the relevant potential electrode.

Make connections to the electrodes by means of suitable clips, taking care to avoid damage to the screen. When testing the conductor screen test piece ensure that the clips are insulated from the insulation screen on the outside of the core.

Place the assembly in an oven pre-heated to (90 ± 2) °C and after an interval of at least 30 min, measure the resistance between the potential electrodes, B and C, by means of a circuit with a power not exceeding 100 mW.

After taking the electrical measurements, measure the diameter over the conductor screen, the diameter over the insulation screen, and the thickness of the conductor screen and of the insulation screen. For each parameter take six measurements evenly distributed around the circumference of the core and calculate the mean. Measure the distance between the two potential electrodes, B and C.

J.3 Calculations

J.3.1 Conductor screen

Calculate the resistivity, ρ, in ohm metres (Ω·m) of the conductor screen from the following equation:

$$\rho = \frac{R \times \pi \times (D - T) \times T}{2L}$$

where:

- R is the measured resistance in ohms (Ω);
- L is the measured distance between the potential electrodes, in metres (m);
- D is the mean diameter over the conductor screen in metres (m);
- T is the mean thickness of the conductor screen in metres (m).

J.3.2 Insulation screen

Calculate the resistivity, ρ, in ohm metres (Ω·m), of the insulation screen from the following equation:

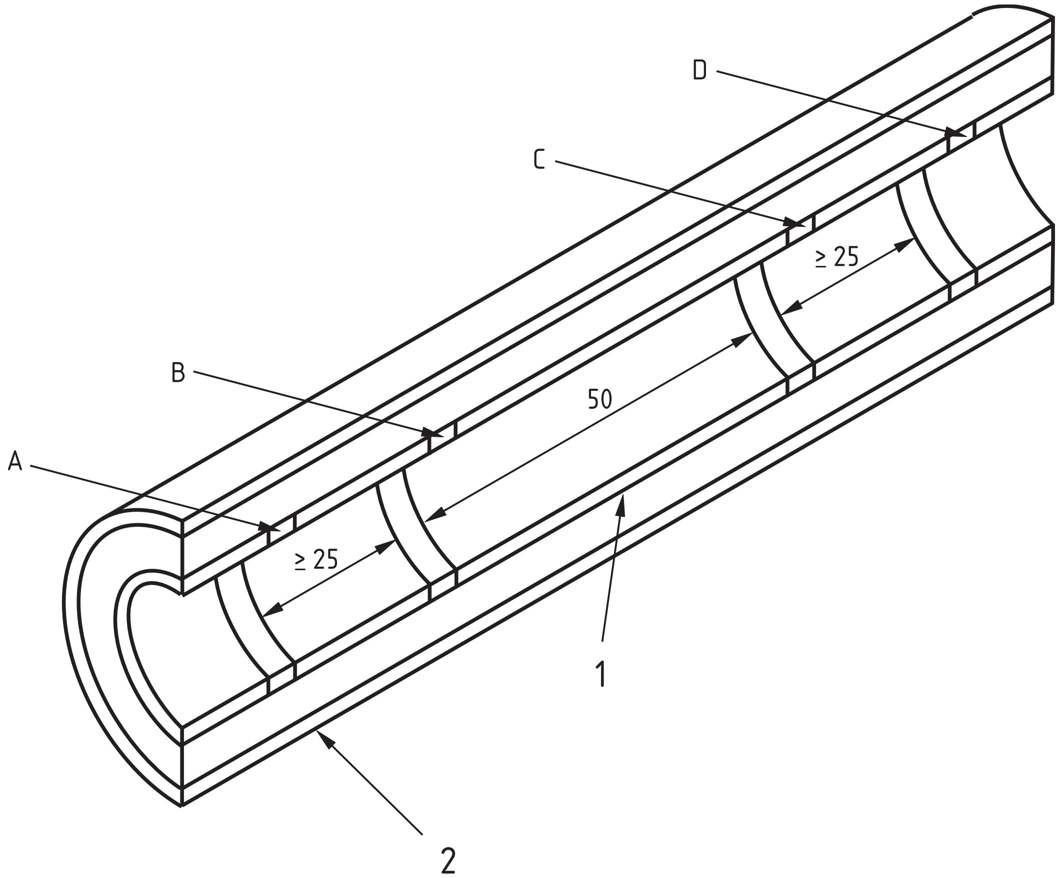
$$\rho = \frac{R \times \pi \times (D + T) \times T}{L}$$

where:

R	is the measured resistance in ohms (Ω);
L	is the measured distance between the potential electrodes in metres (m);
D	is the mean diameter over the insulation screen in metres (m);
T	is the mean thickness of the insulation screen in metres (m).

Figure J.1 **Test piece and arrangement of electrodes for measurement of resistivity of the conductor screen**

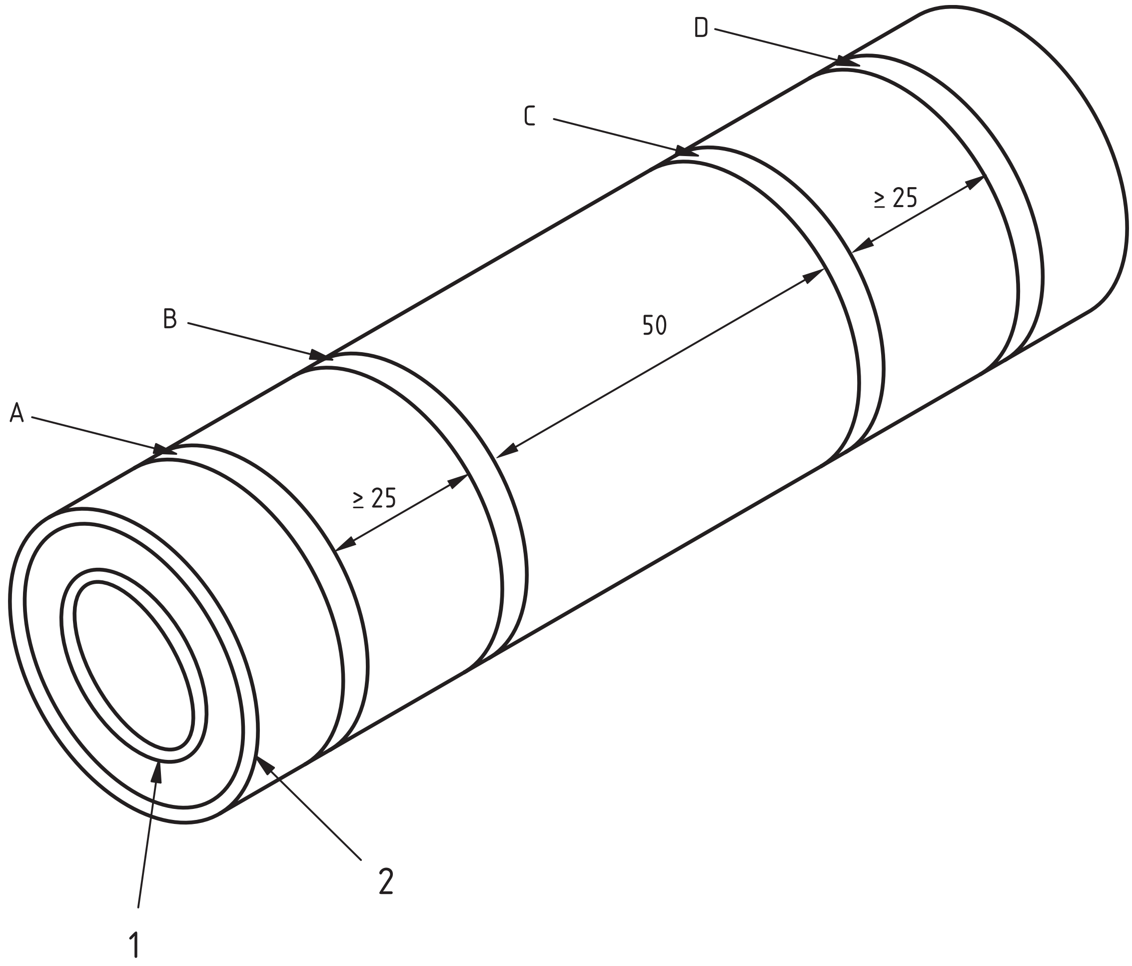
Dimensions in millimetres



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

Figure J.2 **Test piece and arrangement of electrodes for measurement of resistivity of the insulation screen**

Dimensions in millimetres



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

Annex K (normative) Method for measurement of resistivity of lapped inner covering

Cut three samples of the inner covering material, each 10 mm × 150 mm. Condition them for 24 h at (23 ± 5) °C and a relative humidity of (50 ± 5)%.

Keeping the samples in the conditioning environment, place each sample in turn in a jig having two parallel electrical contact clamping bars with a separation distance of 100 mm. Measure the resistance of each sample using a Wheatstone bridge.

Take the mean of the three resistance values and divide by 10 to give the resistivity of the material in ohms per square.

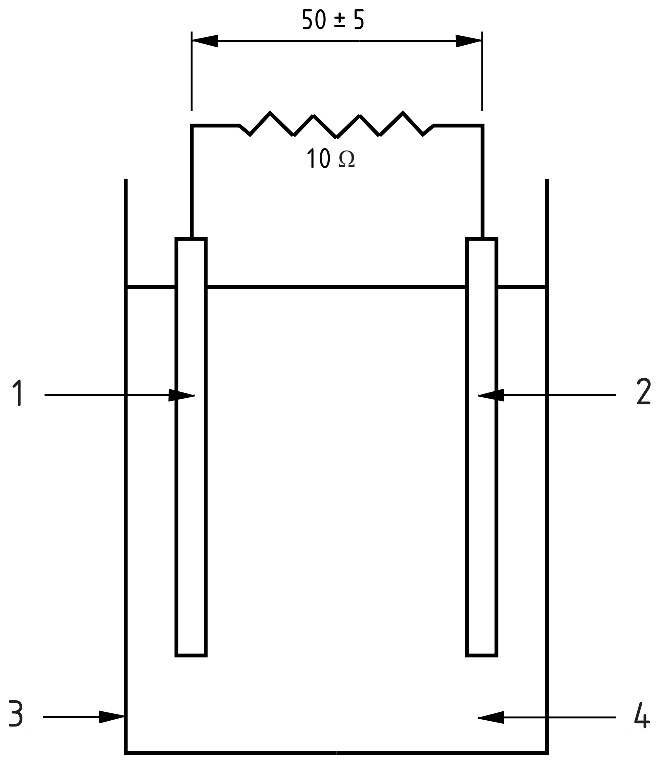
Annex L (normative) Wet compatibility test for galvanized steel wires and semi-conducting tape layers

Samples of the semi-conducting tape layer and steel wire shall be taken from a complete cable and immersed for 7 days in a test cell as shown in Figure L.1.

The cell shall contain a minimum volume of 500 ml of 0.1 M NaCl solution. The total surface area of the tape below the surface of the liquid shall be 500 mm^2 and the ratio of the surface area of the tape to that of the steel wire shall be 1:2.5. The temperature of the electrolyte shall be maintained between 15 °C and 25 °C. The test samples shall be connected through a 10 Ω resistor.

Figure L.1 **Test cell for wet compatibility test of galvanized steel wires and semi-conducting tape layers**

Dimensions in millimetres



Key
1 Galvanized steel wire (below liquid surface)
2 500 mm^2 semi-conducting tape layer (below liquid surface)
3 Beaker 1 l capacity
4 500 ml 0.1 M NaCl

Bibliography

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

Standards publications

BS 7835, *Specification for armoured cables with extruded cross-linked polyethylene or ethylene propylene rubber insulation for rated voltages from 3.8/6.6 kV up to 19/33 kV having low emission of smoke and corrosive gases when affected by fire*

BS 7870-4, *LV and MV polymeric insulated cables for use by distribution and generation utilities – Part 4: Specification for distribution cables with extruded insulation for rated voltages of 11 kV and 33 kV*

IEC 60038:2002, *IEC standard voltages*

IEC 60183, *Guide to the selection of high-voltage cables*

IEC 60502-2:2005, *Power cables with extruded insulation and their accessories for rated voltages from 1 kV (U_m = 1.2 kV) up to 30 kV (U_m = 36 kV) – Part 2: Cables for rated voltages from 6 kV (U_m = 7.2 kV) up to 30 kV (U_m = 36 kV)*

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