BS 7912:2012

Incorporating Corrigenda Nos. 1 and 2

BSI Standards Publication

Power cables with XLPE insulation and metal sheath, and their accessories, for rated voltages from 66 kV (U_m = 72.5 kV) to 132 kV (U_m = 145 kV)

(Implementation of HD 632)

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Contents

Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 56, an inside back cover and a back cover.

Foreword

Publishing information

This British Standard is published by BSI Standards Limited, under licence from The British Standards Institution, and came into effect on 31 December 2012. It was prepared by Subcommittee GEL/20/16, *Medium/high voltage cables,* under the authority of Technical Committee GEL/20, *Electric cables*. A list of organizations represented on these committees can be obtained on request to its secretary.

Supersession

This British Standard supersedes BS 7912:2001, which is withdrawn.

Relationship with other publications

This revision of BS 7912 implements the nationally applicable parts of Harmonization Document HD 632 S2:2008 published by the European Committee for Electrotechnical Standardization (CENELEC), in accordance with the decision of the CENELEC Technical Board.

Information about this document

Text introduced or altered by Corrigenda Nos. 1 and 2 are indicated in the text by tags [C1⟩ ⟨C1] and [C2⟩ ⟨C2]. Minor editorial corrections are not tagged.

This is a full revision of the standard, and introduces the following principal changes:

- alignment with the latest version of HD 632 part 1, being itself identical to Edition 4 of IEC 60840;
- inclusion of matter relating to BS 7970, which is also revised in parallel.

Product certification/inspection/testing

Users of this British Standard are advised to consider the desirability of third-party certification/inspection/testing of product conformity with this British Standard. Users seeking assistance in identifying appropriate conformity assessment bodies or schemes may ask BSI to forward their enquiries to the relevant association.

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.

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

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

1 Scope

This British Standard specifies tests and requirements for power cables with XLPE insulation and metal sheath and their accessories for rated voltages from 66 kV (U_m = 72.5 kV) to 132 kV (U_m = 145 kV) for fixed installations.

NOTE 1 Cable systems to this standard do not normally have high electrical stresses at the conductor or insulation screen. If the calculated nominal electrical stresses at the conductor screen will be higher than 8.0 kV/mm and/or at the insulation screen higher than 4.0 kV/mm, then attention is drawn to the need to conduct a prequalification test in accordance with IEC 60840:2011, Clause ***13****.*

This British Standard is applicable to single-core cables and three-core cables with separate cores and to their accessories for usual conditions of installation and operation. It is not applicable to special cables and their accessories, such as those designed for submarine cables, for which modification to the standard tests might be necessary or special test conditions might need to be devised.

NOTE 2 Annex A gives tests and requirements for cable bonding leads. Annex B gives tests and requirements for sheath voltage limiters (SVLs), while Annex C gives tests and requirements for link housings. Annex D gives an additional water blocking test for phase conductors.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

BS 7870-2:2011, *LV and MV polymeric insulated cables for use by distribution and generation utilities – Part 2: Methods of test*

BS 7970, *Electric cables – Metal foil and longitudinally welded aluminium sheath constructions of power cables having XLPE insulation for rated voltages from 66 kV (U_m = 72.5 kV) to 132 kV (U_m = 145 kV)*

BS EN 60060-1, *High-voltage test techniques – Part 1: General definitions and test requirements*

BS EN 60228, *Conductors of insulated cables*

BS EN 60229, *Electric cables – Tests on extruded oversheaths with a special protective function*

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

BS EN 60287-1-1, *Electric cables – Calculation of the current rating – Part 1-1: Current rating equations (100% load factor) and calculation of losses – General*

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 60811-201, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 201: General test – Measurement of insulation thickness*

BS EN 60811-202, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 202: General test – Measurement of thickness of non-metallic sheath*

BS EN 60811-401, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 401: Miscellaneous tests – Thermal ageing methods – Ageing in an air oven*

BS EN 60811-409, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 409: Miscellaneous tests – Loss of mass test for thermoplastic insulations and sheaths*

BS EN 60811-501, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 501: Mechanical tests – Tests for determining the mechanical properties of insulating and sheathing compounds*

BS EN 60811-502, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 502: Mechanical tests – Shrinkage test for insulations*

BS EN 60811-503, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 503: Mechanical tests – Shrinkage test for sheaths*

BS EN 60811-505, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 505: Mechanical tests – Elongation at low temperature for insulations and sheaths*

BS EN 60811-507, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 507: Mechanical tests – Hot set test for cross-linked materials*

BS EN 60811-508, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 508: Mechanical tests – Pressure test at high temperature for insulation and sheaths*

BS EN 60811-509, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 509: Mechanical tests – Tests for resistance of insulations and sheaths to cracking (heat shock test)*

BS EN 60811-605, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 605: Physical tests – Measurement of carbon black and/or mineral filler in polyethylene compounds*

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

BS EN 61462, *Composite hollow insulators – Pressurised and unpressurised insulators for use in electrical equipment with rated voltage greater than 1 000 V – Definitions, test methods, acceptance criteria and design recommendations*

BS EN 62271-209, *High-voltage switchgear and controlgear – Part 209: Cable connections for gas-insulated metal-enclosed switchgear for rated voltages above 52 kV – Fluid-filled and extruded insulation cables – Fluid-filled and dry type cable-terminations*

IEC 60050-461, *International Electrotechnical Vocabulary – Part 461 – Electric cables*

3 Terms and definitions

For the purposes of this British Standard the terms and definitions given in IEC 60050-461 apply, together with the following.

3.1 rated voltage U_0

nominal power-frequency voltage between any conductor and armour or earth for which the cable and accessories are suitable

3.2 rated voltage U

nominal power-frequency voltage between phase conductors, for which the cable and accessories are suitable

3.3 maximum voltage U_m
maximum sustained power-frequency voltage between phase conductors, for which the cable and accessories are suitable

3.4 routine test
tests made by the manufacturer on each manufactured component (length of cable or accessory) to check that the component meets the specified requirements

3.5 sample test
tests made by the manufacturer on samples of completed cable or components taken from a completed cable or accessory, at a specified frequency to verify that the finished product meets the specified requirements

3.6 test after installation
test intended to demonstrate the integrity of the cable and its accessories after installation and before use

3.7 type test
tests made before supplying on a general commercial basis a type of cable system or cable or accessory covered by this standard, in order to demonstrate satisfactory performance characteristics to meet the intended application

NOTE Once successfully completed, these tests need not be repeated, unless changes are made in the cable or accessory with respect to materials, manufacturing process, design or design electrical stress levels, which might adversely change the performance characteristics.

4 Voltage designation and cable design features

4.1 Voltage designation

Where test voltages are specified in this British Standard as multiples of the rated voltage U_0, the value of U_0 for the determination of the test voltages shall be as specified in Table 1.

For cables and accessories of rated voltage not shown in Table 1, it shall be permissible for the value of U_0 for determination of test voltage to be the same as for the nearest rated voltage which is given, provided that the value U_m for the cable and accessory is not higher than the corresponding value in the table. Otherwise, and particularly if the rated voltage is not close to one of the values in the table, the value of U_0 on which the test voltages are based shall be the specific rated voltage (i.e. U) divided by $\sqrt{3}$.

NOTE The test voltages in this British Standard are based on the assumption that the cables and accessories will be used on systems of Category A, as defined in IEC 60183.

Table 1 **Test voltages**

Rated voltage (between conductors)	Highest voltage for equipment (between conductors)	Value of U_0 (between conductor and screen) for determination of test voltages	Test voltage of voltage test: 9.4	Test voltage of partial discharge test: 9.3, 12.6 and 16.3	Maximum voltage of tan δ measurement: 12.7	Test voltage of tan δ measurement: 12.8	Load cycle voltage test: 12.9 and 16.4	Impulse voltage test: 12.10 and 16.5	Power frequency voltage test: 12.11 and 16.6
U	U_m	U_0	$2.5U_0$	$1.5U_0$	$2U_0$	U_0	$2U_0$	—	$3U_0$
kV	kV	kV	kV	kV	kV	kV	kV	kV	kV
66	72.5	36 A)	90	54	72	36	72	325	108
110	123	64	160	96	128	64	128	550	192
132	145	76	190	114	152	76	152	650	228

A) Nominal service phase voltage is 38 kV. The tabulated value used as a test reference is in accordance with HD 632 S2:2008, Part 1, Table 4 [1].

4.2 Cable maximum temperatures

The maximum operating conductor temperatures upon which the specified conditions are based shall be as given in Table 2.

Table 2 **Cable maximum temperatures**

Insulating compound	Maximum conductor temperature	
	Normal operation °C	Short circuit °C
Cross-linked polyethylene (XLPE)	90	250

4.3 Semi-conducting screens

Both the conductor and insulation semi-conducting screen shall be fully bonded to the XLPE insulation. Easy strip or cold strip types of screens shall not be used.

4.4 Metal cable sheathing materials and metal screen

The metal sheath material shall consist of lead, lead alloy or aluminium. The sheath shall be either a seamless extrusion or a longitudinally welded aluminium sheath or metal foil sheath. The latter two constructions shall, in addition to this British Standard, also conform to BS 7970.

NOTE If necessary, in order to meet the short circuit rating, a layer of copper wires may be applied under the metal sheath.

No wires shall cross other wires.

A metal tape or wires shall be applied helically over, and in contact with, the layer of metal wires in order to equalize the current flowing in the individual wires forming the layer of wires.

4.5 Oversheath materials

*COMMENTARY ON **4.5***

Tests are specified in this British Standard for four types of oversheath material.

- *ST_1 and ST_2 based on PVC.*
- *ST_3 and ST_7 based on polyethylene.*

The choice of the type of sheath shall depend on the design of the cable and the mechanical and thermal properties during operation.

NOTE No temperature limits are given for sheaths in this British Standard.

4.6 Precautions against water penetration in cables

The cable shall be designed to prevent longitudinal water penetration along all internal interfaces i.e.:

a) along the conductor;

b) along the path between the outer surface of the insulation screen and the metal sheath;

c) between the oversheath and the metal sheath.

When tested in accordance with Clause **14**, the resistance to longitudinal water penetration shall conform to **14.3**.

5 Marking of cables

5.1 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	66 000 V or 110 000 V or 132 000 V
c) British Standard number	BS 7912 [1)]
d) Manufacturer's identification	XYZ
e) Number of cores and nominal area and type (CU or AL) of conductor, e.g. single-core cable with 300 mm^2 copper conductor	1 × 300 CU

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

The marking of element e) shall be by embossing, indenting or printing 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 Elements d) and e) may be on one of the primary lines or 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 height of not less than 3 mm.

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

5.2 Identification of year and month of manufacture

A means of identifying the year and month of manufacture of the cable shall be provided throughout the length of the cable by marking on the surface of the cable.

The marking shall be by embossing or indenting on the oversheath. The characters shall have a height of not less than 3 mm and the distance between the end of the one element of marking and the beginning of the next identical element of marking shall be not greater than 1 100 mm.

5.3 Mark of an approval organization

If the mark of an approval organization is used, it shall be provided throughout the length of the cable.

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1) Marking BS 7912 or BS 7912:2012 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.

6 Cable characteristics

For the purpose of carrying out and recording the tests described in this British Standard, the following characteristics shall be known or declared for each cable tested.

a) The rated voltages; values shall be given for U, U_0 and U_m.

b) The type of conductor, its material and cross-sectional area in square millimetres; presence (if any) and nature of measures taken to ensure that the cable is longitudinally watertight.

c) If the nominal cross-sectional area is not in accordance with BS EN 60228, the d.c. conductor resistance shall be declared.

d) Material and nominal thickness of insulation.

e) Nominal thickness of conductor screen and insulation screen.

f) Presence (if any) and nature of measures in screening area to ensure that the cable is longitudinally watertight.

g) Nature and construction of metal sheath, and nature of any copper wires under the sheath.

h) Nature of non-metallic sheathing material.

i) Nominal diameter over conductor (*d*).

j) Nominal diameter over complete cable (*D*).

k) Nominal capacitance between conductor and metal screen/sheath.

7 Accessory characteristics

For the purposes of carrying out and recording the tests described in this British Standard, the following characteristics shall be known or declared for each accessory tested.

a) For conductor connectors (supplied separately from the accessory) used within accessories:
   - assembly technique;
   - tooling and necessary setting;
   - preparation of contact surfaces;
   - type, reference number and any other identification of the connector.

b) For accessories:
   - name of manufacturer;
   - type, nominal bore diameter, designation, manufacturing date or date code;
   - rated voltage [see Clause **6**a)];
   - installation instructions (reference and date);
   - electrostatic screening measures in the region of the conductor connection;
   - details of any fluid filling medium (including chemical type, viscosity range, breakdown strength and any standard to which it conforms);
   - material types for resin and rubber components which form the main electrical insulation.

8 Test conditions

8.1 Ambient temperature

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

8.2 Frequency and waveform of power frequency test voltage

The frequency of the alternating test voltages shall be in the range 49 Hz to 61 Hz. The waveform shall be substantially sinusoidal.

NOTE The test voltage values quoted are r.m.s. values.

8.3 Waveform of impulse test voltage

In accordance with BS EN 60230, the impulse wave shall have a virtual front time between 1 µs and 5 µs and a nominal time to half the peak value between 40 µs and 60 µs. In other respects, the impulse wave shall be in accordance with BS EN 60060-1.

9 Routine tests on cables

9.1 General

The following tests shall be carried out:

a) measurement of electrical resistance of conductor (see **9.2**);

b) partial discharge test (see **9.3**);

c) voltage test (see **9.4**);

d) electrical test on non-metallic sheath, if required (see **9.5**). This test shall only be carried out when required for a particular contract as its applicability depends upon the function of the sheath in the installation (see BS EN 60229);

e) dimensional checks (see **9.6**);

f) presence of water blocking material in the phase conductor (see **9.7**).

NOTE 1 The order in which these tests are carried out is at the discretion of the manufacturer, to suit the testing arrangement.

NOTE 2 Tests classified as sample or routine might be required as part of any type approval scheme.

9.2 Measurement of electrical resistance of conductor

9.2.1 Procedure

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

The d.c. resistance of the conductor shall be corrected to a temperature of 20 °C and 1 km length in accordance with BS EN 60228.

9.2.2 Requirement

The d.c. resistance of the conductor at 20 °C shall not exceed the appropriate maximum value specified in BS EN 60228 or the declared value as applicable.

9.3 Partial discharge test

9.3.1 Procedure

The partial discharge test shall be carried out in accordance with BS EN 60885-3, except that the sensitivity as defined in BS EN 60885-3 shall be 10 pC or less.

The test voltage shall be raised to and held at $1.75U_0$ for 10 s and then slowly reduced to $1.5U_0$.

9.3.2 Requirement

There shall be no detectable discharge exceeding the declared sensitivity from the test object at $1.5\ U_0$.

9.4 Voltage test

9.4.1 Procedure

The voltage test shall be made at ambient temperature using an alternating power frequency test voltage.

The test voltage shall be raised gradually to the specified value, which shall then be held for 30 min between the conductor and metal screen/sheath.

The test voltage shall be $2.5U_0$ (see Table 1).

9.4.2 Requirement

No breakdown of the insulation shall occur.

9.5 Electrical test on oversheath

If required for the particular contract or order, the oversheath shall be subjected to the routine electrical test specified in BS EN 60229.

9.6 Dimensional checks

9.6.1 General

Measurement of the thickness of the insulation, semi-conducting screens, metal sheath and the oversheath shall be made on a sample from every production cable length of the same type and size of cable.

9.6.2 Measurement of thickness of insulation

9.6.2.1 Sampling

Each cable length shall be represented by a piece of cable, taken from the end of that length, after discarding, if necessary, any portion which might have suffered damage.

9.6.2.2 Procedure

The test procedure shall be in accordance with BS EN 60811-201.

9.6.2.3 Requirements

The lowest measured thickness shall not fall below 90% of the nominal thickness [see Clause **6**d)]:

$t_{min} \geq 0.90\ t_n$

and additionally:

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

where:

t_{max} is the maximum thickness, in millimetres;

t_{min} is the minimum thickness, in millimetres;

t_n is the nominal thickness, in millimetres.

NOTE t_{max} and t_{min} are measured at the same cross-section of the insulation.

The thickness of the semi-conducting screens on the conductor and over the insulation shall not be included in the thickness of the insulation.

9.6.3 Measurement of thickness of semi-conducting screens

9.6.3.1 Sampling

Each cable length selected for the test shall be represented by a piece of cable taken from the end of that length after having discarded, if necessary, any portion which might have suffered damage.

9.6.3.2 Procedure

The procedure set out in BS EN 60811-201, refers to cable insulation; the same procedure of thickness measurement shall be used for the semi-conducting screens.

9.6.3.3 Requirements

The mean thickness of the semi-conducting screens shall be not less than the specified value [see Clause **6**e)] and the minimum thickness at any point shall be not less than 60% of the specified value.

9.6.4 Measurement of thickness of metal sheath

9.6.4.1 General

The following tests apply if the cable has a metal sheath of lead, lead alloy or aluminium.

9.6.4.2 Lead or lead alloy sheath

The minimum thickness of the sheath shall not fall below 95% of the nominal thickness by more than 0.1 mm:

$$t_{min} \geq 0.95\ t_n - 0.1$$

where:

t_{min} is the minimum thickness, in millimetres;

t_n is the nominal thickness, in millimetres.

The thickness of the sheath shall be measured by one of the methods in **9.6.4.3** and **9.6.4.4**, at the discretion of the manufacturer.

9.6.4.3 Strip method

The measurement shall be made with a micrometer with plane faces of 4 mm to 8 mm diameter and an accuracy of ±0.01 mm.

The measurement shall be made on a test piece of sheath about 50 mm in length removed from the completed cable. The piece shall be slit longitudinally and carefully flattened. After cleaning the test piece, a sufficient number of measurements shall be made along the circumference of the sheath and not less than 10 mm away from the edge of the flattened piece to ensure that the minimum thickness is measured.

9.6.4.4 Ring method

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

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

9.6.4.5 Plain or corrugated aluminium sheath

The minimum thickness of the sheath shall not fall below 90% of the nominal thickness by more than 0.1 mm for plain aluminium sheath:

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

and 85% of the nominal thickness by more than 0.1 mm for corrugated aluminium sheath:

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

where:

t_{min} is the minimum thickness, in millimetres;

t_n is the nominal thickness, in millimetres.

The measurements shall be made with a micrometer having ball noses of radii about 3 mm. The accuracy shall be ±0.01 mm.

The measurements shall be made on a ring of the sheath, about 50 mm wide, carefully removed from the complete cable. The thickness shall be determined at a sufficient number of points around the circumference of the ring to ensure that the minimum thickness is measured.

9.6.5 Measurement of thickness of oversheath

9.6.5.1 Sampling

Each cable length selected for the test shall be represented by a piece of cable taken from the end of that length after having discarded, if necessary, any portion that might have suffered damage.

9.6.5.2 Procedure

The test procedure shall be in accordance with BS EN 60811-202.

9.6.5.3 Requirements

The lowest measured thickness shall not fall below 85% of the nominal thickness by more than 0.1 mm:

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

where:

t_{min} is the minimum thickness, in millimetres;

t_n is the nominal thickness, in millimetres.

In addition, for oversheaths applied on to a substantially smooth surface, the average of the measured values rounded to 0.1 mm shall be not less than the nominal thickness.

NOTE The latter requirement does not apply to oversheaths applied on to an irregular surface, such as a corrugated metal sheath.

9.7 Presence of water blocking material in the phase conductor

A visual check shall be carried out to confirm the presence of water blocking material between all strands of the phase conductor. This check shall be made on a sample from every production length of cable.

10 Sample tests on cables

10.1 General

The following tests shall be made on samples taken to represent batches:

a) volume resistivity of semi-conducting screens (see **10.4**);

b) hot set test for XLPE insulation (see **10.5**);

c) shrinkage test for XLPE insulation (see **10.6**);

d) insulation/screen moisture content determination (see **10.7**);

e) resistance test for semi-conducting tapes (see **10.8**);

f) confirmation of degassing of XLPE insulation by thermal history measurement (see **10.9**);

g) examination for contaminants in insulation (see **10.10**);

h) measurement of capacitance (see **10.11**).

NOTE Tests classified as sample or routine might be required as part of any type approval scheme.

10.2 Frequency of tests

Tests shall be carried out on numbers of samples, in accordance with Table 3. Samples shall be taken from each batch (manufacturing series) of the same type and cross-section of cable.

Table 3 **Number of samples for sample tests**

Cable length		**Number of samples**
Above km	**Up to and including** km	
2	10	1
10	20	2
20	40	3
40	60	4
>60		Add 1 sample for each additional 20 km

10.3 Repetition of tests

If the samples from any length selected for the tests fail in any of the tests in this Clause, further samples shall be taken from two further lengths of the same batch and subjected to the same tests as those in which the original sample failed. If both additional cables pass the tests, the other cables in the batch from which they were taken shall be deemed to conform to the specified requirements. If either fails, this batch of cables shall be deemed not to conform.

NOTE Further re-sampling and testing should then become a matter for negotiation.

10.4 Volume resistivity of semi-conducting screens

10.4.1 Procedure

The resistivity of extruded semi-conducting screens applied over the conductor and over the insulation shall be determined by measurements on test pieces taken from the core of a sample of cable as made and a sample of cable which has been subjected to the ageing treatment to test the compatibility of component materials specified in **13.2**.

The test procedure shall be in accordance with BS 7870-2:2011, **3.9.3**.

The measurements shall be made at a temperature within ±2 °C of the rated maximum conductor temperature in normal operation for the design of cable.

10.4.2 Requirements

The resistivity, both without ageing and after ageing, shall not exceed the following values:

- conductor screen: 500 Ω·m;
- insulation screen: 500 Ω·m.

10.5 Hot set test for XLPE insulation

10.5.1 Procedure

The sampling and test procedure shall be in accordance with BS EN 60811-507, employing the test conditions specified in Table 4.

The test pieces shall be taken from the inner, middle or outer part of the insulation. The choice of test piece shall be such that it comes from the part of the insulation where, according to the method of processing, the cross-linking is lowest.

10.5.2 Requirements

The test results shall conform to the requirements specified in Table 4.

Table 4 **Test conditions and requirements for particular characteristics of cable insulating materials**

Test/condition	**Units**	**Requirement**
Hot set test		
Treatment:		
• air temperature	°C	200
• tolerance	°C	±3
• time under load	min	15
• mechanical stress	N/cm^2	20
Maximum elongation under load	%	175
Maximum permanent elongation after cooling	%	15
Shrinkage test		
Distance between marks	mm	200
Temperature	°C	130
Tolerance	°C	±3
Duration	h	6
Maximum permissible shrinkage	%	4.0

10.6 Shrinkage test for XLPE insulation

10.6.1 Procedure

The shrinkage test shall be carried out on XLPE insulation using the sampling test procedure specified in BS EN 60811-502, and the conditions specified in Table 4.

10.6.2 Requirement

The results of the test shall conform to the requirements specified in Table 4.

10.7 Insulation/screen moisture content determination

10.7.1 Sampling

Each cable length selected for the test shall be represented by a 300 mm piece of cable taken from the end of that length, after having discarded, if necessary, any portion which might have been contaminated. The sheath shall be removed and the sample tested immediately. Where it is not possible to test immediately, the sample shall be sealed in a double polyethylene bag until ready for testing.

10.7.2 Procedure

Moisture shall be extracted from the test pieces by passing dry nitrogen over the sample contained in a glass oven. Test pieces, of a suitable size to fit in the glass sample oven, shall be prepared for insulation, inner and outer semi-conducting screens. The glass oven containing the sample shall be maintained at 110 °C to 130 °C while the moisture determination is carried out.

The effluent gas shall then be passed into a Karl Fischer titration equipment for measurement of the moisture contained in the gas.

The moisture content of each test piece shall be determined by dividing the total weight of moisture evolved during the test by the final weight of the test piece.

Three determinations shall be made for each material using new test pieces taken from the 300 mm cable sample for each determination.

10.7.3 Requirements

The mean value of the moisture content for the three determinations shall be not greater than:

- insulation material: 150 parts per million (ppm) by weight;
- semi-conducting screen materials: 500 ppm by weight.

10.8 Resistance test for semi-conducting tapes

10.8.1 General

The following tests shall be carried out for those designs of cable where semi-conducting tapes are applied between the cable core and the metal sheath. These might be bedding tapes or water blocking tapes.

The resistance of the tape, which shall be taken from the raw material, shall be measured before it is applied to the cable.

10.8.2 Sampling

Prepare three samples of tape 150 mm × 10 mm.

10.8.3 Procedure

Samples shall be conditioned for 24 h in an environment of (23 ±5) °C and relative humidity of (50 ±5)%.

While still in the environment, the tape samples shall be placed in a jig having two parallel electrical contact clamping bars with a separation distance between them of 100 mm. The resistance of each tape sample shall then be measured.

10.8.4 Requirement

The value of resistance of the tape in ohms per square shall be the average of the three values obtained, divided by 10. It shall not exceed 1 500 Ω per square.

10.9 Confirmation of degassing of XLPE insulation by thermal history measurement

10.9.1 Principle

Polymers which have crystallinity in the solid state undergo a transition to an amorphous phase on heating. This can be observed as an exothermic event in the Differential Scanning Calorimetry (DSC) experiment.

For a specimen which has been cooled from the melt, the exothermic peak observed will typically exhibit a slow onset on the low temperature side of the peak, which itself is usually sharp and has a relatively sharp tail and end. If, however, the specimen has undergone subsequent heating at a temperature within the envelope of the melting event, reorganization of the crystalline structure of the specimen will take place.

This is observable as a subsidiary peak.

Calibration with oven aged samples shows that these peaks are an accurate record of thermal history, but they can be erased by annealing at a higher temperature. Thus there might sometimes be a record of highest, next highest and second next highest temperature events if they occur in that order, but not in the opposite order.

10.9.2 Measurement

*COMMENTARY ON **10.9.2***

Experience has shown that the measurement can be made using either a heat flux DSC or a power compensated DSC. The following experimental conditions are suitable.

Pan:	*Standard aluminium pan*
Purge gas:	*High Purity Nitrogen*
Heat rate:	*10 K min^{-1}*
Temperature range:	*For cross-linked polyethylene, 30 °C to 180 °C is a suitable range. This can be varied for different polymers if necessary.*
Baseline subtraction:	*If necessary, run a baseline check with an empty pan and then use the data file generated for baseline subtraction in accordance with the instrument manufacturer's software instructions.*
Sample size:	*2.5 mg to 5 mg, weighed accurately, is suitable for power compensated DSC work but refer to the instrument manufacturer's guidelines for sample sizing.*

Samples of XLPE insulation shall be taken from close to the outer screen and close to the inner screen for separate DSC measurements.

For each sample, the experiment shall be run a first time using the above parameters, the DSC shall be allowed to slowly cool back to the start temperature so that the specimen can recrystallize fully, and then the experiment shall be run again with a new filename. The melting curves for the as-received specimen and for the recrystallized specimen shall be overlaid on screen.

NOTE The thermal history peak(s) can be found by inspection of the two curves (the recrystallized specimen curve is smooth on the low temperature side of the melting peak). Software (suitable software is usually supplied with DSC instruments) is used to determine the start and finish of the thermal history event.

10.9.3 Requirement

The inspection of the curves for both samples shall show evidence within the endothermic crystalline melting peak, in the range 60 °C to 80 °C consistent with the degassing operation carried out during cable manufacture.

NOTE As an alternative to this measurement, the manufacturer may carry out a direct measurement of methane content of the insulation to demonstrate that this has been reduced to a satisfactory and safe level. No standardized method is currently available for methane determination in XLPE insulation.

10.10 Examination for contaminants in insulation

10.10.1 Procedure

Five approximately 3 000 mm³ cross-sectional slices of insulation, each 1 mm thick, taken from a production length of the cable, shall be examined using a 50 × magnification transmission microscope. It shall be permissible for slices to be taken from one end of the cable length after elimination of any end effects. The dimensions of the largest five particles in each slice shall be recorded. The particle sizes shall be plotted in the form of a histogram for ease of comparison against the requirements specified in **10.10.2**.

10.10.2 Requirements

The quality of the XLPE material and extrusion process shall be such that:

a) there shall be no voids greater than 75 µm in diameter and the number of voids larger than 50 µm in diameter shall not exceed 20 per 15 000 mm³;

b) there shall be no contaminant (any solid or liquid which is opaque or not homogeneous cross-linked polyethylene) larger than 150 µm in any dimension. The number of such contaminants between 50 µm and 150 µm shall not exceed 10 per 15 000 mm³.

10.11 Measurement of capacitance

The capacitance shall be measured between the conductor and metal screen/sheath. The measured value shall not exceed the nominal value specified by the manufacturer by more than 8%.

11 Type tests – Summary

11.1 General

All type tests shall normally be carried out as part of a Type Approval scheme. Tests designated as Routine (Clause **9**) or Sample (Clause **10**) shall also be included as part of a Type Approval scheme when agreed between purchaser and supplier.

NOTE Type tests which have been successfully performed in accordance with the previous edition (BS 7912:2001) of this British Standard are valid.

11.2 Range of type approval for cables

When type tests have been successfully performed on a single sample, or on two samples with different cross-sectional areas of conductors, of one type of cable with a specific value of rated voltage, the type approval shall be deemed to be valid for the following additional types of cable.

a) Cables of similar construction, in the same rated voltage group and with the same cross-sectional areas of conductor.

   *NOTE 1 Cables of similar construction are those having the same type and processing of insulation material and the same forms of semi-conducting screens. Repetition of the electrical type tests (see Clause **12**) is not necessary on account of differences in the protective layers applied over the screened cores, unless these are likely to have a significant effect on the results of the test. However, it should be noted that as this British Standard is confined to dimensional and performance requirements and does not specify cable constructions, the possible effects on the electrical type test resulting from variations in coverings over the core cannot be dealt with in detail. In some instances it might be appropriate to repeat one or more of the tests listed in Clause **12** (e.g. the bending test) or **13.2** (compatibility test) when the coverings of the cable under consideration differ from the cable which has previously been subjected to the full electrical type tests.*

b) Cables in the same rated voltage group with all cross-sectional areas of conductor lying between the two on which the tests were made, provided that the design insulation thicknesses for the intermediate cross-sections give calculated values of maximum electrical stress at the conductor screen not higher than that applying to the smaller cross-section of cable tested and the insulation screen not higher than that applying to the larger cross-section of cable tested.

Furthermore, subject to agreement between manufacturer and purchaser, tests successfully completed on cables of one voltage rating shall be deemed to demonstrate satisfactory performance of cables of a lower voltage rating, provided that the same processing techniques and materials are used by the manufacturer for both voltages and that the operating electrical stresses are not higher for the cables of lower voltage rating.

*NOTE 2 The type tests on cable components (see Clause **13**) are also subject to agreement between the manufacturer and the purchaser and need not be carried out on samples from cables of different voltage ratings and/or conductor cross-sectional areas unless different materials are used to produce them. However, repetition of the ageing tests on pieces of complete cable to check compatibility of materials (see **13.2**) might be required if the combination of materials applied over the screened core is different from that of the cable on which type tests have been carried out previously.*

A type test certificate signed by the representative of a competent witnessing body, or a report by the manufacturer giving the test results and signed by the appropriate qualified officer, shall be deemed to be suitable evidence of type testing.

11.3 Range of type approval for accessories

When type tests have been successfully performed on one or more accessories with one or more cable(s) of specific cross-section(s), and of the same rated voltage and construction, the type approval shall be considered as valid for accessories within the scope of this standard with other rated voltages, constructions and with other cables, provided that all of the following conditions are met.

a) The voltage group is not higher than that of the tested accessory(ies).

NOTE 1 In this context, accessories of the same rated voltage group are those of rated voltages having a common value of U_m, highest voltage for equipment, and the same test voltage levels (see Table 1).

NOTE 2 Type tests which have been successfully performed in accordance with the previous edition of this British Standard are valid.

b) The cable with another conductor cross-section, rated voltage and construction is within the range of type approval as stated in **11.2**. When the calculated nominal electrical stress at the cable insulation screen does not exceed 2.5 kV/mm, the type approval shall be considered as valid for accessories on all cables in this range.

c) The accessories have the same or a similar construction as that of the tested accessory(ies).

NOTE 3 Accessories of similar construction are those of the same type and manufacturing process of insulation and semi-conducting screens. Repetition of the electrical type tests is not necessary on account of the differences in the connector type or material or of the protective layers applied over the main insulation part of the accessory, unless these are likely to have a significant effect on the results of the test. In some instances, it might be appropriate to repeat one or more of the type tests (e.g. partial discharge test).

d) the calculated nominal electrical stresses within the main insulation parts of the accessory and at the cable and accessory interfaces do not exceed those of the tested accessory(ies).

*NOTE 4 In the case of a repair or diversion, a particular accessory design for connecting cables of different insulation thickness/conductor dimensions might be required. If the technical design consideration determines that two sides of the accessory are effectively independent (i.e. the electrical field is radial at the centre) then the joint is considered to be approved if the criteria under **11.2** are applied to each half of the joint independently.*

NOTE 5 Tests on terminations referring to environmental conditions are not specified in this British Standard.

11.4 Summary of type approval tests

The type tests shall comprise the electrical tests on the complete cable as specified in Clause **12**, the electrical and non-electrical tests on accessories as specified in **16.3** to **16.10**, and the appropriate tests on cable components as specified in Clause **13.**

The electrical tests shall be carried out in sequence on one sample of cable, except as provided for in **12.3**. The bending test shall be included in this sequence of tests to check that the electrical properties of the cable after bending are satisfactory.

The tests on accessories shall be carried out in accordance with the requirements detailed in **16.2**.

NOTE The tests on cable components are summarized in Table 5, indicating which tests are applicable to each insulation and sheathing material. The test under fire conditions is required only if the manufacturer wishes to claim compliance with the requirement for use under fire conditions as a special feature of the design of the cable.

Table 5 **Type tests on cable components**

Test	Insulation	Non-metallic sheath			
	XLPE A)	ST_1 A)	ST_2 A)	ST_3 A)	ST_7 A)
Checks on construction					
Resistivity of semi-conducting layers:					
a) without ageing	Applicable irrespective of insulation and sheathing materials				
b) after ageing in complete cable (compatibility test)					
Examination of semi-conducting layers for protrusions and irregularities					
Mechanical properties					
Tensile strength and elongation at break:					
a) without ageing	x	x	x	x	x
b) after ageing in air oven	x	x	x	x	x
c) after ageing in complete cable (compatibility test)	x	x	x	x	x
Pressure test at high temperature		x	x		x
Behaviour at low temperature:					
a) cold elongation test		x	x		
b) cold impact test		x	x		
Loss of mass in air oven			x		
Heat shock test		x	x		
Hot set test	x				
Carbon black content B)				x	x
Shrinkage test	x			x	x
Test under fire conditions C)		x	x		

A) Designation of compound (see **4.2** and **4.5**).

B) For black oversheaths only.

C) Only required if the manufacturer wishes to claim compliance for the cable design.

NOTE "x" indicates that the type test is to be applied.

12 Electrical type tests on cables

12.1 Electrical tests on complete cable

The tests listed in **12.2** shall be performed on samples of complete cable at least 10 m in length excluding the test accessories.

With the exception of the provisions of **12.3**, all the tests listed in **12.2** shall be applied successively to the same sample.

12.2 Sequence of tests

The normal sequence of tests shall be:

a) check on insulation thickness of cable for electrical type tests (see **12.4**);

b) bending test (see **12.5**);

c) partial discharge test (see **12.6**);

d) tan δ measurement as a function of voltage (see **12.7**);

e) tan δ measurement as a function of temperature (see **12.8**);

f) load cycle voltage test (see **12.9**), followed by partial discharge tests which shall be carried out after the final cycle or, alternatively, after the impulse voltage test;

g) lightning impulse voltage withstand test (see **12.10**);

h) power frequency voltage test (see **12.11**);

i) partial discharge test, if not previously carried out in c) above;

j) cable examination (see **12.12**).

12.3 Special provisions

It shall be permissible for the tests in items **12.2** d) and e) to be carried out on a different sample from that used for the remainder of the sequence of tests.

12.4 Check on insulation thickness of cable for electrical type tests

Prior to the electrical type tests, the insulation thickness shall be measured by the method specified in BS EN 60811-201, on a representative piece of the length to be used for the tests, to check that the thickness is not excessive compared with the specified value [see Clause **6**d)].

If the average thickness of insulation does not exceed the specified value [see Clause **6**d)] by more than 5%, the test voltages shall be the normal values specified for the rated voltage of the cable.

If the average thickness of the insulation exceeds the specified value by more than 5% but by not more than 15%, the test voltage shall be adjusted to give an electrical stress at the conductor screen equal to that applying when the average thickness of the insulation is equal to the specified nominal value [see Clause **6**d)] and the test voltages are the normal values specified for the rated voltage of the cable.

The cable length used for the electrical type tests shall have an average thickness that does not exceed the specified value by more than 15%.

12.5 Bending test

As far as is practical the cable sample shall be prevented from twisting about its longitudinal axis during the bending cycles.

The sample shall be bent around a test cylinder (e.g. the hub of a drum) at a temperature not exceeding the upper limit of ambient temperature (i.e. 35 °C) for at least one complete turn. It shall be unwound and the process repeated, except that the bending of the sample shall be in the reverse direction.

The cycle of operations shall be carried out three times in total.

The diameter of the test cylinder shall be not greater than the following values:

a) for cables with plain aluminium sheaths:
   - 36 (d + D) + 5% for single-core cables;
   - 25 (d + D) + 5% for three-core cables;

b) for cables with lead, lead-alloy or corrugated metal sheaths, and for cables as in BS 7970 having a continuous metal foil sheath or a longitudinally welded aluminium sheath:
   - 25 (d + D) + 5% for single-core cables;
   - 20 (d + D) + 5% for three-core cables;

where:

d	is the nominal diameter of the conductor, in millimetres;
D	is the nominal external diameter of the cable, in millimetres.

NOTE A negative tolerance is not specified, but testing at diameters below the specified levels should only be done by agreement with the manufacturer.

On completion of this test, the cable shall be subjected to the partial discharge test at ambient temperature as specified in **12.6**.

12.6 Partial discharge test

The partial discharge test shall be carried out as described in BS EN 60885-3 with a sensitivity of 5 pC or less. There shall be no detectable discharge exceeding the declared sensitivity from the test object at 1.5 U_0.

12.7 Tan δ measurement as a function of the voltage and capacitance measurement

The dielectric loss tangent of the sample shall be measured at ambient temperature with power frequency voltages as specified in Table 6.

The measured values shall not exceed those specified in Table 6.

The capacitance per unit length of the cable-only installation shall be measured and recorded.

Table 6 **Tan δ in relation to voltage**

Rated voltages, *U* kV	**Test voltages** kV	**Requirements**
66	19 36 76	Max. tan δ at 36 kV = 10 × 10^{-4} Max. increment of tan δ between 19 kV and 76 kV = 10 × 10^{-4}
110	32 64 128	Max. tan δ at 64 kV = 10 × 10^{-4} Max. increment of tan δ between 32 kV and 128 kV = 10 × 10^{-4}
132	36 76 152	Max. tan δ at 76 kV = 10 × 10^{-4} Max. increment of tan δ between 36 kV and 152 kV = 10 × 10^{-4}

12.8 Tan δ measurement at high temperature

12.8.1 Procedure

The sample shall be heated by a suitable method and the temperature of the conductor determined either by measuring its resistance or by thermocouples on the surface of the screen, or by thermocouples on the conductor of another sample of the same cable heated by the same means.

The sample shall be heated until the conductor reaches a temperature which shall be not less than 5 K and not greater than 10 K above the maximum conductor temperature in normal operation of 90 °C.

Tan δ shall be measured at a power frequency voltage of U_0 at the temperature specified above.

12.8.2 Requirement

The measured value of tan δ at 95 °C to 100 °C shall not exceed 10 × 10^{-4}.

12.9 Heating cycle voltage test

12.9.1 The sample shall be in a U-bend having the diameter specified in **12.5**.

12.9.2 The sample shall be heated by conductor current, until the conductor reaches a temperature which shall be not less than 5 K and not greater than 10 K above the maximum conductor temperature in normal operation.

NOTE If for practical reasons the test temperature cannot be reached, additional thermal insulation may be applied.

12.9.3 The heating shall be applied for at least 8 h and shall be followed by at least 16 h of natural cooling. The conductor temperature shall be maintained within the stated temperature limits for the last 2 h of each heating period.

12.9.4 The cycle of heating and cooling shall be carried out 20 times.

12.9.5 During the whole of the test period a voltage of 2 U_0 shall be applied to the sample but interruption of the test is allowed provided that 20 complete heating cycles in total under voltage are completed.

NOTE Heating cycles with a conductor temperature higher than 10 K above the maximum conductor temperature in normal operation are considered valid.

12.9.6 After the final cycle or, alternatively, after the lightning impulse voltage test in **12.10**, the sample shall be subjected to and conform to the tan δ tests in accordance with **12.7** and **12.8** and at ambient temperature and high temperature shall be subjected to and conform to the requirements of the partial discharge test in accordance with **12.6**.

12.10 Impulse voltage test

The impulse test shall be performed on the sample at a conductor temperature that shall be not less than 5 K and not greater than 10 K above the maximum conductor temperature in normal operation.

The impulse voltage shall be applied according to the procedure given in BS EN 60230.

The cable shall withstand without failure 10 positive and 10 negative voltage impulses of the appropriate value specified in Table 1.

12.11 Power frequency voltage test

This test shall be made at ambient temperature. The power frequency voltage shall be gradually increased to the value given in Table 7 and shall be applied for 4 h to the sample between conductor and screen. No puncture of the insulation shall occur.

Table 7 **Power frequency voltage test**

System rated voltage kV	Test voltage kV
66	108
110	192
132	228

12.12 Cable examination

After the completion of all electrical tests, a 300 mm sample of cable shall be taken from the mid-point of the cable length. After removal of the metal sheath and any metal screens, three radial sections approximately 25 mm thick shall be cut out.

The conductor shall be removed and the insulation section ends prepared by grinding/polishing/cutting to give smooth surfaces.

Each radial section shall be heated in order to render the insulation transparent.

NOTE Temperatures in the range 120 °C to 160 °C have been found to be suitable.

Each section shall be inspected visually for the following:

- loss of screen adhesion;
- gaps in the screen;
- thin screens;
- indented screens due to external pressure;
- large voids, asperities and inclusions.

In the case of three-core cables, the examination shall be carried out on each core.

The results shall be recorded in the type test report.

13 Type tests on cable components

*COMMENTARY ON CLAUSE **13***

*The non-electrical type tests and type tests to check that the materials used for the cable components have satisfactory properties are listed in Table 5 in summarized form. Details of the tests are specified in **13.1** to **13.13** and Clause **14**.*

13.1 Check of cable construction

The examination of the conductor and measurements of insulation and sheath thicknesses shall be carried out in accordance with and conform to the requirements of **9.6**.

13.2 Ageing tests on pieces of complete cable to check compatibility of materials

13.2.1 General

The ageing test on pieces of complete cable shall be carried out to check that the insulation, non-metallic sheath and extruded semi-conducting layers over the conductor and insulation are not liable to deteriorate excessively in operation due to contact with other components in the cable.

13.2.2 Sampling

Samples for the test on insulation and non-metallic sheath shall be taken from the completed cable in accordance with BS EN 60811-401. Samples for the test on the semi-conducting screens shall be taken from a similar sample of completed cable from a position close to the sample used for the measurement of resistivity of the screens without ageing.

13.2.3 Ageing treatment

The ageing treatment of the pieces of cable shall be carried out in an air oven in accordance with BS EN 60811-401 under the following conditions:

a) temperature: (10 ±2) K above the maximum conductor temperature of the cable in normal operation;

b) duration: 7 × 24 h.

13.2.4 Measurements after ageing

Test pieces of insulation and sheath from the aged pieces of cable shall be prepared and subjected to mechanical tests in accordance with BS EN 60811-501. The resistivity of the extruded semi-conducting layers shall be determined on a test piece from the aged piece of cable in accordance with BS 7870-2:2011, **3.9.3**.

13.2.5 Requirements

13.2.5.1 Insulation and non-metallic sheath

The test results for tensile strength and elongation at break shall conform to the values applying to the test after ageing in an air oven as specified in Table 8 for insulation and Table 9 for sheaths.

13.2.5.2 Semi-conducting layers

The resistivity values shall conform to the requirements specified in **10.4**.

Table 8 **Tests and requirements for mechanical characteristics of XLPE insulating material before and after ageing**

Test	Units	Requirement
Maximum rated conductor temperature	°C	90
Without ageing:		
• Tensile strength, minimum	N/mm²	12.5
• Elongation at break, minimum	%	200
After ageing in air oven		
Treatment:		
• temperature	°C	135
• tolerance	°C	±3
• duration	days	7
Tensile strength:		
a) value after ageing, minimum	N/mm²	—
b) variation [A)], maximum	%	±25
Elongation at break:		
a) value after ageing, minimum	%	—
b) variation [A)], maximum	%	±25

[A)] The variation is between the median value obtained after ageing and the median value obtained without ageing, expressed as a percentage of the latter.

Table 9 – Test requirements for particular characteristics of oversheathing for cables

Test	Units	Requirement			
		ST_1 A)	ST_2 A)	ST_3 A)	ST_7 A)
Without ageing					
Tensile strength, minimum	N/mm²	12.5	12.5	10.0	12.5
Elongation at break, minimum	%	150	150	300	300
After ageing in air oven					
Treatment:					
• temperature	°C	100	100	100	110
• tolerance	°C	±2	±2	±2	±2
• duration	days	7	7	10	14
Tensile strength:					
a) value after ageing, minimum	N/mm²	12.5	12.5	—	—
b) variation B), maximum	%	±25	±25	—	—
Elongation at break:					
a) value after ageing, minimum	%	150	150	300	300
b) variation B), maximum	%	±25	±25	—	—
Pressure test at high temperature					
Test temperature	°C	80	90	—	110
Tolerance	°C	±2	±2	—	±2
Time under load	h	6	6	—	6
Maximum depth of indentation	%	50	50	—	50
Loss of mass test in air oven					
Test temperature	°C	—	100	—	—
Tolerance	°C	—	±2	—	—
Time under load	h	—	168	—	—
Maximum permissible loss of mass	mg/cm²	—	1.5	—	—
Behaviour at low temperature					
Cold elongation test of dumbbells					
Test temperature	°C	–15	–15	—	—
Tolerance	°C	±2	±2	—	—
Heat shock test					
Test temperature	°C	150	150	—	—
Tolerance	°C	±3	±3	—	—
Time under load	h	1	1	—	—

A) Designation of compound (see **4.5**).

B) The variation is the difference between the median value obtained after ageing and the median value obtained without ageing, expressed as a percentage of the latter.

13.3 Tests for determining the mechanical properties of insulation and oversheathing before and after ageing

The following tests shall be carried out to determine the mechanical properties of insulation before and after ageing.

a) Sampling and preparation of test pieces shall be carried out in accordance with BS EN 60811-501.

b) The ageing treatments shall be carried out in accordance with BS EN 60811-401, under the conditions specified in Table 8 for insulation and Table 9 for oversheathing.

c) Conditioning and the measurement of mechanical properties shall be carried out in accordance with BS EN 60811-501.

d) The test results for un-aged and aged test pieces shall conform to the requirements specified in Table 8 for insulation and Table 9 for oversheathing.

13.4 Pressure test at high temperature on oversheaths

13.4.1 Procedure

The pressure test at high temperature for ST_1, ST_2 and ST_7 oversheaths shall be carried out as described in BS EN 60811-508, employing the test conditions given in the test method and in Table 9.

13.4.2 Requirements

The results shall conform to the requirements given in BS EN 60811-508.

13.5 Test on PVC oversheaths (ST_1 and ST_2) at low temperature

13.5.1 Procedure

The test at low temperature for ST_1 and ST_2 oversheaths shall be carried out as described in BS EN 60811-505, employing the test temperature given in Table 9.

13.5.2 Requirements

The results of the test shall conform to the requirements given in BS EN 60811-505.

13.6 Loss of mass test on PVC oversheaths of type ST_2

13.6.1 Procedure

The loss of mass test for ST_2 oversheaths shall be carried out as described in BS EN 60811-409, under the conditions given in Table 9.

13.6.2 Requirements

The results shall conform to the requirements given in Table 9.

13.7 Heat shock test for PVC oversheaths (ST_1 and ST_2)

13.7.1 Procedure

The heat shock test on ST_1 and ST_2 oversheaths shall be carried out as described in BS EN 60811-509, the test temperature and duration being in accordance with Table 9.

13.7.2 Requirements

The results of the test shall conform to the requirements given in BS EN 60811-509.

13.8 Visual examination of semi-conducting screens

13.8.1 General

The semi-conducting screens shall be examined by one of the methods described in **13.8.2** and **13.8.3**.

13.8.2 Method 1

A sample of approximately 50 mm long shall be taken from the cable core. This sample shall be cut into wafers approximately 2 mm thick to enable examination of the semi-conducting conductor and insulation screens. The entire contact area between the semi-conducting screens and the insulation shall be examined under a microscope with a minimum 15 power magnification under transmitted light. The contact surface between the screen and the insulation shall be cylindrical, smooth and free from protrusions and irregularities that extend more than 125 μm into the insulation.

13.8.3 Method 2

The conductor shall be removed from a sample of core 75 mm to 100 mm long. The sample shall either:

a) be rendered transparent by immersion in a suitable heated fluid; or

b) have both end faces microtomed to produce a smooth finish and then the sample heated in an air oven to render the insulation transparent.

NOTE Temperatures from 120 °C to 160 °C are suitable, depending on the size of the cable.

In both cases, the interface between the insulation and the semi-conducting screens shall be examined by the naked eye and shall be smooth and free from protrusions and irregularities. Where protrusions and/or irregularities are observed, the sample shall be allowed to cool to ambient temperature and the entire sample re-inspected in accordance with method 1 (**13.8.2**).

13.9 Hot set test for XLPE insulation

XLPE insulation shall be subjected to the hot set test in accordance with **10.5** and shall conform to its requirements.

13.10 Measurement of carbon black content of black PE oversheaths (ST_3 and ST_7)

13.10.1 Procedure

The carbon black content of ST_3 and ST_7 oversheaths shall be measured using the sampling and test procedure described in BS EN 60811-605.

13.10.2 Requirements

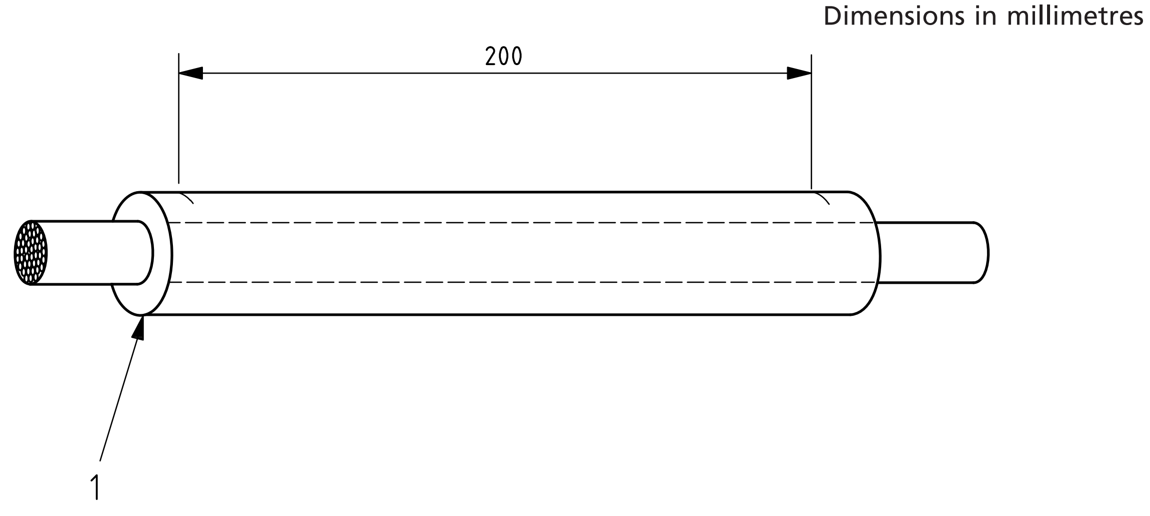
The nominal value of the carbon black content shall be 2.5%, with a tolerance of ±0.5%.

13.11 Shrinkage test for cable insulation

XLPE insulation shall be subjected to the shrinkage test in accordance with **10.6** and shall conform to its requirements.

NOTE See Figure 1.

Figure 1 **Shrinkage test**



Key

1 Insulation

13.12 Shrinkage test on polyethylene sheath

When measured in accordance with BS EN 60811-503, the shrinkage of sheath type ST_3 or ST_7 shall be not greater than 3.0%.

13.13 Test under fire conditions

The test under fire conditions in accordance with BS EN 60332-1-2 shall be carried out on a sample of completed cable, if the manufacturer wishes to claim that the particular design of cable conforms to the requirements.

The results shall conform to the requirements given in BS EN 60332-1-2:2004, Annex A.

14 Longitudinal water penetration type test on complete cables

14.1 Sampling

A sample of completed cable at least 6 m in length, which has not been subjected to any of the tests described in Clause **13**, shall be subjected to the bending test described in **12.5**.

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

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

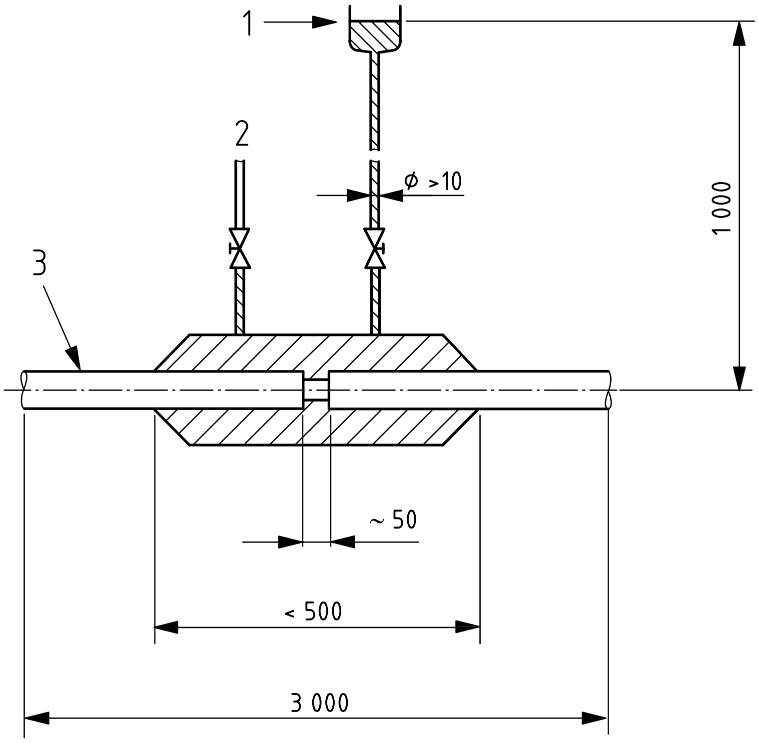
The surfaces shall be cut so that the relevant interstices can be readily exposed to the water.

A suitable device (see Figure 2) shall be arranged to allow a tube having a diameter of at least 10 mm to be placed vertically over the exposed ring and sealed to the surface of the oversheath. The sealing between the cable and the apparatus shall not exert mechanical stress on the cable.

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

Figure 2 **Schematic diagram of apparatus of water penetration test**

Dimensions in millimetres



Key

1 Water header tank

2 Vent

3 Cable

14.2 Procedure

The tube shall be filled within 5 minutes with water at ambient temperature so that the height of the water in the tube is 1 m above the cable centre (see Figure 2).

The sample shall be allowed to stand for 24 h. The sample shall then be subjected to 10 heating cycles. The conductor shall be heated by conductor current until it has reached a temperature which shall be not less than 5 °C and not greater than 10 °C above the maximum conductor temperature in normal operation, and which shall not reach the boiling point of water.

The heating shall be applied for at least 8 h and shall be followed by at least 16 h of natural cooling. The conductor temperature shall be maintained within the stated temperature limits for at least 2 h of each current loading period.

The water head shall be maintained at 1 m.

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

14.3 Requirement

During the period of testing no water shall emerge from the ends of the test sample.

14.4 Additional procedure for phase conductor

When requested by the customer, the additional test described in Annex D shall be conducted.

During the period of testing, no water shall emerge from the exposed end of the test piece.

15 Mechanical and thermal type tests on complete cables

15.1 General

The mechanical and thermal type test methods and requirements for completed cables shall be as follows:

a) impact test (see **15.2**);

b) abrasion, penetration, bending and saline bath tests on anti-corrosion coverings for self contained cables (see **15.3**);

c) corrosion penetration test for aluminium sheathed cables (see **15.4**);

d) internal thermal resistance (see **15.5**).

15.2 Impact test

The test shall be carried out at (20 ±15) °C and performed by dropping a metal weight of 5 kg from a height of 1 m on a cable sample 1 m in length. One impact shall be successively made at five different points along the cable. The distance between two impact points shall exceed 100 mm. At the impact point, the weight shall have a 90° corner angle with a 2 mm radius of curvature. After the test, the sample shall be visually inspected and there shall be no evidence of:

- oversheath penetration;
- damage to the semi-conducting screen, i.e. penetration, loss of adhesion;
- permanent thinning of the insulation.

15.3 Abrasion, penetration, bending and saline bath tests on anti-corrosion coverings for self contained cables

15.3.1 Sampling

A sample of cable shall be taken that has a length of at least four times the diameter of the bending test drum.

15.3.2 Test conditions

The temperature at which abrasion and penetration are carried out shall be (20 ±5) °C.

The saline solution specified in **15.3.3.5** shall be a 0.5% solution of sodium chloride (common salt) and the depth of the solution shall be maintained at least 500 mm above the floor of the tank.

15.3.3 Procedure

15.3.3.1 General

The cable sample shall be subjected in turn to the abrasion, penetration and bending tests specified in **15.3.3.2**, **15.3.3.3** and **15.3.3.4**, respectively. It shall then be immersed in a saline bath (**15.3.3.5**), and examined as specified in **15.3.3.6**.

All the tests specified in **15.3.3.2** to **15.3.3.6** shall be applied at approximately the mid-point of the sample.

The tests specified in **15.3.3.2** and **15.3.3.3** shall be carried out respectively along axes diametrically opposite and at right-angles to the axis used for the bending tests, i.e. 90° abrasion test, 180° bending test, 270° penetration test, 360° bending test.

15.3.3.2 Abrasion

The cable shall be laid out straight and horizontally and a length of steel angle shall be placed at right angles across the cable with its 270° angle pressing into the oversheath. The outer radius of curvature of the 270° angle shall be not less than 1 mm and not more than 2 mm.

The steel angle shall be loaded with a mass equal to $0.018D^{1.7}$ kg, where *D* is the overall diameter of the cable in millimetres, with a maximum loading of 55 kg. The steel angle shall be dragged horizontally for not less than 600 mm along the cable in alternate directions 25 times, making 50 passes in all, at a speed between 150 mm/s and 300 mm/s.

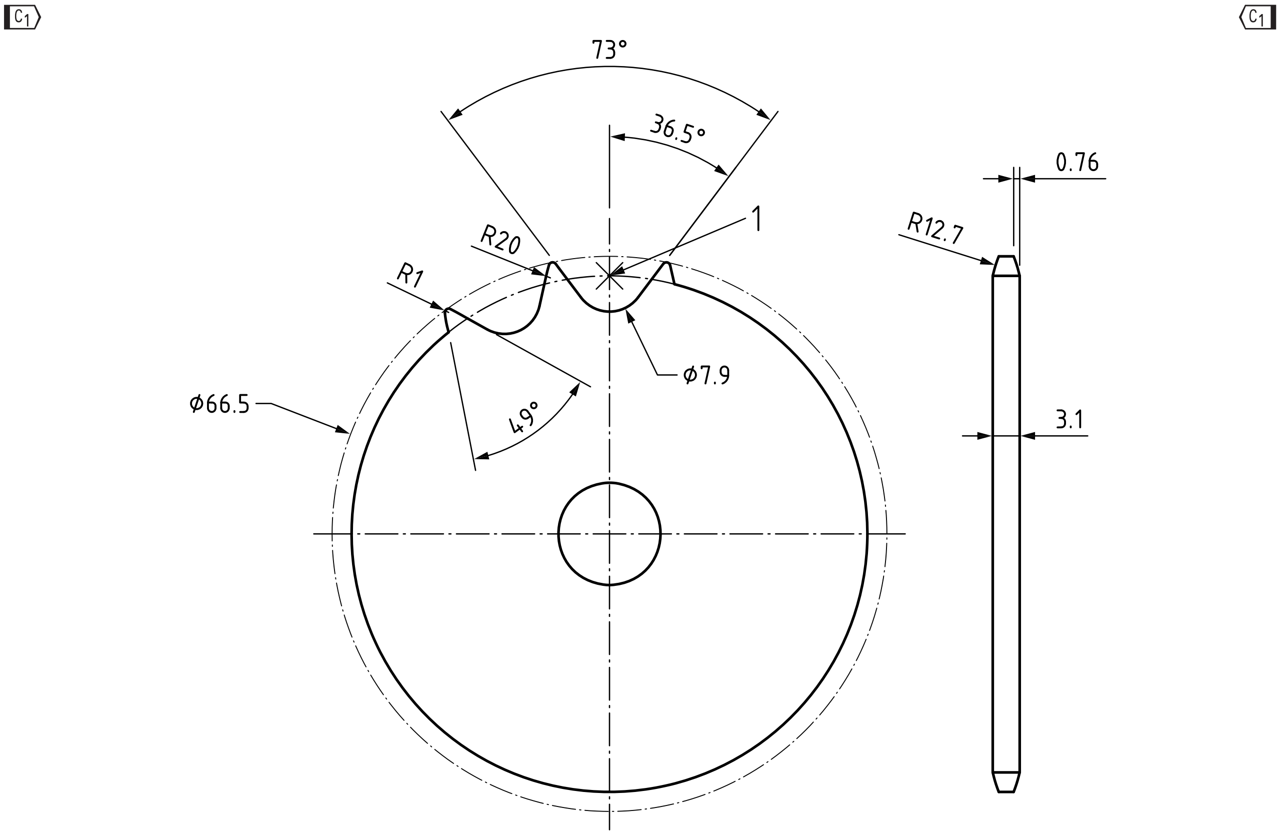
15.3.3.3 Penetration

A toothed wheel, free to rotate, at a pitch circle diameter (PCD) of 61.087 mm and with a total of 15 teeth, and as shown in Figure 3, shall be loaded and dragged once along the cable. The wheel shall be loaded with a mass equal to $0.2\,D + 2.5$ kg subject to a maximum loading of 18 kg.

NOTE D is the calculated diameter under the oversheath in millimetres, rounded down to the nearest 5 mm for cables up to 50 mm diameter, and to the nearest 10 mm diameter for cables of 50 mm and above.

The toothed wheel shall be dragged 600 mm along the cable, which shall be laid out straight and horizontally.

Figure 3 **Toothed wheel: 15 teeth**



Key

1 Centre of the Ø 7.9 circle on a Ø 61.1 PCD

15.3.3.4 Bending

The cable sample shall be subjected to a bending test in accordance with **12.5**.

15.3.3.5 Saline bath

The cable sample shall be placed in a tank of saline solution, such that the length of the sample that has been subjected to the abrasion and penetration tests is totally immersed in the saline solution.

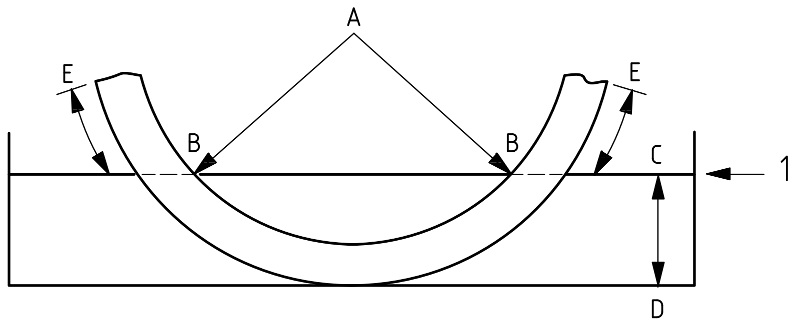
NOTE An example of a suitable test arrangement is shown in Figure 4. Other acceptable arrangements for this test are to place the cable sample in a sleeve enclosure with a header tank, or to cap the ends of the cable sample before immersing it completely in the tank.

A d.c. potential of 10 V shall be applied between the saline solution and the metal cable sheath with the latter connected to the negative pole of the d.c. supply. After 24 h immersion the covering leakage current shall be measured.

100 daily heating cycles shall be applied at a rate of 5 heating cycles per week. Each heating cycle shall consist of heating the saline solution to a temperature of not less than 75 °C and not greater than 80 °C, and maintaining the temperature within these limits for 5 h, the solution then being allowed to cool naturally. Prior to each heating period, the covering leakage current shall be measured and the solution temperature noted. The sensitivity of the meter used for measuring the covering leakage current shall be such that differences of 0.5 μA are indicated.

Within 24 h after shutting off the source of heat for the final heating cycle and before removing the cable sample from the saline solution, a d.c. potential equivalent to 20 kV/mm of covering subject to a maximum of 5 kV, shall be applied for 1 min between the saline solution and the protected metal layer.

Figure 4 **Possible arrangement of sample in saline bath**



Key

1 Solution level

A – B = Bending radius
C – D = Depth of solution, i.e. 500 mL min.
E = 300 mm (approx.) of cable at each end for testing purposes

15.3.3.6 Examination

After completion of the saline bath test, the middle 1 m of the sample shall be stripped and the protected metal layer examined for signs of corrosion.

15.3.3.7 Requirements

The integrity of the anti-corrosion covering shall be deemed to be satisfactory if all the following requirements are met.

a) The initial measured value of leakage current does not exceed its theoretical maximum value calculated from the design resistivity of the oversheath.

b) The leakage current does not increase by more than 10 μA above its initial value, over the test period.

c) The 1 min d.c. voltage test is completed without breakdown of the sample.

d) Examination of the middle 1 m of the sample in accordance with **15.3.3.6** reveals no signs of corrosion.

15.4 Corrosion penetration test for aluminium sheathed cables

15.4.1 Sampling

A sample of cable shall be taken that has a length of at least four times the diameter of the bending test drum.

15.4.2 Procedure

The cable sample shall be subjected to a bending operation around a test drum as specified in **12.5**. The anti-corrosion covering shall be punctured down to the metal sheath in four places in the mid-portion of the specimen by means of a cork drill of 10 mm diameter. The corrosion protection shall be removed from these holes, and the metal sheath carefully cleaned of compound clinging to the sheath. The four holes shall be spaced about 100 mm apart lengthways along the sheath and spaced around the circumference at 90° from each other.

The sample shall be bent into a U-shape with a radius not less than that specified for the bending operation and placed in a bath containing a solution of 1% sodium sulphate in water at ambient temperature in such a way that the four holes are covered by at least 500 mm solution, while the cable ends are protruding. The aluminium sheath shall be connected to the negative pole of a supply of 100 V d.c. The positive pole of the supply shall be connected to a metal electrode immersed in the solution.

The current shall be kept constant at approximately 10 mA by means of a resistor of approximately 10 kΩ (using one resistor per sample).

After electrification as above for (100 ±2) h, the specimen shall be taken out of the water bath.

On completion of the test, the covering shall be removed from the aluminium sheath, and the sheath shall be cleaned of all compound.

15.4.3 Requirements

The performance of the covering shall be deemed to be satisfactory if no signs of corrosion are visible on the sheath to the unaided eye, extending for more than 10 mm beyond the boundaries of any of the initial holes at any point.

15.5 Internal thermal resistance of complete cable

15.5.1 Sampling

A sample shall be taken that consists of at least 11 m of cable excluding terminations.

15.5.2 Procedure

Thermocouples shall be attached to the metal sheath of the cable sample at intervals not exceeding 0.5 m over the central 10 m sample. Thermocouples shall be inserted in the conductor at intervals of 2 m over the central 10 m of the cable sample.

Potential connections, for the purpose of conductor resistance measurements, shall be made to the cable conductor at distances of 3 m and 4 m from, and on both sides of, the mid-point of the cable length.

Either a.c. or d.c. current could be used to heat the conductor. The d.c. resistance of the conductor shall be measured with the conductor at ambient temperature, by a 4-terminal method using the potential connections specified above.

The measured resistance value shall be converted to 20 °C in accordance with BS EN 60228 and the resulting value used to calculate the a.c. or d.c. conductor resistance, whichever is applicable, at the thermal resistance measurement temperature, in accordance with BS EN 60287-1-1.

NOTE Alternatively, the a.c. resistance of the conductor may be measured using one of the techniques in CIGRE Brochure 272 [1].

The relevant value of conductor resistance, together with the value of heating current, shall be used to calculate the power loss in the conductor.

15.5.3 Requirement

The internal thermal resistance as determined by conductor power loss, measured temperatures and dimensions shall not exceed the declared value by more than 10%.

16 Type tests on accessories

16.1 General

It shall be permissible for any or all of the tests specified in this clause to be omitted, provided that:

a) certified type tests have been made on a similar accessory according to the definitions in **11.2** (where relevant); and

b) the critical electrical design stresses are the same or lower in the accessory to be supplied.

Accessories shall be assembled in the manner specified by the manufacturer's instructions, using the grade and quantity of materials supplied by the manufacturer, including lubricants if applicable.

Accessories shall be dry and clean, but neither the cables nor the accessories shall be subjected to any form of conditioning which might modify the electrical or thermal or mechanical performance of the test assemblies.

16.2 Tests and requirements

16.2.1 General

Accessories shall conform to the requirements in **16.3** to **16.10**. These tests shall be considered valid for both the cable and the accessories, provided that the requirements of Clause **12** are fully met by the cable.

Where a single joint is included in the sample, the minimum length of free cable between the joint and the bottom of each termination shall be 5 m.

Where more than one joint is included in the sample, the minimum length of free cable between the joint and the bottom of each termination shall be 5 m, and there shall be a minimum length of 4 m of free cable between successive joints.

16.2.2 Sequence of tests

Accessories shall be subjected to the following sequence of tests.

a) Partial discharge test at ambient temperature (see **16.3**).

b) Heating cycle voltage test (see **16.4**).

*NOTE 1 The cable might have a U-bend with the diameter as specified in **12.5**.*

c) Partial discharge tests (see **16.3**).

- at ambient temperature; and
- at high temperature.

The tests shall be carried out after the final cycle of item b) or, alternatively, after the lightning impulse voltage test in item d).

d) lightning impulse voltage test (see **16.5**) followed by a power frequency voltage test (see **16.6**);

e) partial discharge tests, if not previously carried out in item c) above;

f) tests of outer protection for buried joints (see **16.8**);

*NOTE 2 These tests might be applied to a joint which has passed the test in item b), heating cycle voltage test, or to a separate joint which has passed at least three thermal cycles (see **16.8**).*

*NOTE 3 If the joint is not to be subjected to wet conditions in service (i.e. not directly buried in earth or not intermittently or continuously immersed in water), only the tests in **16.8.4** and **16.8.5** are required to be carried out, where applicable.*

g) examination of the accessories after completion of the above tests (see **16.7**).

Test voltages shall be in accordance with the values given in the appropriate column of Table 1.

16.3 Partial discharge test

The test shall be performed at ambient temperature in accordance with the method specified in BS EN 60885-3.

The sensitivity of the test shall be 5 pC or less. The voltage shall be applied up to 1.75 U_0 for at least 10 s and then decreased to the value of 1.5 U_0 for the partial discharge measurements. There shall be no detectable discharge exceeding the declared sensitivity from the test object at 1.5 U_0.

16.4 Load cycle voltage test

The load cycle voltage test shall be performed in the same way and meet the conditions and requirements as specified in **12.9** with the exception of **12.9.1** and **12.9.2.** The assembly shall be heated by a suitable method until the cable conductor reaches a steady temperature 5 K to 10 K above the maximum conductor temperature in normal operation. The heating arrangements shall be selected so that the cable conductor attains the temperature specified in this subclause, remote from the accessories and, as far as practicable, also within the accessories. Partial discharge at ambient temperature shall conform to **16.3** throughout the test period and after the final cycle or, alternatively, after the impulse voltage test in **16.5**.

16.5 Impulse voltage test

The impulse test shall be performed in the same way and under the same conditions as specified in **12.10**.

The assembly shall withstand without failure or flashover 10 positive and 10 negative voltage impulses of the appropriate value specified in Table 1.

16.6 Power frequency voltage test

This test shall be made at ambient temperature. A power frequency test voltage shall be gradually increased to the value given in Table 7 and shall be applied for 4 h to the sample between conductor and screen.

No puncture of the insulation shall occur.

16.7 Examination

Examination of the cable and dismantled accessories with unaided vision shall reveal no signs of deterioration that could affect the system integrity in service operation.

In the case of liquid filled accessories, samples of the insulating liquid shall be taken and the declared properties shall be measured. The values of these properties shall conform to the values declared in Clause **7**.

16.8 Tests on buried joints

16.8.1 General

Protective joint boxes and joint oversheath material such as dip-coated PVC, heatshrink and tapes shall be subjected to the tests specified in **16.8.2** to **16.8.5** unless agreed otherwise with the purchaser.

The tests shall be carried out in the sequence given in **16.8.2** to **16.8.5**.

16.8.2 Mechanical test

The test area shall be a pit, or open topped container, that does not deform when filled and the required additional mass applied.

The joint, complete with power cable and any bonding leads, shall be assembled in the test area and the appropriate covering placed around them and, if appropriate, filled with compound to the manufacturer's instructions. The test area shall then be filled with consolidated dry sand such that the highest point of the protective covering is buried to a depth of (100 ±25) mm. Concrete cable protection covers shall then be placed in the normal manner over the sand such that they overlap the protective box in all directions by at least 50 mm.

Additional mass (in kilograms), equal to the total area of covers (in metres squared) multiplied by 5 000, shall then be applied evenly over the concrete cable protection covers for a period not less than 30 min.

The test rig shall then be carefully dismantled to make sure there is no visible evidence of deformation, fracture or disturbance to any part of the protective cover.

16.8.3 Water immersion and heat cycling

The joint encased with the protective cover shall then be immersed in water to a depth of not less than 1 000 mm above the highest point of the protective covering. The water shall then be heated and maintained at a temperature not less than 75 °C and not greater than 80 °C for a period of not less than 5 h and then allowed to cool to within 10 K of ambient temperature or 30 °C, whichever is the higher. This cycle shall be repeated 7 times.

16.8.4 D.C. voltage withstand test

With the assembly still immersed, a withstand test voltage of 25 kV d.c. shall be applied for 5 min as follows.

a) For test assemblies without sheath sectionalizing insulation, the voltage shall be applied between the cable sheath and the earthed exterior of the protective covering.

b) For cable test assemblies with sheath sectionalizing insulation, the test voltage shall be applied between the sheaths of the power cables at either end of the accessory and also between each sheath and the earthed exterior of the protective cover.

16.8.5 Lightning impulse voltage tests

These tests shall be applied between the sheaths of the power cable at either end of the accessory and also between each sheath and the earthed exterior of the protective box. The testing shall be in accordance with BS EN 60230. The lightning impulse levels shall be as specified in Table 10.

Table 10 **Lightning impulse voltage test levels**

System voltage kV	Between halves kVp	Each half to earth kVp
66	60	30
110	75	37.5
132	75	37.5

If it is not practicable to carry out the impulse test on the assembly while it is immersed, it shall be removed from the water, a conductive coating shall be applied over the entire exterior surface of the test assembly, and it shall be impulse tested with the minimum of delay.

The accessory shall withstand the above tests without failure or flashover.

16.9 Test for accessories with mechanical connections to sheath or screen wires

*COMMENTARY ON **16.9***

Plumbed connections, for which no specific tests are required, have traditionally been made between metal joint components and the cable screen wires and metal sheath. Mechanical (clamped, compressed or spring assisted) connections, however, are more likely to suffer inadequate performance, either on initial assembly or later due to corrosion or heating effects at the mechanical interfaces.

16.9.1 General

The test detailed in **16.9.2** and **16.9.3** shall be carried out for each mechanical connection type.

NOTE A connection type might be used on different types of accessories, e.g. on both joints and terminations.

16.9.2 Test assembly

Two of the mechanical connections to be tested shall be assembled on the cable type for which use is to be approved. These shall be either connections forming part of a complete accessory or the relevant components shall be used on their own (e.g. just the relevant end bell components). The two connections shall be installed with 5 m of cable in between.

Connections shall be made to the accessories (or accessory components) such that a.c. current can be passed through the metal screen of the 5 m length of cable via the accessories (or accessory components) under test. Thermocouples shall be attached to the metal cable sheath at the centre of its length and to the cable sheath at the mechanical connections as close as practicable to the connections but without disrupting or interfering with the connection assemblies.

The electrical resistance between the two accessories shall be measured and the temperatures recorded.

Current shall be passed through the mechanical connections and metal cable sheath to raise the temperature of the metal cable sheath at the centre of the cable length to 90 °C ±3 °C within 6 hours. The sheath shall then be maintained at this temperature for at least 2 hours. The total heating time shall be 8 hours. The current shall then be switched off and the assembly allowed to cool for 16 hours. This cycle shall be repeated 20 times.

The temperatures shall be recorded continuously.

When the assembly has cooled to ambient temperature, the electrical resistance between the two accessories shall be measured and the temperatures recorded.

16.9.3 Requirements

Except during the first hour of heating, the temperature measured at the mechanical connections shall not exceed the temperature of the metal cable sheath during the heating period of the test.

NOTE This is to cater for the possible effects of ambient temperature variations.

There shall be no progressive increase in maximum temperature measured at the mechanical connections, over the period of the test.

If (after correcting for any temperature difference) the final value of resistance is higher than the initial value of resistance, then the difference between the two values shall not be greater than the nominal resistance of the metal screen of a 1 m length of cable.

16.9.4 Outdoor termination insulators

Composite type outdoor terminations conforming to BS EN 61462 shall normally be used unless otherwise specified by the user.

16.10 SF_6 switchgear cable connections

Cable connections for SF_6 switchgear shall conform to BS EN 62271-209.

17 Type tests on ancillary equipment

For the following pieces of ancillary equipment, test requirements shall be as detailed in Annex A, Annex B and Annex C.

- Bonding leads (Annex A).
- Sheath voltage limiters (SVLs) (Annex B).
- Link housings (Annex C).

NOTE The tests and requirements in Annex A, Annex B and Annex C are subject to agreement between the purchaser and the supplier.

18 Electrical tests after installation

18.1 Testing of insulation (cable and accessory)

18.1.1 General

Tests on new installations shall be made when the installation of the cable and its accessories has been completed.

18.1.2 A.C. testing

The a.c. test voltage to be applied shall be subject to agreement between the purchaser and the contractor. The waveform shall be substantially sinusoidal and the frequency shall be between 20 Hz and 300 Hz. A voltage according to Table 11 shall be applied for 1 h.

Table 11 **A.C. test voltages**

System voltage kV	r.m.s test voltage phase to earth kV
66	72
110	128
132	132

Alternatively, a voltage of U_0 shall be applied for 24 h.

The requirement for the measurement of partial discharge during commissioning tests shall be agreed between the purchaser and the contractor.

NOTE 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.

18.2 Verification of specially bonded sheath systems

18.2.1 Cross-bonded systems

Once the installation of the cross-bonded system is complete, the correctness of the bonding connections shall be determined by applying a 3-phase current of approximately 100 A to the phase conductors and measuring the resulting sheath currents and voltages to earth with:

a) the bonding links in their correct position;

b) the bonding leads re-positioned to simulate erroneous bonding;

c) the bonding links returned to their correct position.

18.2.2 Contact resistances

The contact resistance of all earthing and sheath bonding connections shall be measured using a calibrated digital micro-ohmmeter.

The contact resistance between each lug attached to the joint sleeve of a sectionalized joint and the corresponding bonding lead connector shall be measured prior to the fitting of the outer protective cover.

The contact resistance shall not exceed the maximum values specified in Table 12.

Table 12 **Maximum contact resistance values**

Contact	Maximum contact resistance μΩ
Link contact	20
SVL terminal connection	50
Joint lug and bonding connector	20
Earth connection	50

18.3 Verification of positive phase and zero sequence impedance

18.3.1 General

For determining the values of the positive and zero impedance, the test shall be carried out in accordance with the method and requirements specified in **18.3.2** and **18.3.3**.

Measurements shall be made and recorded on all single core 132 kV cable circuits where the route length exceeds 400 m, to determine positive and zero sequence impedances. To do this, 3-phase and single-phase current injection tests shall be carried out, preferably in the range 25 A to 100 A, together with measurements of current, voltage and power or alternatively current, voltage and phase angle.

All sheath bonding and earthing connections shall be as for normal circuit operation.

Where there is more than one cable per phase, the conductors and sheaths shall be connected as for normal operation and the tests detailed in **18.3.2** and **18.3.3** carried out on the total circuit.

Particular care shall be taken to ensure that contact resistances are small compared with the resistance of the conductor. At the time of the tests, an estimate shall be made of cable temperature so that allowance can be made for the temperature dependence of resistance.

For measurements of positive sequence impedance, the cable conductors shall be bonded together and earthed at the end remote from the test. A 3-phase star connected supply with the star point unearthed shall be used for this test. If the supply is not isolated, the three cable conductors at the remote end shall be bonded together to form an unearthed star point.

For measurements of zero sequence impedance, the conductors shall be shorted together at the test end. At the remote end, the conductors shall be bonded together and to the cable sheaths and to earth.

A single-phase supply shall be applied between the shorted conductors and the earthed cable sheaths.

NOTE One phase of the transformer used for the measurement of positive sequence impedance could be used for this purpose.

18.3.2 Positive sequence impedance (Z_p)

3-phase currents shall be injected, equalizing the magnitudes of the currents so far as possible. Measurements of current, voltage and either power or phase angle shall be made on each of the single core cables. From these arrangements, the following shall be calculated:

Using wattmeter

$$Z_p = \frac{V_p}{I_p}$$

$$R_p = \frac{W_p}{I_p^2}$$

$$X_p = \sqrt{Z_p^2 - R_p^2}$$

Using phase angle meter

$$Z_p = \frac{V_p}{I_p}$$

$$R_p = \frac{V_p}{I_p}\cos\theta$$

$$X_p = \frac{V_p}{I_p}\sin\theta$$

and

$$Z_1 = \frac{\sum Z_p}{3} \text{ohms/phase}$$

$$R_1 = \frac{\sum R_p}{3} \text{ohms/phase}$$

$$X_1 = \frac{\sum X_p}{3} \text{ohms/phase}$$

where:

I_p	is the measured phase current, in amps;
R_p	is the phase resistance, in ohms;
R_1	is the positive sequence resistance, in ohms;
V_p	is the measured phase voltage, in volts;
W_p	is the measured phase power, in watts;
X_p	is the phase reactance, in ohms;
X_1	is the positive sequence reactance, in ohms;
Z_p	is the phase impedance, in ohms;
Z_1	is the positive sequence impedance, in ohms;
θ	is the measured phase angle, in degrees.

18.3.3 Zero sequence impedance (Z_0)

Single-phase currents shall be injected into the cables connected in parallel, with the test current returning through the sheaths and earth.

Measurements of current, voltage and either power or phase angle shall be made, from which the following shall be calculated:

Using wattmeter

$$Z_0 = \frac{3V}{I}$$

$$R_0 = \frac{3W}{3I^2}$$

$$X_0 = \sqrt{Z_0^2 - R_0^2}$$

Using phase angle meter

$$Z_0 = \frac{3V}{I}$$

$$R_0 = \frac{3V}{I}\cos\theta$$

$$X_0 = \frac{3V}{I}\sin\theta$$

giving Z_0, R_0 and X_0 in ohms/phase;

where:

I is the measured total current, in amps;

R_0 is the zero sequence resistance, in ohms;

V is the measured conductor to earth voltage, in volts;

W is the measured total power, in watts;

X_0 is the zero sequence reactance, in ohms;

Z_0 is the zero sequence impedance, in ohms;

θ is the measured phase angle, in degrees.

18.4 D.C. conductor resistance test

The d.c. conductor resistance of each completed circuit shall be measured to three significant figures and recorded.

18.5 Voltage test on sheath insulation

After completion, all the sheath insulating provisions, including external joint insulation, terminal base insulation, sheath-sectionalizing insulation (if any), the insulation of bonding leads, link boxes, etc. shall, for a period of 1 min, safely withstand a voltage dependant on the thickness of the cable oversheath as follows:

- extruded PVC or polyethylene – 4 kV d.c. per mm of thickness with a maximum of 10 kV d.c.

In calculating the test voltage, the specified nominal thickness of the oversheath shall be used.

In the case of a repetition of the test, the value of the voltage shall be restricted to 5 kV.

For cross-bonded systems the above voltage test on oversheath shall be carried out after disconnection of the SVLs which otherwise would be damaged or destroyed by the test voltage. The SVLs shall be returned to their former position in the system after completion of the test.

18.6 Test on sheath voltage limiters

18.6.1 General

Tests on completed assemblies shall be as specified in **18.6.2** to **18.6.5**.

18.6.2 Resistor characteristics

With the SVL leads disconnected from the bonding links, a suitable variable voltage d.c. supply shall be connected in turn between each of the three disc leads and the earth lead.

NOTE The d.c. supply should be substantially free from a.c. ripple otherwise erroneous results might be obtained.

18.6.3 Zinc oxide units

The test voltage shall be adjusted to give a test current of 10 mA and an average shall be taken of the voltages measured in the forward and reverse directions. If the ambient temperature is different from 20 °C, the recorded currents shall be decreased by 0.1% for every degree centigrade above 20 °C, or increased by 0.1% for every degree centigrade below 20 °C. The corrected current values for 20 °C shall be within the following range:

- commissioning test: rated voltage +20% to +45%;

- maintenance test: rated voltage +17% to +45%;

where the rated voltage is the maximum r.m.s. value of power frequency voltage that can be applied to the unit for a period of 1 s, without causing damage.

NOTE The 1 s value of rated voltage specified here is higher by about 5% than the rated voltage defined in BS EN 60099-4 which is a 10 s value. The latter might be quoted on some product datasheets.

In addition, a visual examination shall show the leads and external surface of the unit or container to be free from substantial bulges or other signs of deterioration.

18.6.4 Maintenance test for silicone carbide units

In each case the voltage shall be adjusted to a value appropriate to the disc under test as given in Table 13 and the resulting current shall be measured. If the ambient temperature is different from 20 °C, the recorded currents shall be decreased by 1% for every degree celsius above 20 °C, or increased by 1% for every degree celsius below 20 °C. The corrected current values for 20 °C shall be within the range specified in Table 13.

Table 13 **Voltage and current range for maintenance test on silicon carbide units**

Type of disc	Test voltage V (d.c.)	Current limits at 20 °C mA
SVL 8	70	0.5 to 50
SVL 16	140	0.5 to 50
SVL 28	210	0.5 to 50

18.6.5 Internal insulation resistance for SVL housing with separate earth lead

With the three disc leads connected to the earth lead and all four disconnected from earth, the resistance between them and any metallic casing shall be not less than 10 MΩ when measured with a 1 000 V insulation resistance test instrument.

Annex A (normative) Tests and requirements for cable bonding leads

A.1 Construction

Bonding leads shall have stranded plain copper conductors with insulation of one of the sheath material types specified in **4.5**. The leads shall be one of the following two types as appropriate:

a) single-core construction, in accordance with Table A.1;

b) concentric construction, in accordance with Table A.2.

NOTE Tables A.1 and A.2 show examples of typical bonding lead sizes.

Table A.1 **Examples of the construction of single core bonding leads**

Component	Nominal conductor size											
	120 mm²			240 mm²			300 mm²			500 mm²		
	Build or min. av. wall	Diameter		Build or min. av. wall	Diameter		Build or min. av. wall	Diameter		Build or min. av. wall	Diameter	
		Min.	Max.		Min.	Max.		Min.	Max.		Min.	Max.
	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
Conductor	37/2.03	14.1	14.7	91/1.78	19.5	20.1	91/2.03	22.3	22.9	127/2.25	29.2	29.8
Graphite coated insulation	3.3	20.7	24.7	3.3	26.5	30.1	3.3	28.9	32.2	3.3	35.8	38.2

Table A.2 – Examples of the construction of concentric bonding leads

Component	Nominal conductor size														
	120 mm² A)			240 mm²			300 mm²			500 mm²			120 mm² Special		
	Build or min. av. wall	Diameter		Build or min. av. wall	Diameter		Build or min. av. wall	Diameter		Build or min. av. wall	Diameter		Build or min. av. wall	Diameter	
		Min.	Max.		Min.	Max.		Min.	Max.		Min.	Max.		Min.	Max.
	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
Inner conductor	37/2.03	14.1	14.7	91/1.78	19.5	20.1	91/2.03	22.3	22.9	127/ 2.25	29.3	29.9	37/2.03	14.1	14.7
Inner insulation	4.6	23.3	27.3	4.6	28.7	32.7	4.6	31.5	35.5	7.0	43.3	47.3	7.0	28.1	32.1
Outer conductor (approximate make up)	64/1.13 + 70/1.13	27.8	31.8	59/1.53 + 65/1.53	34.8	38.8	56/1.78 + 62/1.78	38.6	42.6	60/2.25 + 66/2.25	52.3	56.3	50/1.78	31.7	35.7
Graphite coated outer insulation	3.3	34.4	38.2	3.3	41.4	45.0	3.3	45.2	50.0	3.3	58.9	62.0	3.3	38.4	43.0

A) Also for 132 kV system connections not subject to full fault current, e.g. SVL connections.

A.2 Application

The bonding leads to be employed shall be as follows.

a) On 3-core and solidly bonded single core cable systems – all bonding leads shall be of the single-core type except in conjunction with sheath sectionalizing joints, when concentric leads (or closely bound single core leads) shall be used.

b) On specially bonded cable systems – except as indicated in the Note below, all bonding leads shall be of the concentric type (or alternatively, closely bound single-core leads). Leads brought out from sheath sectionalizing insulation shall be so arranged that the two leads from the two sides of any one insulation are bound together or comprise the inner and outer conductors of one concentric bonding lead. At earthed terminations single-core bonding leads may be used, while at unearthed terminations, the leads connected to the cable sheaths shall be the inner conductors of concentric leads. The outer conductors of the said leads shall be connected to the steelwork of the sealing end supporting structures (alternatively, closely bound single-core leads may be used). In the case of link boxes, the outer conductors of concentric leads to terminations shall in all cases be connected to the metallic casing of the link housing into which they run; in the case of link pillars the outer conductors shall be connected to the insulated earth bar (closely bound single-core leads may also be used in these situations).

NOTE While concentric leads have a superior transient performance, single-core leads can also be used and might offer other advantages such as needing simpler joint protection systems. It is, however, recommended that in single-core lead applications, go/return leads are tie-wrapped. In those conditions where the link boxes are very close to the joints (or unearthed terminations), bundling the leads might not be practical, but is not needed due to the low inductance. The use of single-core leads in this way should be verified by system design calculations.

Bonding arrangements shall be designed to minimize the length of bonding lead. Wherever possible, no bonding lead of the concentric type shall exceed 10 m in length.

Joints in bonding leads shall not be used in new installations, but may be used in subsequent alterations, e.g. diversion or remedial work. Their use and design shall be to the approval of the appropriate qualified officer.

In addition, other exceptional cases in which single-bonding leads shall be connected to specially bonded sheath systems are:

- leads used for earthing the cable sheaths at an uninterrupted junction for single point bonded sections;
- leads used for earthing normally earthed terminations, if circumstances permit each individual termination to be earthed via an individual single link box mounted in the immediate vicinity of the termination concerned;
- leads used for earthing or other connections at terminations into metal-clad equipment.

Subject to the appropriate qualified officer's agreement, it shall be permissible for any larger size of bonding lead chosen from the ranges indicated to be employed. Any such alternative lead size shall have an insulation thickness not less than that shown in Table A.2 for the system voltage in question.

A.3 Marking

The insulation of the single-core type and the outer insulation of the concentric type shall be embossed with the legend:

ELECTRIC CABLE – BONDING LEAD

A.4 Electrical requirements

The exterior surface of all bonding leads shall be coated with graphite to serve as an electrode for voltage testing.

All bonding leads shall have insulation suitable for a short-circuit temperature of 160 °C.

The bonding leads shall be routine tested. The test voltages and conductor resistance shall be in accordance with Table A.3 and Table A.4 respectively.

The design shall be compatible with the maximum short circuit current and short circuit duration as agreed between customer and supplier.

Table A.3 **Test voltages for bonding leads**

Component	**Test voltage**			
	Spark test	**Voltage test on finished cables**		
	kV a.c.	kV	a.c. or d.c.	Time (min)
Insulation of single-core leads	20	25	d.c.	1
Inner insulation of 120 mm², 240 mm² and 300 mm² concentric leads	25	15	a.c.	5
Inner insulation of 500 mm² and 120 mm² (special) concentric leads	30	20	a.c.	5
Outer insulation of concentric leads	20	25	d.c.	1

Table A.4 **Conductor d.c. resistance**

Nominal conductor size	**Maximum conductor resistance**
mm²	Ω/km at 20 °C
120	0.153
240	0.080 8
300	0.062 3
500	0.036 6

A.5 Type test requirements

A.5.1 Abrasion test

The test shall be carried out as specified in BS EN 60229. This shall be followed by the tests specified in **A.5.2** and **A.5.3.3**.

A.5.2 Water immersion and heat cycling test

A length of bonding lead not less than 10 m shall be laid such that the centre portion is immersed in water to a depth of not less than 1 m and both ends are above the water surface. The water shall then be heated and maintained at a temperature not less than 75 °C and not more than 80 °C for a period not less than 5 h. The water shall then be allowed to cool naturally to within 10 °C of ambient or 30°C, whichever is the higher. This cycle shall be repeated 7 times. With the bonding lead still immersed, it shall be subjected to the sequence of tests in **A.5.3**.

A.5.3 Electrical tests

A.5.3.1 General

Test voltages shall be applied as follows:

a) single core – between the conductor and the lead's conductive outer coating;

b) concentric leads – between the outer conductor and the lead's conductive outer coating.

A.5.3.2 D.C. withstand voltage test

A 25 kV d.c. withstand voltage shall be applied for a period not less than 5 min. No breakdown of the insulation shall occur.

A.5.3.3 Impulse voltage test

All bonding leads shall withstand 10 positive, followed by 10 negative, impulses. The magnitude of the impulses between conductor and earth and between conductors shall be 37.5 kVρ and 75 kVρ respectively. The test shall be performed in accordance with BS EN 60230.

A.6 Routine test requirements

The routine testing requirements for bonding leads shall be as specified in BS EN 60229. The spark test, however, shall not be used as an alternative to the d.c. withstand voltage test.

Annex B (normative) Tests and requirements for sheath voltage limiters (SVLs)

B.1 General requirements

Where the cable system design requires the induced transient voltages between the metal cable sheath and earth to be limited, sheath voltage limiters (SVLs) may be used, and where they are used they shall satisfy the following requirements.

SVLs shall be installed:

a) at all sheath sectionalizing joint positions and terminations which are not bonded to earth or where the sectionalizing insulation is not solidly bridged across;

b) at all unearthed terminations;

NOTE Unearthed terminations connected directly into metal clad equipment should be avoided where at all possible.

c) in certain circumstances at earthed terminations into metal clad equipment.

SVLs shall be identified by fitting a label detailing the following information:

- rated voltage;
- maximum continuous operating voltage;
- manufacturer's name;
- resistor material;
- serial number;
- year of manufacture.

B.2 Performance requirements

The SVL shall be capable of continuously withstanding a maximum sheath standing voltage of 65 V for system voltages up to and including 132 kV, unless otherwise agreed between the purchaser and the supplier.

NOTE Where the SVL star point is not connected to earth, transient voltages can occur across two SVLs in series. Unless these SVLs are matched units, one of them is likely to be subjected to a higher voltage than the other.

Where matched SVLs are not used, the matched design SVL rated voltage shall be increased by 20% to compensate for any such imbalance.

B.3 Type testing requirements

The type test report shall be submitted in standard format.

A component drawing of the SVL shall be submitted for each type of SVL detailing the lengths of leads, non-linear resistors, manufacturer's reference, component identity and type.

NOTE An SVL might be a single-phase or 3-phase unit.

To obtain type approval for a particular design of SVL device, six units shall be subjected to the type tests consisting of a classification test, sequence of withstand tests (**B.3** to **B.7**) and a repeat of the classification test.

Each of the six units shall satisfy the pass criteria in **B.8**.

The classification test shall be performed as follows: the SVL shall be maintained at a temperature of (20 ±10) °C and the mean voltage between the SVL terminals shall be measured and recorded when the SVL conducts +10 mA and –10 mA.

B.4 Lightning current impulse test

B.4.1 Each SVL shall be subjected to a 2 kA, 5 kA, 10 kA and 15 kA current impulse with the following waveshape:

- time to peak (T_p): (8 ±1) μs;
- time to half value (T_2): (20 ±2) μs.

B.4.2 Before each test the non-linear resistor shall be allowed to cool naturally to within 10 °C of ambient temperature. The waveform of the current into and the residual voltage across each phase shall be recorded.

B.4.3 The 10 kA current impulse shall be applied 20 times with a time interval between impulses of (60 ±6) s, and the results of the first and last test recorded as before.

B.5 Step current impulse test

The step current impulse test shall consist of the application of a 30 kA current impulse of the following waveshape:

- time to peak:

  (T_p): $1^{+0.2}_{-0.1}$ μs;
- time to half value (T_2): up to 20 μs.

Waveforms of the SVL current and residual voltage across each tested phase shall be recorded.

B.6 High current impulse test

The high current impulse test shall consist of two applications of a 40 kA discharge current with the following impulse waveform:

- time to peak (T_p): (4 ±0.5) μs;
- time to half value (T_2): (10 ±1) μs.

Between current impulses the SVL shall be allowed to cool naturally to within 10 °C of ambient temperature. Waveforms of the SVL current and residual voltage for the duration of each impulse voltage shall be recorded.

B.7 Rated voltage duty test

Rated power frequency voltage shall be applied for 1 s on two occasions, with a time interval between applications of between 10 s and 15 s. Superimposed on the peak of one of the first five half-cycles of each rated voltage application shall be a single 600 A rectangular current impulse of 2 000 μs duration.

Waveforms of the SVL current and residual voltage shall be recorded.

All the lightning current impulse tests in **B.4.1** and **B.4.2** shall be repeated and the result of the repeat 10 kA current impulse compared with that originally obtained.

The classification test in **B.3** shall then be repeated.

B.8 Pass criteria

The maximum variation in classification measurements before and after the sequence of tests shall not exceed ±5% for each unit tested.

Visual inspection of the SVL shall not show any evidence of flashover or damage.

Inspection of the recorded waveforms shall show no abnormal occurrence.

Annex C (normative) Tests and requirements for link housings

C.1 Physical requirements for link housings

C.1.1 General

All links and SVLs, other than those directly connected across sectionalizing insulation at metal-clad equipment terminations, shall be enclosed in metal housings, which shall be earthed. SVLs and associated links shall be accommodated in a common housing unless otherwise approved by the appropriate qualified officer.

The housings shall be provided with a means of preventing incorrect link positioning and shall also be provided with a label showing the normal link arrangement.

The terminal posts shall be designed so that the contact resistance requirements of **18.2.2** can be readily achieved and maintained. The terminal posts and links shall also be suitable for the short circuit requirements. The manufacturer shall declare the short circuit current and associated time for which the equipment is suitable.

Subject to agreement between supplier and user, the terminal posts or blocks shall have been drilled and tapped to accommodate suitable earth connections. The required positions for the tapped holes shall be agreed with the appropriate qualified officer. There shall be sufficient clearances around each hole to permit attachment of the earths.

The internal insulation of the link housing shall meet the requirements of the following:

a) 25 kV d.c. for 5 min between links and from links to earth;

b) impulse withstand voltage (nominal 1/50 μs waveshape) of 35 kVp between links and 17.5 kVp from links to earth.

C.1.2 Link boxes

All boxes enclosing SVLs and all other boxes not mounted above ground shall be of the horizontal type with bolted-on lids suitable for installation in shallow pits below ground surface, unless otherwise agreed by the appropriate qualified officer (e.g. in anticipation of future civil engineering works entailing a change in ground level). The highest point of a pit-mounted type box (excluding lifting handles) shall be not more than 1 m below ground level.

Unless the appropriate qualified officer otherwise directs or agrees, above-ground mounting shall be employed only for the purpose of earthing normally earthed terminations, i.e. at positions where SVLs are not required. Boxes intended for outdoor installation above ground shall be of the weatherproof outdoor type suitable for vertical mounting, e.g. on sealing end-supporting structures. Boxes for indoor installation shall be to the requirements of the appropriate qualified officer.

The boxes shall be earthed by connection to the adjacent earth electrode system or earth continuity conductor.

The lid of each box shall have a label fitted externally bearing the legend:

DANGER – ELECTRICITY

The label shall also give circuit identification details.

There shall be a label inside the box, which shall repeat the circuit identification details and shall bear the legend:

DANGER – ELECTRICITY

THIS/THESE LINK/S MUST BE CLOSED WHEN THE CABLE IS IN SERVICE

Where the bonding system requires no link to be present in service the legend shall read:

DANGER – ELECTRICITY

NO LINK SHALL BE FITTED WHEN THE CABLE IS IN SERVICE

Additionally, at connections into metal-clad busbars, the legend shall also include the following phrase:

BEFORE REMOVING OR REPLACING THE LINKS/SVLS ACROSS THE SECTIONALIZING INSULATION, THIS LINK MUST BE IN POSITION

A phase identification label shall be provided adjacent to each terminal. In the case of concentric bonding lead terminations a blank label shall be provided for each termination to which the inner and outer conductors respectively of incoming cables are connected, with space to record a geographical reference to which side of the joint barrier insulation they are connected. Provision shall be made for padlocking the lid.

C.1.3 Link pillars

Link pillars shall be to the approval of the appropriate qualified officer. Specific design aspects shall be as follows.

a) The back of the pillar shall be a fixed panel and not a door(s).

b) The door(s) shall be locked by a suitable integral security deadlock or by an alternative method specified by the appropriate qualified officer. The lock and key scheme shall be to the approval of the appropriate qualified officer.

NOTE Where the pillar has two doors, only one door need be lockable. The other door could be fastened by internal bolts at the top and bottom of the door.

c) Where the pillar houses links are associated with more than one circuit, there shall be provision for separate lockable compartments, arranged in such a way that access is available to the links of either circuit which may be made dead, with the other circuit live.

Where the pillar is located within the area of a substantial earth mat (e.g. in a substation), the carcass of the pillar shall be connected to the internal earth bar which in turn is connected to the earth mat.

Where the pillar is not so located (e.g. at joint positions along the cable route), the earth bar to which the bonding leads are linked (via SVLs, where appropriate) in normal operation shall be connected to the joint bay earthing system and shall be insulated from the carcass of the pillar, which shall be connected to its own local earth. The insulation between the internal earth bar and the carcass of the pillar shall be adequate to withstand the link-to-earth test level specified in **C.1.1**. The insulation between the SVL container and the carcass of the pillar shall also meet this requirement.

The links shall have drilled, not slotted, holes and shall be of the same cross-section as those approved for use in link boxes.

The link arrangements shall be covered by a hinged transparent insulating screen of polymethyl methacrylate (PPMA), or other approved material.

Unless specified by the appropriate qualified officer, labelling of the pillars shall be as follows.

- The pillar shall have a label fitted externally bearing the legend:

  DANGER – ELECTRICITY.

- The label shall also give circuit identification details. Where the pillar is divided into compartments to accommodate the linking of more than one circuit per pillar, each compartment shall be identified by a label giving the circuit identification details.
- There shall be a label inside each compartment bearing the legend:

  DANGER – ELECTRICITY

  THIS/THESE LINK/S MUST BE CLOSED WHEN THE CABLE IS IN SERVICE.

- A phase identification label shall be provided for each incoming bonding lead.
- In the case of concentric bonding lead terminations a blank label shall be provided for each termination to which the inner and outer conductors respectively of incoming cables are connected, with space to record a geographical reference to which side of the joint barrier insulation they are connected.

C.2 Type testing requirements for link housings

C.2.1 Water immersion test for underground boxes

The box shall be assembled complete with bonding leads. An electronic moisture probe shall be fitted inside and the box sealed. For bolt-on lid box designs the box shall be immersed in water to a depth of not less than 2 m at the highest point of the box or subject to an external pressure of not less than 200 mbar. The water shall then be heated and maintained at a temperature of 40 °C for 5 h and then allowed to cool naturally to within 10 °C of ambient temperature or 30 °C, whichever is higher. This heating/cooling cycle shall be repeated not fewer than seven times. There shall be no evidence of moisture penetration into the box or corrosion at the end of the test.

C.2.2 D.C. voltage test

For underground boxes, this test shall be undertaken with the box still immersed as described in **C.2.1**.

A test voltage of 25 kV d.c. shall be applied for 5 min between all link connections and the earthed exterior of the box. There shall be no breakdown of the insulation.

C.2.3 Short circuit test

All link combinations and a link to earth shall be subjected to the short circuit current declared in **C.1**. No signs of overheating, deterioration or other damage shall be evident when the housing is inspected.

C.2.4 Internal arcing test for SVL housing

A length of fuse wire shall be laced between the cable terminations so as to initiate an internal power arc condition. A symmetrical 40 kA r.m.s. current shall then be passed through the fuse wire for a period not less than 0.1 s. The housing shall not disintegrate and no flying debris shall be emitted.

C.2.5 Impulse test

A series of voltage impulses of 75 kVp shall be applied between all link combinations and 37.5 kVp between one link to earth. The application of the impulses and shape of the impulse waveform shall be as specified in BS EN 60230. No electrical breakdown shall occur during this test.

Annex D (normative) Additional water blocking test for phase conductor

D.1 Test piece

A 3 m sample of cable shall be cut from the drum length and placed horizontally.

Both ends of the sample shall be cut so that the full cross-section of the cable shall be exposed.

Arrange a suitable device (see Figure D.1) to allow a tube having a diameter of at least 10 mm to be placed vertically over one exposed end and sealed to the surface of the oversheath. The seals where the cable exits the apparatus shall not exert mechanical stress on the cable.

D.2 Test

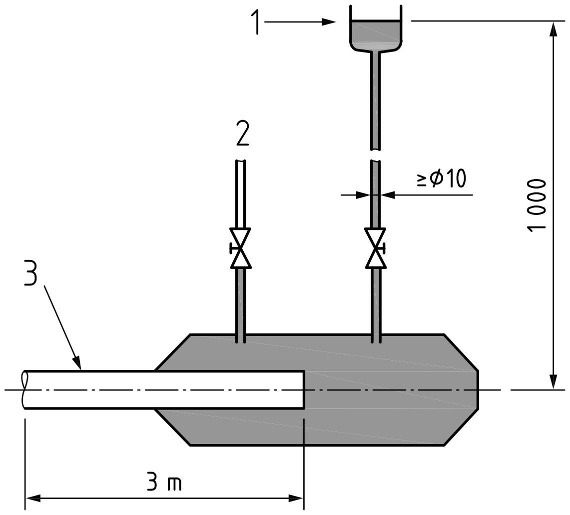
The tube shall be filled within 5 min with water at a temperature of (20 ±10) °C so that the height of the water in the tube is 1 m above the cable centre.

The sample shall be allowed to stand for 11 days at ambient temperature.

The water head shall be maintained at 1 m.

Figure D.1 **Apparatus for water penetration test**

Dimensions in millimetres



Key

1 Water header tank

2 Vent

3 Cable

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389 Chiswick High Road London W4 4AL UK

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