

INTERNATIONAL STANDARD



**Power cables with extruded insulation and their accessories for rated voltages from 1 kV ($U_m = 1,2$ kV) up to 30 kV ($U_m = 36$ kV) –
Part 2: Cables for rated voltages from 6 kV ($U_m = 7,2$ kV) up to 30 kV ($U_m = 36$ kV)**



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Part 2: Cables for rated voltages from 6 kV ($U_m = 7,2$ kV) up to 30 kV ($U_m = 36$ kV)**

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

**POWER CABLES WITH EXTRUDED INSULATION
AND THEIR ACCESSORIES FOR RATED VOLTAGES
FROM 1 kV ($U_m = 1,2$ kV) UP TO 30 kV ($U_m = 36$ kV) –****Part 2: Cables for rated voltages from 6 kV
($U_m = 7,2$ kV) up to 30 kV ($U_m = 36$ kV)**

FOREWORD

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International Standard IEC 60502-2 has been prepared by IEC technical committee 20: Electric cables.

This third edition cancels and replaces the second edition, published in 2005, and constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

- a) a simplified calculation procedure for the thickness of the lead sheath and the oversheath;
- b) a new subclause for the determination of the cable conductor temperature;
- c) a modified procedure for the routine voltage test;
- d) a new subclause for a routine electrical test on oversheath;
- e) modified requirements for the non-metal sheaths including semi-conductive layer;
- f) modified tolerances for the bending test cylinder;
- g) the inclusion of a 0,1Hz test after installation.

In addition, the modified structure of the IEC 60811 series has been adopted for this third edition.

The following editorial changes have been made within the English version:

- 'metallic' has been replaced by 'metal';
- 'thermosetting' has been replaced by 'crosslinked'.

The text of this standard is based on the following documents:

FDIS	Report on voting
20/1469A/FDIS	20/1472/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts in the IEC 60502 series, published under the general title *Power cables with extruded insulation and their accessories for rated voltages from 1kV ($U_m = 1,2$ kV) up to 30 kV ($U_m = 36$ kV)*, can be found on the IEC website.

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- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

POWER CABLES WITH EXTRUDED INSULATION AND THEIR ACCESSORIES FOR RATED VOLTAGES FROM 1 kV ($U_m = 1,2$ kV) UP TO 30 kV ($U_m = 36$ kV) –

Part 2: Cables for rated voltages from 6 kV ($U_m = 7,2$ kV) up to 30 kV ($U_m = 36$ kV)

1 Scope

This part of IEC 60502 specifies the construction, dimensions and test requirements of power cables with extruded solid insulation from 6 kV up to 30 kV for fixed installations such as distribution networks or industrial installations.

When determining applications, it is recommended that the possible risk of radial water ingress is considered. Cable designs with barriers claimed to prevent longitudinal water penetration and an associated test are included in this part of IEC 60502.

Cables for special installation and service conditions are not included, for example cables for overhead networks, the mining industry, nuclear power plants (in and around the containment area) nor for submarine use or shipboard application.

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.

IEC 60038, *IEC standard voltages*

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

IEC 60060-3, *High-voltage test techniques – Part 3: Definitions and requirements for on-site testing*

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

IEC 60228, *Conductors of insulated cables*

IEC 60229:2007, *Tests on cable oversheaths which have a special protective function and are applied by extrusion*

IEC 60230, *Impulse tests on cables and their accessories*

IEC 60287-3-1, *Electric cables – Calculation of the current rating – Part 3: Sections on operating conditions – Section 1: Reference operating conditions and selection of cable type*

IEC 60332-1-2, *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*

~~IEC 60811-1-1, Common test methods for insulating and sheathing materials of electric cables and optical cables – Part 1-1: Methods for general application – Measurement of thickness and overall dimensions – Tests for determining the mechanical properties~~

~~IEC 60811-1-2, Common test methods for insulating and sheathing materials of electric cables – Part 1: Methods for general application – Section 2: Thermal ageing methods~~

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

~~IEC 60811-1-4, Common test methods for insulating and sheathing materials of electric cables – Part 1: Methods for general application – Section 4: Test at low temperature~~

~~IEC 60811-2-1, Common test methods for insulating and sheathing materials of electric and optical cables – Part 2-1: Methods specific to elastomeric compounds – Ozone resistance, hot set and mineral oil immersion tests~~

~~IEC 60811-3-1, Common test methods for insulating and sheathing materials of electric cables – Part 3: Methods specific to PVC compounds – Section 1: Pressure test at high temperature – Tests for resistance to cracking~~

~~IEC 60811-3-2, Common test methods for insulating and sheathing materials of electric cables – Part 3: Methods specific to PVC compounds – Section 2: Loss of mass test – Thermal stability test~~

~~IEC 60811-4-1, Insulating and sheathing materials of electric and optical cables – Common test methods – Part 4-1: Methods specific to polyethylene and polypropylene compounds – Resistance to environmental stress cracking – Measurement of the melt flow index – Carbon black and/or mineral filler content measurement in polyethylene by direct combustion – Measurement of carbon black content by thermogravimetric analysis (TGA) – Assessment of carbon black dispersion in polyethylene using a microscope~~

IEC 60811 (all parts), Electric and optical fibre cables – Test methods for non-metallic materials

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

IEC 60811-202, Electric and optical fibre cables – Test methods for non-metallic materials – Part 202: General tests – Measurement of thickness of non-metallic sheath

IEC 60811-203, Electric and optical fibre cables – Test methods for non-metallic materials – Part 203: General tests – Measurement of overall dimensions

IEC 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

IEC 60811-402, Electric and optical fibre cables – Test methods for non-metallic materials – Part 402: Miscellaneous tests – Water absorption tests

IEC 60811-403, Electric and optical fibre cables – Test methods for non-metallic materials – Part 403: Miscellaneous tests – Ozone resistance test on cross-linked compounds

IEC 60811-404, Electric and optical fibre cables – Test methods for non-metallic materials – Part 404: Miscellaneous tests – Mineral oil immersion tests for sheaths

IEC 60811-405, Electric and optical fibre cables – Test methods for non-metallic materials – Part 405: Miscellaneous tests – Thermal stability test for PVC insulations and PVC sheaths

IEC 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

IEC 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*

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

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

IEC 60811-504, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 504: Mechanical tests – Bending tests at low temperature for insulation and sheaths*

IEC 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*

IEC 60811-506, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 506: Mechanical tests – Impact test at low temperature for insulations and sheaths*

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

IEC 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*

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

IEC 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*

IEC 60811-606, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 606: Physical tests – Methods for determining the density*

IEC 60853 (all parts), *Calculation of the cyclic and emergency current rating of cables*

IEC 60853-2, *Calculation of the cyclic and emergency current rating of cables – Part 2: Cyclic rating of cables greater than 18/30 (36) kV and emergency ratings for cables of all voltages*

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

IEC 60986, *Short-circuit temperature limits of electric cables with rated voltages from 6 kV ($U_m = 7,2$ kV) up to 30 kV ($U_m = 36$ kV)*

ISO 48, *Rubber, vulcanized or thermoplastic – Determination of hardness (hardness between 10 IRHD and 100 IRHD)*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1 Definitions of dimensional values (thicknesses, cross-sections, etc.)

3.1.1**nominal value**

value by which a quantity is designated and which is often used in tables

Note 1 to entry: Usually, in this standard, nominal values give rise to values to be checked by measurements taking into account specified tolerances.

3.1.2**approximate value**

value which is neither guaranteed nor checked; it is used, for example, for the calculation of other dimensional values

3.1.3**median value**

when several test results have been obtained and ordered in an increasing (or decreasing) succession, the median value is the middle value if the number of available values is odd, and the mean of the two middle values if the number is even

3.1.4**fictitious value**

value calculated according to the "fictitious method" described in Annex A

3.2 Definitions concerning the tests**3.2.1****routine tests**

tests made by the manufacturer on each manufactured length of cable to check that each length meets the specified requirements

3.2.2**sample tests**

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

3.2.3**type tests**

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

Note 1 to entry: 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 materials or design or manufacturing process which might change the performance characteristics.

3.2.4**electrical tests after installation**

tests made to demonstrate the integrity of the cable and its accessories as installed

4 Voltage designations and materials**4.1 Rated voltages**

The rated voltages $U_0/U(U_m)$ of the cables considered in this standard are as follows:

$$U_0/U(U_m) = 3,6/6 (7,2) - 6/10 (12) - 8,7/15 (17,5) - 12/20 (24) - 18/30 (36) \text{ kV.}$$

NOTE 1 The voltages given above are the correct designations although in some countries other designations are used, e.g. 3,5/6 – 5,8/10 – 11,5/20 – 17,3/30 kV.

In the voltage designation of cables $U_0/U(U_m)$:

U_0 is the rated power frequency voltage between conductor and earth or metallic screen for which the cable is designed;

U is the rated power frequency voltage between conductors for which the cable is designed;

U_m is the maximum value of the "highest system voltage" for which the equipment may be used (see IEC 60038).

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

- category A: this category comprises those systems in which any phase conductor that comes in contact with earth or an earth conductor is disconnected from the system within 1 min;
- category B: this category comprises those systems which, under fault conditions, are operated for a short time with one phase earthed. This period, according to IEC 60183, should not exceed 1 h. For cables covered by this standard, a longer period, not exceeding 8 h on any occasion, can be tolerated. The total duration of earth faults in any year should not exceed 125 h;
- category C: this category comprises all systems which do not fall into category A or B.

NOTE 2 It should be realized that in a system where an earth fault is not automatically and promptly isolated, the extra stresses on the insulation of cables during the earth fault reduce the life of the cables to a certain degree. If the system is expected to be operated fairly often with a permanent earth fault, it may be advisable to classify the system in category C.

The values of U_0 recommended for cables to be used in three-phase systems are listed in Table 1.

Table 1 – Recommended rated voltages U_0

Highest system voltage (U_m) kV	Rated voltage (U_0) kV	
	Categories A and B	Category C
7,2	3,6	6,0
12,0	6,0	8,7
17,5	8,7	12,0
24,0	12,0	18,0
36,0	18,0	–

4.2 Insulating compounds

The types of insulating compound covered by this standard are listed in Table 2, together with their abbreviated designations.

Table 2 – Insulating compounds

Insulating compound	Abbreviated designation
a) <i>Thermoplastic</i> polyvinyl chloride intended for cables with rated voltages $U_0/U = 3,6/6$ kV	PVC/B*
b) <i>Thermosetting Crosslinked:</i> ethylene propylene rubber or similar (EPM or EPDM)	EPR
high modulus or hard grade ethylene propylene rubber	HEPR
cross-linked polyethylene	XLPE
* Insulating compound based on polyvinyl chloride intended for cables with rated voltages $U_0/U \leq 1,8/3$ kV is designated PVC/A in IEC 60502-1.	

The maximum conductor temperatures for different types of insulating compound covered by this standard are given in Table 3.

Table 3 – Maximum conductor temperatures for different types of insulating compound

Insulating compound		Maximum conductor temperature °C	
		Normal operation	Short-circuit (5 s maximum duration)
Polyvinyl chloride	(PVC/B)		
	Conductor cross-section ≤ 300 mm ²	70	160
	Conductor cross-section > 300 mm ²	70	140
Cross-linked polyethylene	(XLPE)	90	250
Ethylene propylene rubber	(EPR and HEPR)	90	250

The temperatures in Table 3 are based on the intrinsic properties of the insulating materials. It is important to take into account other factors when using these values for the calculation of current ratings.

For example, in normal operation, if a cable directly buried in the ground is operated under continuous load (100 % load factor) at the maximum conductor temperature shown in the table, the thermal resistivity of the soil surrounding the cable may, in the course of time, increase from its original value as a result of drying-out processes. As a consequence, the conductor temperature may greatly exceed the maximum value. If such operating conditions are foreseen, adequate provisions shall be made.

For guidance on continuous current ratings, reference should be made to Annex B, including the ratings under standard laying conditions, in Tables B.2 to B.9, and correction factors for deviation laying conditions, in Tables B.10 to B.23.

For guidance on the short-circuit temperatures, reference should be made to IEC 60986.

4.3 Sheathing compounds

The maximum conductor temperatures for the different types of sheathing compound covered by this standard are given in Table 4.

Table 4 – Maximum conductor temperatures for different types of sheathing compound

Sheathing compound	Abbreviated designation	Maximum conductor temperature in normal operation °C
a) <i>Thermoplastic</i> :		
polyvinyl chloride (PVC)	ST ₁	80
	ST ₂	90
polyethylene	ST ₃	80
	ST ₇	90
b) <i>Elastomeric</i> :		
polychloroprene, chlorosulfonated polyethylene or similar polymers	SE ₁	85

5 Conductors

The conductors shall be either of class 1 or class 2 of plain or metal-coated annealed copper or of plain aluminium or aluminium alloy in accordance with IEC 60228. For class 2 conductors measures may be taken to achieve longitudinal watertightness.

6 Insulation

6.1 Material

Insulation shall be extruded dielectric of one of the types listed in Table 2.

6.2 Insulation thickness

The nominal insulation thicknesses are specified in Tables 5 to 7.

The thickness of any separator or semi-conducting screen on the conductor or over the insulation shall not be included in the thickness of the insulation.

Table 5 – Nominal thickness of PVC/B insulation

Nominal cross-sectional area of conductor mm ²	Nominal thickness of insulation at rated voltage 3,6/6 (7,2) kV mm
10 to 1 600	3,4

NOTE 1 Any smaller conductor cross-section than those given in this table is not recommended. However, if a smaller cross-section is needed, either the diameter of the conductor may be increased by a conductor screen (see 7.2), or the insulation thickness may be increased in order to limit, at the values calculated with the smallest conductor size given in this table, the maximum electrical stresses applied to the insulation under test voltage.

NOTE 2 For conductor cross-sections larger than 1 000 mm², the insulation thickness may be increased to avoid any mechanical damage during installation and service.

Table 6 – Nominal thickness of cross-linked polyethylene (XLPE) insulation

Nominal cross-sectional area of conductor mm ²	Nominal thickness of insulation at rated voltage U_0/U (U_m)				
	3,6/6 (7,2) kV mm	6/10 (12) kV mm	8,7/15 (17,5) kV mm	12/20 (24) kV mm	18/30 (36) kV mm
10	2,5	–	–	–	–
16	2,5	3,4	–	–	–
25	2,5	3,4	4,5	–	–
35	2,5	3,4	4,5	5,5	–
50 to 185	2,5	3,4	4,5	5,5	8,0
240	2,6	3,4	4,5	5,5	8,0
300	2,8	3,4	4,5	5,5	8,0
400	3,0	3,4	4,5	5,5	8,0
500 to 1 600	3,2	3,4	4,5	5,5	8,0

NOTE 1 Any smaller conductor cross-section than those given in this table is not recommended. However, if a smaller cross-section is needed, either the diameter of the conductor may be increased by a conductor screen (see 7.2), or the insulation thickness may be increased in order to limit, at the values calculated with the smallest conductor size given in this table, the maximum electrical stresses applied to the insulation under test voltage.

NOTE 2 For conductor cross-sections larger than 1 000 mm², the insulation thickness may be increased to avoid any mechanical damage during installation and service.

Table 7 – Nominal thickness of ethylene propylene rubber (EPR) and hard ethylene propylene rubber (HEPR) insulation

Nominal cross-sectional area of conductor mm ²	Nominal thickness of insulation at rated voltage U_0/U (U_m)					
	3,6/6 (7,2) kV		6/10 (12) kV	8,7/15 (17,5) kV	12/20 (24) kV	18/30 (36) kV
	Unscreened mm	Screened mm	mm	mm	mm	mm
10	3,0	2,5	–	–	–	–
16	3,0	2,5	3,4	–	–	–
25	3,0	2,5	3,4	4,5	–	–
35	3,0	2,5	3,4	4,5	5,5	–
50 to 185	3,0	2,5	3,4	4,5	5,5	8,0
240	3,0	2,6	3,4	4,5	5,5	8,0
300	3,0	2,8	3,4	4,5	5,5	8,0
400	3,0	3,0	3,4	4,5	5,5	8,0
500 to 1 600	3,2	3,2	3,4	4,5	5,5	8,0

NOTE 1 Any smaller conductor cross-section than those given in this table is not recommended. However, if a smaller cross-section is needed, either the diameter of the conductor may be increased by a conductor screen (see 7.2), or the insulation thickness may be increased in order to limit, at the values calculated with the smallest conductor size given in this table, the maximum electrical stresses applied to the insulation under test voltage.

NOTE 2 For conductor cross-sections larger than 1 000 mm², the insulation thickness may be increased to avoid any mechanical damage during installation and service.

7 Screening

7.1 General

All cables shall have a metallic layer surrounding the cores, either individually or collectively.

Screening of individual cores in single or three-core cables, when required, shall consist of a conductor screen and an insulation screen. These shall be employed in all cables with the following exceptions:

- a) at rated voltage 3,6/6 (7,2) kV cables insulated with EPR and HEPR may be unscreened, provided the larger insulation thickness in Table 7 is used;
- b) at rated voltage 3,6/6 (7,2) kV cables insulated with PVC shall be unscreened.

7.2 Conductor screen

The conductor screen shall be non-metallic and shall consist of an extruded semi-conducting compound, which may be applied on top of a semi-conducting tape. The extruded semi-conducting compound shall be firmly bonded to the insulation.

7.3 Insulation screen

The insulation screen shall consist of a non-metallic, semi-conducting layer in combination with a metallic layer.

The non-metallic layer shall be extruded directly upon the insulation of each core and consist of either a bonded or strippable semi-conducting compound.

A layer of semi-conducting tape or compound may then be applied over the individual cores or the core assembly.

The metallic layer shall be applied over either the individual cores or the core assembly collectively and shall comply with the requirements of Clause 10.

8 Assembly of three-core cables, inner coverings and fillers

8.1 General

The assembly of three-core cables depends on the rated voltage and whether a metallic screen is applied to each core.

Subclauses 8.2 to 8.4 do not apply to assemblies of sheathed single-core cables.

8.2 Inner coverings and fillers

8.2.1 Construction

The inner coverings may be extruded or lapped.

For cables with circular cores, a lapped inner covering shall be permitted only if the interstices between the cores are substantially filled.

A suitable binder is permitted before application of an extruded inner covering.

8.2.2 Material

The materials used for inner coverings and fillers shall be suitable for the operating temperature of the cable and compatible with the insulating material.

8.2.3 Thickness of extruded inner covering

The approximate thickness of extruded inner coverings shall be derived from Table 8.

Table 8 – Thickness of extruded inner covering

Fictitious diameter over laid-up cores		Thickness of extruded inner covering (approximate values) mm
Above mm	Up to and including mm	
–	25	1,0
25	35	1,2
35	45	1,4
45	60	1,6
60	80	1,8
80	–	2,0

8.2.4 Thickness of lapped inner covering

The approximate thickness of lapped inner coverings shall be 0,4 mm for fictitious diameters over laid-up cores up to and including 40 mm and 0,6 mm for larger diameters.

8.3 Cables having a collective metallic layer (see Clause 9)

Cables shall have an inner covering over the laid-up cores. The inner covering and fillers shall comply with 8.2 and shall be non-hygroscopic except if the cable is claimed to be longitudinally watertight.

For cables having a semi-conducting screen over each individual core and a collective metallic layer, the inner covering shall be semi-conducting; the fillers may be semi-conducting.

8.4 Cables having a metallic layer over each individual core (see Clause 10)

The metallic layers of the individual cores shall be in contact with each other.

Cables with an additional collective metallic layer (see Clause 9) of the same material as the underlying individual metallic layers shall have an inner covering over the laid-up cores. The inner covering and fillers shall comply with 8.2 and shall be non-hygroscopic except if the cable is claimed to be longitudinally watertight. The inner covering and fillers may be semi-conducting.

When the underlying individual metallic layers and the collective metallic layer are of different materials, they shall be separated by an extruded sheath of one of the materials specified in 14.2. For lead sheathed cables, the separation from the underlying individual metallic layers may be obtained by an inner covering according to 8.2.

For cables without a collective metallic layer (see Clause 9), the inner covering may be omitted provided the outer shape of the cable remains practically circular.

9 Metallic layers for single-core and three-core cables

The following types of metallic layers are included in this standard:

- a) metallic screen (see Clause 10);
- b) concentric conductor (see Clause 11);
- c) metallic sheath (see Clause 12);
- d) metallic armour (see Clause 13).

The metallic layer(s) shall comprise one or more of the types listed above and shall be non-magnetic when applied to either single-core cables or individual cores of three-core cables.

Measures may be taken to achieve longitudinal watertightness in the region of the metallic layers.

10 Metallic screen

10.1 Construction

The metallic screen shall consist of one or more tapes, or a braid, or a concentric layer of wires or a combination of wires and tape(s).

It may also be a sheath or, in the case of a collective screen, an armour which complies with 10.2.

When choosing the material of the screen, special consideration shall be given to the possibility of corrosion, not only for mechanical safety but also for electrical safety.

Gaps in the screen shall comply with the national regulations and/or standards.

10.2 Requirements

The dimensional, physical and electrical requirements of the metallic screen shall be determined by national regulations and/or standards.

10.3 Metallic screens not associated with semi-conducting layers

Where metallic screens are employed at rated voltage of 3,6/6 (7,2) kV with PVC, EPR and HEPR insulations, these need not be associated with semi-conducting layers.

11 Concentric conductor

11.1 Construction

Gaps in the concentric conductor shall comply with national regulations and/or standards.

When choosing the material of the concentric conductor, special consideration shall be given to the possibility of corrosion, not only for mechanical safety but also for electrical safety.

11.2 Requirements

The dimensional and physical requirements of the concentric conductor and its electrical resistance shall be determined by national regulations and/or standards.

11.3 Application

When a concentric conductor is required, it shall be applied over the inner covering in the case of three-core cables; in the case of single-core cables, it shall be applied either directly over the insulation or over the semi-conducting insulation screen or over a suitable inner covering.

12 Metal~~lic~~ sheath

12.1 Lead sheath

The sheath shall consist of lead or lead alloy and shall be applied as a reasonably tight-fitting seamless tube.

The nominal thickness shall be calculated by the following formula:

~~a) for all single-core cables or assemblies thereof:~~

$$\del{t_{pb} = 0,03 D_g + 0,8}$$

~~b) for all cables with sector-shaped conductors up to and including 8,7/15 kV:~~

$$\del{t_{pb} = 0,03 D_g + 0,6}$$

~~c) for all other cables:~~

$$t_{pb} = 0,03 D_g + 0,7$$

where

t_{pb} is the nominal thickness of the lead sheath, in millimetres;

D_g is the fictitious diameter under the lead sheath, in millimetres (rounded to the first decimal place in accordance with Annex C).

In all cases, the smallest nominal thickness shall be 1,2 mm. Calculated values shall be rounded to the first decimal place (see Annex C).

12.2 Other metal~~lic~~ sheaths

Under consideration.

13 Metal~~lic~~ armour

13.1 Types of metal~~lic~~ armour

The armour types covered by this standard are as follows:

- a) flat wire armour;
- b) round wire armour;
- c) double tape armour.

13.2 Materials

Round or flat wires shall be of galvanized steel, copper or tinned copper, aluminium or aluminium alloy.

Tapes shall be of steel, galvanized steel, aluminium or aluminium alloy. Steel tapes shall be hot or cold rolled of commercial quality.

In those cases where the steel armour wire layer is required to comply with a minimum conductance, it is permissible to include sufficient copper or tinned copper wires in the armour layer to ensure compliance.

When choosing the material of the armour, special consideration shall be given to the possibility of corrosion, not only for mechanical safety, but also for electrical safety, especially when the armour is used as a screen.

The armour of single-core cables for use on a.c. systems shall consist of non-magnetic material, unless a special construction is chosen.

13.3 Application of armour

13.3.1 Single-core cables

In the case of single-core cables, an inner covering, extruded or lapped, of the thickness specified in 8.2.3 or 8.2.4, shall be applied under the armour if there is no screen.

13.3.2 Three-core cables

When an armour is required in the case of three-core cables, it shall be applied on an inner covering complying with 8.2.

13.3.3 Separation sheath

When the underlying metallic layer and the armour are of different materials, they shall be separated by an extruded sheath of one of the materials specified in 14.2.

When an armour is required for a lead-sheathed cable, it may be applied over a separation sheath or a lapped bedding according to 13.3.4.

If a separation sheath is used, it shall be applied under the armour instead of, or in addition to, the inner covering.

A separation sheath is not required when measures have been taken to achieve longitudinal watertightness in the region of the metallic layers.

The nominal thickness of the separation sheath T_s expressed in millimetres shall be calculated by the following formula:

$$T_s = 0,02 D_u + 0,6$$

where D_u is the fictitious diameter under this sheath, in millimetres, calculated as described in Annex A.

The value resulting from the formula shall be rounded off to the nearest 0,1 mm (see Annex C).

For cables without a lead sheath, the nominal thickness shall be not less than 1,2 mm. For cables where the separation sheath is applied directly over the lead sheath, the nominal thickness shall be not less than 1,0 mm.

13.3.4 Lapped bedding under armour for lead sheathed cables

The lapped bedding applied to the compound coated lead sheath shall consist of either impregnated and compounded paper tapes or a combination of two layers of impregnated and compounded paper tapes followed by one or more layers of compounded fibrous material.

The impregnation of bedding materials may be made with bituminous or other preservative compounds. In case of wire armour, these compounds shall not be applied directly under the wires.

Synthetic tapes may be applied instead of impregnated paper tapes.

The total thickness of the lapped bedding between the lead sheath and the armour after application of the armour shall have an approximate value of 1,5 mm.

13.4 Dimensions of the armour wires and armour tapes

The nominal dimensions of the armour wires and armour tapes shall preferably be one of the following values:

round wires:

0,8 – 1,25 – 1,6 – 2,0 – 2,5 – 3,15 mm diameter;

flat wires:

0,8 mm thickness;

tapes of steel:

0,2 – 0,5 – 0,8 mm thickness;

tapes of aluminium or aluminium alloy:

0,5 – 0,8 mm thickness.

13.5 Correlation between cable diameters and armour dimensions

The nominal diameters of round armour wires and the nominal thicknesses of the armour tapes shall be not less than the values given in Tables 9 and 10 respectively.

Table 9 – Nominal diameter of round armour wires

Fictitious diameter under the armour		Nominal diameter of armour wire mm
Above mm	Up to and including mm	
–	10	0,8
10	15	1,25
15	25	1,6
25	35	2,0
35	60	2,5
60	–	3,15

Table 10 – Nominal thickness of armour tapes

Fictitious diameter under the armour		Nominal thickness of tape	
Above mm	Up to and including mm	Steel or galvanized steel mm	Aluminium or aluminium alloy mm
–	30	0,2	0,5
30	70	0,5	0,5
70	–	0,8	0,8

For flat wire armour and fictitious diameters under armour greater than 15 mm, the nominal thickness of the flat steel wire shall be 0,8 mm. Cables with fictitious diameters under the armour up to and including 15 mm shall not be armoured with flat wires.

13.6 Round or flat wire armour

The wire armour shall be closed, i.e. with a minimum gap between adjacent wires. An open helix consisting of galvanized steel tape with a nominal thickness of at least 0,3 mm may be provided over flat steel wire armour and over round steel wire armour, if necessary. Tolerances on this steel tape shall comply with 17.7.3.

13.7 Double tape armour

When a tape armour and an inner covering as specified in 8.2 are used, the inner covering shall be reinforced by a taped bedding. The total thickness of the inner covering and the additional taped bedding shall be as given in 8.2 plus 0,5 mm if the armour tape thickness is 0,2 mm, and plus 0,8 mm if the armour tape thickness is more than 0,2 mm.

The total thickness of the inner covering and the additional taped bedding shall be not less than these values by more than 0,2 mm with a tolerance of +20 %.

If a separation sheath is required or if the inner covering is extruded and satisfies the requirements of 13.3.3, the additional taped bedding is not required.

The tape armour shall be applied helically in two layers so that the outer tape is approximately central over the gap of the inner tape. The gap between adjacent turns of each tape shall not exceed 50 % of the width of the tape.

14 Oversheath

14.1 General

All cables shall have an oversheath.

The oversheath is normally black, but a colour other than black may be provided by agreement between the manufacturer and the purchaser, subject to its suitability for the particular conditions under which the cable is to be used.

NOTE A UV stability test is under consideration.

14.2 Material

The oversheath shall consist of a thermoplastic compound (PVC or polyethylene) or an elastomeric compound (polychloroprene, chlorosulfonated polyethylene or similar polymers).

The oversheathing material shall be suitable for the operating temperature in accordance with Table 4.

Chemical additives may be necessary in the oversheath for special purposes, for example termite protection, but they should not include materials harmful to mankind and/or environment.

NOTE Examples of materials¹⁾ considered to be undesirable include:

- Aldrin: 1,2,3,4,10,10-hexachloro-1,4,4a,5,8,8a-hexahydro-1,4,5,8-dimethanonaphthalene
- Dieldrin: 1,2,3,4,10,10-hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8a-octahydro-1,4,5,8-dimethanonaphthalene
- Lindane: Gamma Isomer of 1,2,3,4,5,6-hexachloro-cyclohexane.

14.3 Thickness

Unless otherwise specified the nominal thickness t_s expressed in millimetres shall be calculated by the following formula:

$$t_s = 0,035 D + 1,0$$

¹⁾ Source: *Dangerous properties of industrial materials*, N.I. Sax, fifth edition, Van Nostrand Reinhold, ISBN 0-441-27078-9.

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

The value resulting from the formula shall be rounded off to the nearest 0,1 mm (see Annex C).

~~For unarmoured cables and cables with the oversheath not applied directly over the armour, metallic screen or concentric conductor, The nominal thickness shall be not less than 1,4 mm for single-core cables and 1,8 mm for three-core cables.~~

~~For cables with the oversheath applied directly over the armour, metallic screen or concentric conductor, the nominal thickness shall be not less than 1,8 mm.~~

The nominal thickness shall be not less than 1,4 mm for single-core cables and not less than 1,8 mm for multicore cables.

15 Test conditions

15.1 Ambient temperature

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

15.2 Frequency and waveform of power frequency test voltages

The frequency of the alternating test voltages shall be in the range 49 Hz to 61 Hz. The waveform shall be substantially sinusoidal. The values quoted are r.m.s. values.

15.3 Waveform of impulse test voltages

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, it shall be in accordance with IEC 60060-1.

15.4 Determination of the cable conductor temperature

It is recommended that one of the test methods described in Annex G is used to determine the actual temperature.

16 Routine tests

16.1 General

Routine tests are normally carried out on each manufactured length of cable (see 3.2.1). The number of lengths to be tested may however be reduced or an alternative test method adopted, according to agreed quality control procedures.

The routine tests required by this standard are as follows:

- a) measurement of the electrical resistance of conductors (see 16.2);
- b) partial discharge test (see 16.3) on cables having cores with conductor screens and insulation screens in accordance with 7.2 and 7.3;
- c) voltage test (see 16.4).
- d) electrical test on oversheath, if required (see 16.5).

16.2 Electrical resistance of conductors

Resistance measurements shall be made on all conductors of each cable length submitted to the routine tests, including the concentric conductor, if any.

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

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

The d.c. resistance of each conductor at 20 °C shall not exceed the appropriate maximum value specified in IEC 60228. For concentric conductors, the resistance shall comply with national regulations and/or standards.

16.3 Partial discharge test

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 better.

For three-core cables, the test shall be carried out on all insulated cores, the voltage being applied between each conductor and the screen.

The test voltage shall be raised gradually to and held at $2 U_0$ for 10 s and then slowly reduced to $1,73 U_0$.

There shall be no detectable discharge exceeding the declared sensitivity from the test object at $1,73 U_0$.

NOTE Any partial discharge from the test object may be harmful.

16.4 Voltage test

16.4.1 General

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

16.4.2 Test procedure for single-core cables

For single-core cables, the test voltage shall be applied for 5 min between the conductor and the metal screen.

16.4.3 Test procedure for three-core cables

For three-core cables with individually screened cores, the test voltage shall be applied for 5 min between each conductor and the metal layer.

For three-core cables without individually screened cores, the test voltage shall be applied for 5 min in succession between each insulated conductor and all the other conductors and collective metal layers.

Three-core cables may be tested in a single operation by using a three-phase transformer.

16.4.4 Test voltage

The power frequency test voltage shall be $3,5 U_0$. Values of the single-phase test voltage for the standard rated voltages are given in Table 11.

Table 11 – Routine test voltages

Rated voltage U_0	kV	3,6	6	8,7	12	18
Test voltage	kV	12,5	21	30,5	42	63

If, for three-core cables, the voltage test is carried out with a three-phase transformer, the test voltage between the phases shall be 1,73 times the values given in this table.

In all cases, the test voltage shall be increased gradually to the specified value.

16.4.5 Requirement

No breakdown of the insulation shall occur.

16.5 Electrical test on oversheath of the cable

If agreed between customer and supplier the cable shall be subjected to the electrical test specified in 3.2 of IEC 60229:2007.

Cables having an extruded semi-conductive layer on the oversheath shall be excluded and the d.c. voltage test specified in 3.1 of IEC 60229:2007 may be applied.

17 Sample tests

17.1 General

The sample tests required by this standard are as follows:

- conductor examination (see 17.4);
- check of dimensions (see 17.5 to 17.8);
- voltage test for cables of rated voltage above 3,6/6 (7,2) kV (see 17.9);
- hot set test for EPR, HEPR and XLPE insulations and elastomeric sheaths (see 17.10).

17.2 Frequency of sample tests

17.2.1 Conductor examination and check of dimensions

Conductor examination, measurement of the thickness of insulation and sheath and measurement of the overall diameter shall be made on one length from each manufacturing series of the same type and nominal cross-section of cable, but shall be limited to not more than 10 % of the number of lengths in any contract.

17.2.2 Electrical and physical tests

Electrical and physical tests shall be carried out on samples taken from manufactured cables according to agreed quality control procedures. In the absence of such an agreement, for contracts where the total length exceeds 2 km for three-core cables, or 4 km for single-core cables, tests shall be made on the basis of Table 12.

Table 12 – Number of samples for sample tests

Cable length				Number of samples
Multicore cables		Single-core cables		
Above km	Up to and including km	Above km	Up to and including km	
2	10	4	20	1
10	20	20	40	2
20	30	40	60	3
etc.		etc.		etc.

17.3 Repetition of tests

If any sample fails in any of the tests in Clause 17, two further samples shall be taken from the same batch and submitted to the same test or tests in which the original sample failed. If both additional samples pass the tests, all the cables in the batch from which they were taken shall be regarded as complying with the requirements of this standard. If either of the additional samples fails, the batch from which they were taken shall be regarded as failing to comply.

17.4 Conductor examination

Compliance with the requirements for conductor construction of IEC 60228 shall be checked by inspection and by measurement, when practicable.

17.5 Measurement of thickness of insulation and of non-metallic sheaths (including extruded separation sheaths, but excluding inner extruded coverings)

17.5.1 General

The test method shall be in accordance with ~~Clause 8 of IEC 60811-1-1~~ IEC 60811-201 and IEC 60811-202.

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

17.5.2 Requirements for the insulation

For each piece of core, the smallest value measured shall not fall below 90 % of the nominal value by more than 0,1 mm, i.e.:

$$t_{\min} \geq 0,9 t_n - 0,1$$

and additionally:

$$(t_{\max} - t_{\min}) / t_{\max} \leq 0,15$$

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.

17.5.3 Requirements for the non-metallic sheaths

~~The piece of sheath shall comply with the following:~~

- ~~a) for unarmoured cables and cables with an oversheath not applied directly over armour, metallic screen or concentric conductor, the smallest value measured shall not fall below 85 % of the nominal value by more than 0,1 mm, i.e.:~~

$$t_{\min} \geq 0,85 t_n - 0,1$$

- ~~b) for an oversheath applied directly over armour, metallic screen or concentric conductor and for a separation sheath, the smallest value measured shall not fall below 80 % of the nominal value by more than 0,2 mm, i.e.~~

If an extruded semi-conductive outer layer is used and it is fully bonded to the non-metal sheath, a thickness up to 0,3 mm of the semi-conductive layer can be accepted as a part of the sheath thickness. The sheath including the semi-conductive outer layer shall fulfil the same mechanical requirements as required for the sheath compound type specified, no matter how the dumbbell has been prepared.

The minimum thickness of the non-metal sheath shall not fall below 80 % of the nominal value by more than 0,2 mm, i.e.

$$t_{\min} \geq 0,8 t_n - 0,2$$

17.6 Measurement of thickness of lead sheath

17.6.1 General

The minimum thickness of the lead sheath shall be determined by one of the following methods, at the discretion of the manufacturer, and shall not fall below 95 % of the nominal thickness by more than 0,1 mm i.e.:

$$t_{\min} \geq 0,95 t_n - 0,1$$

NOTE Methods of measuring thickness of other types of metallic sheath are under consideration.

17.6.2 Strip method

The measurement shall be made with a micrometer with plane faces of 4 mm to 8 mm diameter and an accuracy of $\pm 0,01$ 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.

17.6.3 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 $\pm 0,01$ 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.

17.7 Measurement of armour wires and tapes

17.7.1 Measurement on wires

The diameter of round wires and the thickness of flat wires shall be measured by means of a micrometer having two flat noses to an accuracy of $\pm 0,01$ mm. For round wires, two measurements shall be made at right angles to each other at the same position and the average of the two values taken as the diameter.

17.7.2 Measurement on tapes

The measurement shall be made with a micrometer having two flat noses of approximately 5 mm in diameter to an accuracy of $\pm 0,01$ mm. For tapes up to 40 mm in width the thickness shall be measured at the centre of the width. For wider tapes the measurements shall be made 20 mm from each edge of the tape and the average of the results taken as the thickness.

17.7.3 Requirements

The dimensions of armour wires and tapes shall not fall below the nominal values given in 13.5 by more than:

- 5 % for round wires;
- 8 % for flat wires;
- 10 % for tapes.

17.8 Measurement of external diameter

If the measurement of the external diameter of the cable is required as a sample test, it shall be carried out in accordance with ~~Clause 8 of IEC 60811-1-1~~ IEC 60811-203.

17.9 Voltage test for 4 h

This test is applicable only to cables of rated voltage above 3,6/6 (7,2) kV.

17.9.1 Sampling

The sample shall be a piece of completed cable at least 5 m in length between the test terminations.

17.9.2 Procedure

A power frequency voltage shall be applied for 4 h at ambient temperature between each conductor and the metal ~~lie~~ layer(s).

17.9.3 Test voltages

The test voltage shall be $4 U_0$. Values of the test voltage for the standard rated voltages are given in Table 13.

Table 13 – Sample test voltages

Rated voltage U_0	kV	6	8,7	12	18
Test voltage	kV	24	35	48	72

The test voltage shall be increased gradually to the specified value and maintained for 4 h.

17.9.4 Requirements

No breakdown of the insulation shall occur.

17.10 Hot set test for EPR, HEPR and XLPE insulations and elastomeric sheaths

17.10.1 Procedure

The sampling and test procedure shall be carried out in accordance with ~~Clause 9 of IEC 60811-2-1~~ IEC 60811-507, employing the conditions given in Tables 19 and 23.

17.10.2 Requirements

The test results shall comply with the requirements given in Table 19, for EPR, HEPR and XLPE insulations and in Table 23 for SE₁ sheaths.

18 Type tests, electrical

18.1 General

When type tests have been successfully performed on a type of cable covered by this standard with a specific conductor cross-sectional area and rated voltage, type approval shall be accepted as valid for cables of the same type with other conductor cross-sectional areas and/or rated voltages, provided the following three conditions are all satisfied:

- a) the same materials, i.e. insulation and semi-conducting screens, and manufacturing process are used;
- b) the conductor cross-sectional area is not larger than that of the tested cable, with the exception that all cross-sectional areas up to and including 630 mm² are approved when the cross-sectional area of the previously tested cable is in the range of 95 mm² to 630 mm² inclusive;
- c) the rated voltage is not higher than that of the tested cable.

Approval shall be independent of the conductor material.

18.2 Cables having conductor screens and insulation screens

18.2.1 General

A sample of completed cable 10 m to 15 m in length shall be subjected to the tests listed in 18.2.2.

With the exception of the provisions of 18.2.3 all the tests listed in 18.2.2 shall be applied successively to the same sample.

In three-core cables, each test or measurement shall be carried out on all cores.

Measurement of resistivity of semi-conducting screens described in 18.2.10 shall be made on a separate sample.

18.2.2 Sequence of tests

The normal sequence of tests shall be as follows:

- a) bending test, followed by a partial discharge test (see 18.2.4 and 18.2.5);
- b) tan δ measurement (see 18.2.3 and 18.2.6);
- c) heating cycle test, followed by a partial discharge test (see 18.2.7);

- d) impulse test, followed by a voltage test (see 18.2.8);
- e) voltage test for 4 h (see 18.2.9).

18.2.3 Special provisions

Measurement of $\tan \delta$ may be carried out on a different sample from the sample used for the normal sequence of tests listed in 18.2.2.

Measurement of $\tan \delta$ is not required on cables with rated voltage below 6/10 (12) kV.

A new sample may be taken for test e), provided this test sample is submitted previously to tests a) and c) listed in 18.2.2.

18.2.4 Bending test

The sample shall be bent around a test cylinder (for example, the hub of a drum) at ambient temperature for at least one complete turn. It shall then be unwound and the process repeated, except that the bending of the sample shall be in the reverse direction without axial rotation.

This cycle of operation shall be carried out three times.

The diameter of the test cylinder shall **not be greater than**

- for cables with a lead sheath or with an overlapped metal foil longitudinally applied:
 - 25 ($d + D$) $\pm$ 5 % for single-core cables;
 - 20 ($d + D$) $\pm$ 5 % for three-core cables;
- for other cables:
 - 20 ($d + D$) $\pm$ 5 % for single-core cables;
 - 15 ($d + D$) $\pm$ 5 % for three-core cables.

where

D is the actual external diameter of the cable sample, in millimetres, measured according to 17.8;

d is the actual diameter of the conductor, in millimetres.

If the conductor is not circular:

$$d = 1,13\sqrt{S}$$

where S is the nominal cross-section, in square millimetres.

On completion of this test, the sample shall be subjected to a partial discharge test and shall comply with the requirements given in 18.2.5.

18.2.5 Partial discharge test

The partial discharge test shall be carried out in accordance with IEC 60885-3, the sensitivity being 5 pC or better.

The test voltage shall be raised gradually to and held at $2 U_0$ for 10 s and then slowly reduced to $1,73 U_0$.

There shall be no detectable discharge exceeding the declared sensitivity from the test object at $1,73 U_0$.

NOTE Any partial discharge from the test object may be harmful.

18.2.6 Tan δ measurement for cables of rated voltage 6/10 (12) kV and above

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

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

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

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

The measured values shall not be higher than those given in Table 15.

18.2.7 Heating cycle test

The sample, which has been subjected to the previous tests, shall be laid out on the floor of the test room and heated by passing a current through the conductor, until the conductor reaches a steady temperature 5°C K to 10°C K above the maximum conductor temperature in normal operation.

For three-core cables, the heating current shall be passed through all conductors.

The heating cycle shall be of at least 8 h duration. The conductor temperature shall be maintained within the stated temperature limits for at least 2 h of each heating period. This shall be followed by at least 3 h of natural cooling in air to a conductor temperature within 10 K of ambient temperature.

This cycle shall be carried out 20 times.

After the last cycle, the sample shall be subjected to a partial discharge test and shall comply with the requirements given in 18.2.5.

18.2.8 Impulse test followed by a voltage test

This test shall be performed on the sample at a conductor temperature 5°C K to 10°C K above the maximum conductor temperature in normal operation.

The impulse voltage shall be applied according to the procedure given in IEC 60230 and shall have a peak value as given in Table 14.

Table 14 – Impulse voltages

Rated voltage U_0/U (U_m)	kV	3,6/6 (7,2)	6/10 (12)	8,7/15 (17,5)	12/20 (24)	18/30 (36)
Test voltage (peak)	kV	60	75	95	125	170

Each core of the cable shall withstand without failure 10 positive and 10 negative voltage impulses.

After the impulse test, each core of the cable sample shall be subjected, at ambient temperature, to a power frequency voltage test for 15 min. The test voltage shall be as specified in Table 11. No breakdown of the insulation shall occur.

18.2.9 Voltage test for 4 h

This test shall be made at ambient temperature. A power frequency voltage shall be applied for 4 h to the sample between conductor(s) and screen(s).

The test voltage shall be $4 U_0$. The voltage shall be increased gradually to the specified value. No breakdown of the insulation shall occur.

18.2.10 Resistivity of semi-conducting screens

18.2.10.1 General

The resistivity of the extruded semi-conducting screens applied over the conductor and over the insulation shall be determined by measurements on test pieces taken from the core of a sample of cable as made and a sample of cable, which has been subjected to the ageing treatment to test the compatibility of component materials specified in 19.7.

18.2.10.2 Procedure

The test procedure shall be in accordance with Annex D.

The measurements shall be made at a temperature within $\pm 2^\circ\text{C}$ K of the maximum conductor temperature in normal operation.

18.2.10.3 Requirements

The resistivity, both before and after ageing, shall not exceed the following:

- conductor screen: $1\,000\ \Omega \times \text{m}$,
- insulation screen: $500\ \Omega \times \text{m}$.

18.3 Cables of rated voltage 3,6/6 (7,2) kV having unscreened insulation

18.3.1 General

Each core of a sample of completed cable 10 m to 15 m in length shall be subjected to the following tests, applied successively:

- a) insulation resistance measurement at ambient temperature (see 18.3.2);
- b) insulation resistance measurement at maximum conductor temperature in normal operation (see 18.3.3);
- c) voltage test for 4 h (see 18.3.4).

The cables shall also be subjected to an impulse test on a separate sample of completed cable, 10 m to 15 m in length (see 18.3.5).

18.3.2 Insulation resistance measurement at ambient temperature

18.3.2.1 Procedure

This test shall be made on the sample length before any other electrical test.

All outer coverings shall be removed and the cores shall be immersed in water at ambient temperature for at least 1 h before the test.

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

The measurement shall be made between each conductor and the water.

If requested, measurement may be confirmed at a temperature of $(20 \pm 1) ^\circ\text{C}$.

18.3.2.2 Calculations

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

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

where

ρ is the volume resistivity, in ohms $\times$ centimetres;

R is the measured insulation resistance, in ohms;

l is the length of the cable, in centimetres;

D is the outer diameter of the insulation, in millimetres;

d is the inner diameter of the insulation, in millimetres.

The "insulation resistance constant K_i " expressed in megohms $\times$ kilometres may also be calculated, using the formula:

$$K_i = \frac{l \times R \times 10^{-11}}{\lg \frac{D}{d}} = 10^{-11} \times 0,367 \times \rho$$

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

18.3.2.3 Requirements

The values calculated from the measurements shall be not less than those specified in Table 15.

18.3.3 Insulation resistance measurement at maximum conductor temperature

18.3.3.1 Procedure

The cores of the cable sample shall be immersed in water at a temperature within $\pm 2^\circ\text{C}$ K of the maximum conductor temperature in normal operation for at least 1 h before the test.

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

The measurement shall be made between each conductor and the water.

18.3.3.2 Calculations

The volume resistivity and/or the insulation resistance constant shall be calculated from the insulation resistance by the formulae given in 18.3.2.2.

18.3.3.3 Requirements

The values calculated from the measurements shall be not less than those specified in Table 15.

18.3.4 Voltage test for 4 h

18.3.4.1 Procedure

The cores of the cable sample shall be immersed in water at ambient temperature for at least 1 h.

A power frequency voltage equal to $4 U_0$ shall then be gradually applied and maintained continuously for 4 h between each conductor and the water.

18.3.4.2 Requirements

No breakdown of the insulation shall occur.

18.3.5 Impulse test

18.3.5.1 Procedure

This test shall be performed on the sample at a conductor temperature 5°C K to 10°C K above the maximum conductor temperature in normal operation.

The impulse voltage shall be applied according to the procedure given in IEC 60230 and shall have a peak value of 60 kV.

Each series of impulses shall be applied in turn between each phase conductor and all the other conductors connected together and to earth.

18.3.5.2 Requirements

Each core of the cable shall withstand without failure 10 positive and 10 negative voltage impulses.

19 Type tests, non-electrical

19.1 General

The non-electrical type tests required by this standard are given in Table 16.

19.2 Measurement of thickness of insulation

19.2.1 Sampling

One sample shall be taken from each insulated cable core.

19.2.2 Procedure

The measurements shall be made as described in ~~8.1 of IEC 60811-1-1~~ IEC 60811-201.

19.2.3 Requirements

See 17.5.2.

19.3 Measurement of thickness of non-metallic sheaths (including extruded separation sheaths, but excluding inner coverings)

19.3.1 Sampling

One sample of cable shall be taken.

19.3.2 Procedure

The measurements shall be made as described in ~~8.2 of IEC 60811-1-1~~ IEC 60811-202.

19.3.3 Requirements

See 17.5.3.

19.4 Measurement of thickness of lead sheath

19.4.1 Sampling

One sample of cable shall be taken.

19.4.2 Procedure

The measurements shall be made as described in 17.6.2 or 17.6.3.

19.4.3 Requirements

See 17.6.1.

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

19.5.1 Sampling

Sampling and the preparation of the test pieces shall be carried out as described in ~~9.1 of IEC 60811-1-1~~ IEC 60811-501.

19.5.2 Ageing treatments

The ageing treatments shall be carried out as described in ~~8.1 of IEC 60811-1-2401~~ under the conditions specified in Table 17.

19.5.3 Conditioning and mechanical tests

Conditioning and the measurement of mechanical properties shall be carried out as described in ~~9.1 of IEC 60811-1-1~~ IEC 60811-501.

19.5.4 Requirements

The test results for unaged and aged test pieces shall comply with the requirements given in Table 17.

19.6 Tests for determining the mechanical properties of non-metallic sheaths before and after ageing

19.6.1 Sampling

Sampling and the preparation of the test pieces shall be carried out as described in ~~9.2 of IEC 60811-1-1~~ IEC 60811-501.

19.6.2 Ageing treatments

The ageing treatments shall be carried out as described in ~~8.1 of IEC 60811-1-2~~ IEC 60811-401, under the conditions specified in Table 20.

19.6.3 Conditioning and mechanical tests

Conditioning and the measurement of mechanical properties shall be carried out as described in ~~9.2 of IEC 60811-1-1~~ IEC 60811-501.

19.6.4 Requirements

The test results for unaged and aged test pieces shall comply with the requirements given in Table 20.

19.7 Additional ageing test on pieces of completed cables

19.7.1 General

This test is intended to check that the insulation and non-metallic sheaths are not liable to deteriorate in operation due to contact with other components in the cable.

The test is applicable to cables of all types.

19.7.2 Sampling

Samples shall be taken from the completed cable as described in ~~8.1.4 of IEC 60811-1-2~~ IEC 60811-401.

19.7.3 Ageing treatment

The ageing treatment of the pieces of cable shall be carried out in an air oven, as described in ~~8.1.4 of IEC 60811-1-2~~ IEC 60811-401, under the following conditions:

- temperature: $(10 \pm 2)^\circ\text{C}$ K above the maximum conductor temperature of the cable in normal operation (see Table 17);
- duration: 7×24 h.

19.7.4 Mechanical tests

Test pieces of insulation and oversheath from the aged pieces of cable shall be prepared and subjected to mechanical tests as described in ~~8.1.4 of IEC 60811-1-2~~ IEC 60811-401.

19.7.5 Requirements

The variations between the median values of tensile strength and elongation-at-break after ageing and the corresponding values obtained without ageing (see 19.5 and 19.6), if applicable, shall not exceed the values applying to the test after ageing in an air oven specified in Table 17 for insulations and Table 20 for non-metallic sheaths.

19.8 Loss of mass test on PVC sheaths of type ST₂

19.8.1 Procedure

The sampling and test procedure shall be in accordance with ~~8.2 of IEC 60811-3-2~~ IEC 60811-409.

19.8.2 Requirements

The test results shall comply with the requirements given in Table 21.

19.9 Pressure test at high temperature on insulations and non-metallic sheaths

19.9.1 Procedure

The pressure test at high temperature shall be carried out in accordance with ~~Clause 8 of IEC 60811-3-1~~ IEC 60811-508, employing the test conditions given in the test method and in Tables 18, 21 and 22.

19.9.2 Requirements

The test results shall comply with the requirements given in ~~Clause 8 of IEC 60811-3-1~~ IEC 60811-508.

19.10 Test on PVC insulation and sheaths at low temperatures

19.10.1 Procedure

The sampling and test procedures shall be in accordance with ~~Clause 8 of IEC 60811-1-4~~ IEC 60811-504, IEC 60811-505 and IEC 60811-506, employing the test temperature specified in Tables 18 and 21.

19.10.2 Requirements

The results of the test shall comply with the requirements given in ~~Clause 8 of IEC 60811-1-4~~ IEC 60811-504, IEC 60811-505 and IEC 60811-506.

19.11 Test for resistance of PVC insulation and sheaths to cracking (heat shock test)

19.11.1 Procedure

The sampling and test procedure shall be in accordance with ~~Clause 9 of IEC 60811-3-1~~ IEC 60811-509, the test temperature and duration being in accordance with Tables 18 and 21.

19.11.2 Requirements

The results of the tests shall comply with the requirements given in ~~Clause 9 of IEC 60811-3-1~~ IEC 60811-509.

19.12 Ozone resistance test for EPR and HEPR insulations

19.12.1 Procedure

The sampling and test procedure shall be carried out in accordance with ~~Clause 8 of IEC 60811-2-1~~ IEC 60811-403. The ozone concentration and test duration shall be in accordance with Table 19.

19.12.2 Requirements

The results of the test shall comply with the requirements given in ~~Clause 8 of IEC 60811-2-1~~ IEC 60811-403.

19.13 Hot set test for EPR, HEPR and XLPE insulations and elastomeric sheaths

The sampling and test procedure shall be carried out in accordance with 17.10 and shall comply with its requirements.

19.14 Oil immersion test for elastomeric sheaths

19.14.1 Procedure

The sampling and test procedure shall be carried out in accordance with ~~Clause 10 of IEC 60811-2-1~~ IEC 60811-404 employing the conditions given in Table 23.

19.14.2 Requirements

The results of the test shall comply with the requirements given in Table 23.

19.15 Water absorption test on insulation

19.15.1 Procedure

The sampling and test procedure shall be carried out in accordance with ~~9.1 or 9.2 of IEC 60811-1-3~~ IEC 60811-402 employing the conditions specified in Tables 18 or 19 respectively.

19.15.2 Requirements

The results of the test shall comply with the requirements specified in Tables 18 or 19.

19.16 Flame spread test on single cables

This test is only applicable to cables having sheaths of ST₁, ST₂ or SE₁ compound and shall be carried out on such cables only when specially required.

The test method and requirements shall be those specified in IEC 60332-1-2.

19.17 Measurement of carbon black content of black PE oversheaths

19.17.1 Procedure

The sampling and test procedure shall be carried out in accordance with ~~Clause 11 of IEC 60811-4-1~~ IEC 60811-605.

19.17.2 Requirements

The results of the test shall comply with the requirements of Table 22.

19.18 Shrinkage test for XLPE insulation

19.18.1 Procedure

The sampling and test procedure shall be carried out in accordance with ~~Clause 10 of IEC 60811-1-3~~ IEC 60811-502 under the conditions specified in Table 19.

19.18.2 Requirements

The results of the test shall comply with the requirements of Table 19.

19.19 Thermal stability test for PVC insulation

19.19.1 Procedure

The sampling and test procedure shall be carried out in accordance with ~~Clause 9 of IEC 60811-3-2~~ IEC 60811-405 under the conditions specified in Table 18.

19.19.2 Requirements

The results of the test shall comply with the requirements of Table 18.

19.20 Determination of hardness of HEPR insulation

19.20.1 Procedure

The sampling and test procedure shall be carried out in accordance with Annex E.

19.20.2 Requirements

The results of the test shall comply with the requirements of Table 19.

19.21 Determination of the elastic modulus of HEPR insulation

19.21.1 Procedure

Sampling, preparation of the test pieces and the test procedure shall be carried out in accordance with ~~Clause 9 of IEC 60811-1-1~~ IEC 60811-501.

The loads required for 150 % elongation shall be measured. The corresponding stresses shall be calculated by dividing the loads measured by the cross-sectional areas of the unstretched test pieces. The ratios of the stresses to strains shall be determined to obtain the elastic moduli at 150 % elongation.

The elastic modulus shall be the median value.

19.21.2 Requirements

The results of the test shall comply with the requirements of Table 19.

19.22 Shrinkage test for PE oversheaths

19.22.1 Procedure

The sampling and test procedure shall be carried out in accordance with ~~Clause 11 of IEC 60811-1-3~~ IEC 60811-503 under the conditions specified in Table 22.

19.22.2 Requirements

The results of the test shall comply with the requirements of Table 22.

19.23 Strippability test for insulation screen

19.23.1 General

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

19.23.2 Procedure

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

Core lengths of at least 250 mm shall be taken from the cable to be tested, before and after being aged according to 19.7.3.

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

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

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

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

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

19.23.3 Requirements

The force required to remove the extruded semiconducting screen from the insulation shall be not less than 4 N and not more than 45 N, before and after ageing.

The insulation surface shall not be damaged and no trace of the semiconducting screen shall remain on the insulation.

19.24 Water penetration test

The water penetration test shall be applied to those designs of cable where the manufacturer claims that barriers to longitudinal water penetration have been included. The test is designed to meet the requirements for buried cables and is not intended to apply to cables which are constructed for use as submarine cables.

The test is applicable to the following cable designs:

- a) a barrier is included which prevents longitudinal water penetration in the region of the metal~~lic~~ layers;
- b) a barrier is included which prevents longitudinal water penetration along the conductor.

The apparatus, sampling and test procedure shall be in accordance with Annex F.

20 Electrical tests after installation

20.1 General

Tests after installation are carried out when the installation of the cable and its accessories has been completed.

A d.c. oversheath test according to 20.2 is recommended and, if required, a test on the insulation according to 20.3. For installations where only the oversheath test according to 20.2 is carried out, quality assurance procedures during installation of accessories may, by agreement between the purchaser and the contractor, replace the insulation test.

20.2 DC voltage test of the oversheath

The voltage level and duration specified in Clause 5 of IEC 60229:2007 shall be applied between each metal sheath or metal~~lic~~ screen and the ground.

For the test to be effective, it is necessary that the ground makes good contact with all of the outer surface of the oversheath. A conductive layer on the oversheath can assist in this respect.

20.3 Insulation test

20.3.1 AC testing

By agreement between the purchaser and the contractor, an a.c. voltage test ~~at power frequency in accordance with IEC 60060-3 and~~ in accordance with item a), b) or c) as below may be used:

- a) test for ~~5~~ 15 min with the phase-to-phase voltage ~~of the system U , at a frequency between 20 Hz to 300 Hz shall be~~ applied between the conductor and the metallic screen/sheath;
- b) test for 24 h with the normal ~~operating rated~~ voltage U_0 of the system.
- c) test for 15 min with the RMS rated voltage value of 3 U_0 at a frequency of 0,1 Hz applied between the conductor and the metal screen/sheath.

NOTE 1 During the a.c. test, $\tan \delta$ and/or partial discharge may be monitored.

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

20.3.2 DC testing

As an alternative to the a.c. test, a d.c. test voltage equal to 4 U_0 may be applied for 15 min.

~~NOTE 1 A d.c. test may endanger the insulation system under test. Other test methods are under consideration. Where possible an a.c. test as described above should be used.~~

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

Table 15 – Electrical type test requirements for insulating compounds

Designation of compounds (see 4.2)		PVC/B	EPR/ HEPR	XLPE
Maximum conductor temperature in normal operation (see 4.2)	°C	70	90	90
Volume resistivity ρ *				
– at 20 °C (see 18.3.2)	$\Omega \times \text{cm}$	10^{14}	–	–
– at maximum conductor temperature in normal operation (see 18.3.3)	$\Omega \times \text{cm}$	10^{11}	10^{12}	–
Insulation resistance constant K_i *				
– at 20 °C (see 18.3.2)	$\text{M}\Omega \times \text{km}$	367	–	–
– at maximum conductor temperature in normal operation (see 18.3.3)	$\text{M}\Omega \times \text{km}$	0,37	3,67	–
Tan δ (see 18.2.6)				
– tan δ at maximum conductor temperature in normal operation plus 5 °C K up to 10 °C K, maximum	$\times 10^{-4}$	–	400	40
* For unscreened cables according to items a) and b) of Clause 7, rated voltage 3,6/6 (7,2) kV for PVC, EPR and HEPR insulation.				

Table 16 – Non-electrical type tests
(see Tables 17 to 23)

Designation of compounds (see 4.2 and 4.3)	Insulations				Sheaths				
	PVC/B	EPR	HEPR	XLPE	PVC		PE		SE ₁
					ST ₁	ST ₂	ST ₃	ST ₇	
<i>Dimensions</i>									
Measurements of thicknesses	x	x	x	x	x	x	x	x	x
<i>Mechanical properties</i> (tensile strength and elongation at break)									
Without ageing	x	x	x	x	x	x	x	x	x
After ageing in air oven	x	x	x	x	x	x	x	x	x
After ageing of pieces of complete cable	x	x	x	x	x	x	x	x	x
After immersion in hot oil	–	–	–	–	–	–	–	–	x
<i>Thermoplastic properties</i>									
Hot pressure test (indentation)	x	–	–	–	x	x	–	x	–
Behaviour at low temperature	x	–	–	–	x	x	–	–	–
<i>Miscellaneous</i>									
Loss of mass in air oven	–	–	–	–	–	x	–	–	–
Heat shock test (cracking)	x	–	–	–	x	x	–	–	–
Ozone resistance test	–	x	x	–	–	–	–	–	–
Hot set test	–	x	x	x	–	–	–	–	x
Flame spread test on single cables (if required)	–	–	–	–	x	x	–	–	x
Water absorption	x	x	x	x	–	–	–	–	–
Thermal stability	x	–	–	–	–	–	–	–	–
Shrinkage test	–	–	–	x	–	–	x	x	–
Carbon black content *	–	–	–	–	–	–	x	x	–
Determination of hardness	–	–	x	–	–	–	–	–	–
Determination of elastic modulus	–	–	x	–	–	–	–	–	–
Strippability test **									
Water penetration test ***									
NOTE x indicates that the type test is to be applied.									
* For black oversheaths only.									
** To be applied to those designs of cable where the manufacturer claims that the insulation screen is strippable.									
*** To be applied to those designs of cable where the manufacturer claims that barriers to longitudinal water penetration have been included.									

Table 17 – Test requirements for mechanical characteristics of insulating compounds (before and after ageing)

Designation of compounds (see 4.2)		PVC/B	EPR	HEPR	XLPE
Maximum conductor temperature in normal operation (see 4.2)	°C	70	90	90	90
<i>Without ageing (~~IEC 60811-1-1, 9-1~~ IEC 60811-501)</i>					
Tensile strength, minimum	N/mm ²	12,5	4,2	8,5	12,5
Elongation-at-break, minimum	%	125	200	200	200
<i>After ageing in air oven (~~IEC 60811-1-2, 8-1~~ IEC 60811-401)</i>					
After ageing without conductor					
Treatment:					
– temperature	°C	100	135	135	135
– tolerance	~~°C~~ K	±2	±3	±3	±3
– duration	h	168	168	168	168
Tensile strength:					
a) value after ageing, minimum	N/mm ²	12,5	–	–	–
b) variation*, maximum	%	±25	±30	±30	±25
Elongation-at-break:					
a) value after ageing, minimum	%	125	–	–	–
b) variation*, maximum	%	±25	±30	±30	±25
* Variation: difference between the median value obtained after ageing and the median value obtained without ageing expressed as a percentage of the latter.					

**Table 18 – Test requirements for particular characteristics
for PVC insulating compound**

Designation of compound (see 4.2 and 4.3)		PVC/B
Use of the PVC compound		Insulation
<i>Pressure test at high temperature</i> (~~IEC 60811-3-1, Clause 8~~ IEC 60811-508) Temperature (tolerance $\pm 2^{\circ}\text{C K}$)	$^{\circ}\text{C}$	80
<i>Behaviour at low temperature *</i> (~~IEC 60811-1-4, Clause 8~~ IEC 60811-504, IEC 60811-505 and IEC 60811-506) Test to be carried out without previous ageing: – cold bending test for diameter <12,5 mm – temperature (tolerance $\pm 2^{\circ}\text{C K}$) Cold elongation test on dumb-bells: – temperature (tolerance $\pm 2^{\circ}\text{C K}$)	$^{\circ}\text{C}$ $^{\circ}\text{C}$	 –5 –5
<i>Heat shock test</i> (~~IEC 60811-3-1, Clause 9~~ IEC 60811-509) Temperature (tolerance $\pm 3^{\circ}\text{C K}$) Duration	$^{\circ}\text{C}$ h	150 1
<i>Thermal stability</i> (~~IEC 60811-3-2, Clause 9~~ IEC 60811-405) Temperature (tolerance $\pm 0,5^{\circ}\text{C K}$) Minimum time	$^{\circ}\text{C}$ min	200 100
<i>Water absorption</i> (~~IEC 60811-1-3, 9.1~~ IEC 60811-402) Electrical method: Temperature (tolerance $\pm 2^{\circ}\text{C K}$) Duration	$^{\circ}\text{C}$ h	 70 240
* Due to climatic conditions, national standards may require the use of a lower temperature.		