

Power cables with XLPE insulation and metallic sheath, and their accessories, for rated voltages from 66 kV ($U_m = 72.5$ kV) to 132 kV ($U_m = 145$ kV) — Requirements and test methods

(Implementation of HD 632)

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- British Plastics Federation
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Foreword

This British Standard has been prepared by Subcommittee GEL/20/2, Mains cables, 1 kV and above, under the direction of Technical Committee GEL/20, Electric cables.

It implements the nationally applicable parts of Harmonization Document HD 632 published by the European Committee for Electrotechnical Standardization (CENELEC), in accordance with the decision of the CENELEC Technical Board.

BS 7912 applies to power cables with XLPE insulation and metallic sheath, and their accessories for rated voltages $U(U_m)$ from 66 kV (72.5 kV) to 132 kV (145 kV).

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

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 41 and a back cover.

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1 Scope

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

This British Standard is applicable to single core cables and 3-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 may be necessary or special test conditions may need to be devised.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of this British Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. For undated references, the latest edition of the publication referred to applies.

BS 228:1994, *Specification for short-pitch transmission precision roller chains and chain wheels*.

BS 4727-2:Group 08:1994, *Glossary of electrotechnical, power, telecommunication, electronics, lighting and colour terms — Part 2: Terms particular to power engineering — Group 08: Electric cables*.

BS 6346, *Specification for 600/1000 V and 1900/3300 V armoured electric cables having PVC insulation*.

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

BS EN 50062, *Ceramic pressurized hollow insulators for high-voltage switchgear and controlgear*.

BS EN 60811-1-1:1995, *Insulating and sheathing materials of electric cables — Common test methods — General application — Part 1-1: Measurement of thickness and overall dimensions — Tests for determining the mechanical properties*.

BS EN 60811-1-2:1995, *Insulating and sheathing materials of electric cables — Common test methods — General application — Part 1-2: Thermal ageing methods*.

BS EN 60811-1-3:1995, *Insulating and sheathing materials of electric cables — Common test methods — General application — Part 1-3: Methods for determining the density — Water absorption tests — Shrinkage test*.

BS EN 60811-2-1:1995, *Insulating and sheathing materials of electric cables — Common test methods — Methods specific to elastomeric compounds — Part 2-1: Ozone resistance test — Hot set test — Mineral oil immersion test*.

BS EN 60811-3-1:1995, *Insulating and sheathing materials of electric cables — Common test methods — Methods specific to PVC compounds — Part 3-1: Pressure test at high temperature — Tests for resistance to cracking*.

IEC 60060-1, *Guide on high-voltage testing techniques — Part 1: General (published as BS 923 Part 1)*.

IEC 60228, *Conductors of insulated cables (published as BS 6360)*.

IEC 60229, *Tests on cable oversheaths which have a special protective function and are applied by extrusion*.

IEC 60230, *Impulse tests on cables and their accessories (implemented by CENELEC as HD 48)*.

IEC 60507:1991, *Artificial pollution tests on high-voltage insulators to be used on a.c. systems*.

IEC 60885-2, *Electrical test methods for electric cables — Part 2: Partial discharge tests*.

IEC 60885-3, *Electrical test methods for electric cables — Part 3: Test methods for partial discharge measurements on lengths of extruded power cable*.

3 Definitions

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

3.1

rated voltage U_0

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

3.2

rated voltage U

nominal power-frequency voltage between phase conductors, for which the cable is suitable

3.3

maximum voltage U_m

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

4 Voltage designation and materials

4.1 Voltage designation

NOTE 1 In this standard the symbols U_0 , U and U_m are used to designate the rated voltages of cables and accessories.

Where test voltages are specified in this 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 the table, 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 2 The test voltages in the 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 $\tan \delta$ measurement: 12.7	Test voltage of $\tan \delta$ 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 kV	U_m kV	U_0 kV	$2.5U_0$ kV	$1.5U_0$ kV	$2U_0$ kV	U_0 kV	$2U_0$ kV	kV	$3U_0$ kV
66	72.5	36 ^a	90	54	72	36	72	342	108
110	123	64	160	96	128	64	128	550	192
132	145	76	190	114	152	76	152	640	228
^a Nominal service phase voltage is 38 kV. The tabulated value used as a test reference is in accordance with HD 632, Table 1.									

4.2 Cable maximum temperatures

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

Table 2 — Cable maximum temperatures

Insulating compound	Maximum conductor temperature	
	Normal operation ^a °C	Short circuit ^b °C
Cross-linked polyethylene (XLPE)	90	250
^a The possibility of allocating maximum temperatures for emergency operation for limited periods, together with the need for a corresponding test specification, is under consideration. At present the operation at higher temperatures of cables tested according to this standard is not recommended. ^b Normally short circuit durations are of 3 s.		

4.3 Metallic cable sheathing materials

The metal sheath material shall consist of lead, lead alloy or aluminium.

NOTE Tests and performance requirements for foil sheath constructions are specified in BS 7970¹⁾.

4.4 Non-metallic cable sheathing materials

Tests are specified in this standard for four types of non-metallic sheath as follows:

- ST 1 and ST 2 based on PVC;
- ST 3 and ST 7 based on polyethylene.

NOTE 1 The choice of the type of sheath will depend on the design of the cable and the mechanical and thermal properties during operation.

NOTE 2 No temperature limits are given for sheaths in this standard.

5 Precautions against water penetration in cables

When tested in accordance with clause 14, the resistance to water penetration shall conform to 14.4.

NOTE A water impermeable barrier around the cable is recommended.

6 Cable characteristics

For the purpose of carrying out and recording the tests described in this 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 IEC 60228, the d.c. conductor resistance shall be declared;
- d) nominal thickness of insulation;
- e) presence (if any) and nature of measures in screening area to ensure that the cable is watertight;
- f) nature and construction of metallic sheath if any, or, nature, construction and thickness of metallic screen;
- g) nature of non-metallic sheathing material;
- h) nominal diameter over conductor (d);
- i) nominal diameter over complete cable (D);
- j) nominal capacitance between conductor and metallic screen/sheath.

¹⁾ In preparation.

7 Accessory characteristics

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

- a) For conductor connectors used within accessories:
 - assembly technique;
 - tooling and necessary setting;
 - preparation of contact surfaces;
 - type, reference number and any other identification of the connector;
 - electrostatic screening measures in the region of the conductor connection.
- 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).

8 Test categories and conditions

8.1 Categories of tests

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

8.1.1 Routine tests

Tests made on all production cable lengths to demonstrate their integrity.

8.1.2 Sample tests

Tests made on samples of completed cable, or components taken from a completed cable adequate to verify that the finished product meets the design specifications.

8.1.3 Type tests

Tests required to be made before supplying a type of cable covered by this standard on a general commercial basis in order to demonstrate satisfactory performance characteristics to meet the intended application. These tests are of such a nature that, after they have been made, they need not be repeated unless changes are made in the cable material, design or type of manufacturing process, which might change the performance characteristics.

8.1.4 Tests after installation

Tests intended to demonstrate the integrity of the cable and its accessories after installation and before use.

8.2 Ambient temperature

Unless otherwise specified in the details for the particular test, tests shall be made at an ambient temperature of $(20 \pm 15) ^\circ\text{C}$.

8.3 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.

8.4 Waveform of impulse test voltage

In accordance with IEC 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 IEC 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 IEC 60229);
- e) dimensional checks (see **9.6**).

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

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 IEC 60228.

9.2.2 Requirement

The d.c. resistance of the conductor at 20 °C shall not exceed the appropriate maximum value specified in IEC 60228 if applicable.

9.3 Partial discharge test

9.3.1 Procedure

The partial discharge test shall be carried out in accordance with IEC 60885-3 except that the sensitivity as defined in IEC 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

The magnitude of the discharge at $1.5U_0$ shall not exceed 10 pC.

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 metallic 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 non-metallic sheath

If required for the particular contract or order, the non-metallic sheath shall be subjected to the routine electrical test specified in IEC 60229.

9.6 Dimensional checks

9.6.1 General

Measurement of the thickness of the insulation, semiconducting screens, metallic 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 may have suffered damage.

9.6.2.2 Procedure

The test procedure shall be in accordance with BS EN 60811-1-1:1995, 8.1.

9.6.2.3 Requirements

The average value shall be greater than or equal to the specified nominal thickness [see clause 6, d)] and the minimum thickness at any point shall not fall below the specified nominal value by more than 10 % + 0.1 mm.

9.6.3 Measurement of thickness of semiconducting 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 may have suffered damage.

9.6.3.2 Procedure

The procedure set out in BS EN 60811-1-1:1995, 8.1 refers to cable insulation. The same procedure of thickness measurement shall be used for the semiconducting screens.

9.6.3.3 Requirements

The minimum average thickness of the semiconducting screens shall be not less than the specified value [see clause 6, f)] and the minimum thickness at any point shall be not less than 60 % of the specified value.

9.6.4 Measurement of thickness of metallic sheath

The following test applies if the cable has a metallic sheath of lead, lead alloy or aluminium.

The minimum thickness shall not fall below the specified nominal thickness [see clause 6, f)] by more than 0.1 mm + 5 % of the nominal thickness for lead and alloy sheaths and 0.1 mm + 15 % of the nominal thickness for aluminium sheaths, i.e.:

- for lead and lead alloy sheaths: $t_{\min.} \geq t_n - (0.1 + 0.05t_n)$;
- for aluminium sheaths: $t_{\min.} \geq t_n - (0.1 + 0.15t_n)$.

where

- $t_{\min.}$ is the measured value, in millimetres (mm);
- t_n is the nominal thickness, in millimetres (mm).

The thickness of the lead sheath shall be measured by one of the methods specified in BS 7870-2:1999, 2.1.5 at the discretion of the manufacturer.

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 may have suffered damage.

9.6.5.2 Procedure

The test procedure shall be in accordance with BS EN 60811-1-1: 1995, 8.2.

9.6.5.3 Requirements

The average thickness of the oversheath shall be not less than the specified nominal value [see clause 6, g)] and the minimum thickness shall not fall below the specified nominal value by more than 15 % + 0.1 mm.

10 Sample tests on cables

10.1 General

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

- a) volume resistivity of semiconducting 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 (see 10.7);
- e) properties of water blocking tape (see 10.8);
- f) cross-linking by-product concentration (see 10.9);
- g) insulation contamination examination (see 10.10);
- h) measurement of capacitance (see 10.11).

10.2 Frequency of tests

Samples shall be taken from manufactured lengths in accordance with Table 3.

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
etc.	etc.	etc.

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 semiconducting layers

10.4.1 Procedure

The resistivity of extruded semiconducting layers 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 7870-2:1999, 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: $500 \Omega \cdot \text{m}$;
- core screen: $500 \Omega \cdot \text{m}$.

10.5 Hot set test for XLPE insulation

10.5.1 Procedure

The sampling and test procedure shall be in accordance with BS EN 60811-2-1:1995, clause 9 employing the test conditions specified in Table 4.

The test pieces shall be taken from the inner, middle or outer part of the insulation where the degree of cross-linking is generally the lowest for the curing process employed.

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
<i>Hot set test</i> (BS EN 60811-2-1:1995, clause 9) 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
<i>Shrinkage test</i> (BS EN 60811-1-3:1995, clause 10)		
Distance between marks	mm	200
Temperature	°C	130
Tolerance	°C	±3
Duration	h	6
Maximum permissible shrinkage	%	4

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 60811-1-3:1995, clause 10 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 may have been contaminated. The sheath shall be removed and the sample sealed in a double polyethylene bag. The sample shall be tested within 24 h of sampling.

The cable sample shall be placed in a dry environment for desiccation. Complete sections of insulation including the inner and outer semiconducting screens shall be taken. The mass of sample shall be in line with the particular moisture determination method adopted.

10.7.2 Procedure

A glass oven containing the sample shall be maintained at 110 °C to 130 °C and dry nitrogen shall be used to transport the water vapour into an automatic Karl Fischer titration equipment.

The test shall be carried out on three separate cable sections taken from the 300 mm sample.

10.7.3 Requirements

The three determinations and the mean shall be recorded.

10.8 Properties of water blocking tape**10.8.1 General**

The following tests shall be carried out for those designs of cable where the manufacturer wishes to claim that barriers to longitudinal water penetration have been included.

10.8.2 Resistance test for water blocking tape

The resistance of the water blocking tape shall be measured before it is applied to the cable.

10.8.2.1 Sampling

Prepare three samples of tape 150 mm × 10 mm.

10.8.2.2 Procedure

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

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

10.8.2.3 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 /10 mm square.

10.8.3 Swell height of water blocking tape**10.8.3.1 Sampling**

The swell height of the water blocking tape shall be measured before it is applied to the cable.

10.8.3.2 Procedure

A polyamide (e.g. nylon) measuring apparatus shall be used, consisting of a cup in which a perforated ram can sit. The ram shall be free to move vertically (see Figure 1).

Cut the tape so as to fill the base of the cup completely, without any overlaps. Cover the tape with a thin circular tissue before placing the ram on top of the sample.

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

At the end of 10 min measure the height of the apparatus again.

10.8.3.3 Requirement

The swell height shall be not less than 7 mm.