IEC 60502-2

Edition 3.0 2014-02
REDLINE VERSION

INTERNATIONAL STANDARD

colour inside

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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FOREWORD

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This redline version of the official IEC Standard allows the user to identify the changes made to the previous edition. A vertical bar appears in the margin wherever a change has been made. Additions are in green text, deletions are in strikethrough red text.

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– 'metallic' has been replaced by 'metal';
– 'thermosetting' has been replaced by 'crosslinked'.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

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- 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 metal~~lic~~ 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) *Thermoplastic*	
polyvinyl chloride intended for cables with rated voltages U_0/U = 3,6/6 kV	PVC/B*
b) ~~*Thermosetting*~~ *Crosslinked*:	
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 mm²	70	160
	Conductor cross-section >300 mm²	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) *Thermoplastic:*		
polyvinyl chloride (PVC)	ST_1	80
	ST_2	90
polyethylene	ST_3	80
	ST_7	90
b) *Elastomeric:*		
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 mm^2, 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 mm²	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 mm²	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 metal~~lic~~ 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-metal~~lic~~ 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-metal~~lic~~, semi-conducting layer in combination with a metal~~lic~~ layer.

The non-metal~~lic~~ 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 metal~~lic~~ 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 metal~~lic~~ 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 metal~~lic~~ 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 metal~~lic~~ layer, the inner covering shall be semi-conducting; the fillers may be semi-conducting.

8.4 Cables having a metal~~lic~~ layer over each individual core (see Clause 10)

The metal~~lic~~ layers of the individual cores shall be in contact with each other.

Cables with an additional collective metal~~lic~~ layer (see Clause 9) of the same material as the underlying individual metal~~lic~~ 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 metal~~lic~~ layers and the collective metal~~lic~~ 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 metal~~lic~~ layers may be obtained by an inner covering according to 8.2.

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

9 Metal~~lic~~ layers for single-core and three-core cables

The following types of metal~~lic~~ layers are included in this standard:

a) metal~~lic~~ screen (see Clause 10);

b) concentric conductor (see Clause 11);

c) metal~~lic~~ sheath (see Clause 12);

d) metal~~lic~~ armour (see Clause 13).

The metal~~lic~~ 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 metal~~lic~~ layers.

10 Metal~~lic~~ screen

10.1 Construction

The metal~~lic~~ 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 metal~~lic~~ screen shall be determined by national regulations and/or standards.

10.3 Metal~~lic~~ screens not associated with semi-conducting layers

Where metal~~lic~~ 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 Metallic 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:~~

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

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

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

~~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 metallic sheaths

Under consideration.

13 Metallic armour

13.1 Types of metallic 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 metal~~lic~~ 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 metal~~lic~~ 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 materials[1)] 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 0-442-27373-8.

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 ± 15) °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~~lic~~ 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~~lic~~ 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~~lic~~ 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:

a) conductor examination (see 17.4);
b) check of dimensions (see 17.5 to 17.8);
c) voltage test for cables of rated voltage above 3,6/6 (7,2) kV (see 17.9);
d) 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-metal~~lic~~ 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.

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

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 ±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 ±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 ±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 ± 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~~lic~~ 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 SE_1 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 mm^2 are approved when the cross-sectional area of the previously tested cable is in the range of 95 mm^2 to 630 mm^2 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 δ 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 δ 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 ($d + D$) ~~±~~+ 5 % for single-core cables;
  - 20 ($d + D$) ~~±~~+ 5 % for three-core cables;
- for other cables:
  - 20 ($d + D$) ~~±~~+ 5 % for single-core cables;
  - 15 ($d + D$) ~~±~~+ 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 metal~~lic~~ 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 ±2 ~~°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 Ω × m,

– insulation screen: 500 Ω × 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 ± 1) °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 × 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 × 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 ±2 ~~°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-metal~~lic~~ 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 ± 2) ~~°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-metal~~lic~~ sheaths.

19.8 Loss of mass test on PVC sheaths of type ST_2

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-metal~~lic~~ 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 ST_1, ST_2 or SE_1 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 metal~~lic~~ 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 δ 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)	Ω × cm	10^{14}	–	–
– at maximum conductor temperature in normal operation (see 18.3.3)	Ω × cm	10^{11}	10^{12}	–
Insulation resistance constant K_i *				
– at 20 °C (see 18.3.2)	MΩ × km	367	–	–
– at maximum conductor temperature in normal operation (see 18.3.3)	MΩ × 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	x 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**		
					ST_1	**ST_2**	**ST_3**	**ST_7**	**SE_1**
Dimensions									
Measurements of thicknesses	x	x	x	x	x	x	x	x	x
Mechanical properties									
(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
Thermoplastic properties									
Hot pressure test (indentation)	x	–	–	–	x	x	–	x	–
Behaviour at low temperature	x	–	–	–	x	x	–	–	–
Miscellaneous									
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**
Without ageing (~~IEC 60811-1-1, 9.1~~ IEC 60811-501)					
Tensile strength, minimum	N/mm2	12,5	4,2	8,5	12,5
Elongation-at-break, minimum	%	125	200	200	200
After ageing in air oven (~~IEC 60811-1-2, 8.1~~ IEC 60811-401)					
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/mm2	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**
Pressure test at high temperature (~~IEC 60811-3-1, Clause 8~~ IEC 60811-508)		
Temperature (tolerance ±2 ~~°C~~ K)	°C	80
Behaviour at low temperature * (~~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 ±2 ~~°C~~ K)	°C	–5
Cold elongation test on dumb-bells:		
– temperature (tolerance ±2 ~~°C~~ K)	°C	–5
Heat shock test (~~IEC 60811-3-1, Clause 9~~ IEC 60811-509)		
Temperature (tolerance ±3 ~~°C~~ K)	°C	150
Duration	h	1
Thermal stability (~~IEC 60811-3-2, Clause 9~~ IEC 60811-405)		
Temperature (tolerance ±0,5 ~~°C~~ K)	°C	200
Minimum time	min	100
Water absorption (~~IEC 60811-1-3, 9.1~~ IEC 60811-402)		
Electrical method:		
Temperature (tolerance ±2 ~~°C~~ K)	°C	70
Duration	h	240
* Due to climatic conditions, national standards may require the use of a lower temperature.		

Table 19 – Test requirements for particular characteristics of various ~~thermosetting~~ crosslinked insulating compounds

Designation of compounds (see 4.2)		**EPR**	**HEPR**	**XLPE**
Ozone resistance (~~IEC 60811-2-1, Clause 8~~ IEC 60811-403)				
Ozone concentration (by volume)	%	0,025 to 0,030	0,025 to 0,030	–
Test duration without cracks	h	24	24	–
Hot set test (~~IEC 60811-2-1, Clause 9~~ IEC 60811-507)				
Treatment:				
– air temperature (tolerance ±3 ~~°C~~ K) – time under load – mechanical stress	°C min N/cm²	250 15 20	250 15 20	200 15 20
Maximum elongation under load	%	175	175	175
Maximum permanent elongation after cooling	%	15	15	15
Water absorption (~~IEC 60811-1-3, 9.2~~ IEC 60811-402) Gravimetric method:				
Temperature (tolerance ±2 ~~°C~~ K)	°C	85	85	85
Duration	h	336	336	336
Maximum increase of mass	mg/cm²	5	5	1 *
Shrinkage test (~~IEC 60811-1-3, Clause 10~~ IEC 60811-502)				
Distance *L* between marks	mm	–	–	200
Temperature (tolerance ±3 ~~°C~~ K)	°C	–	–	130
Duration	h	–	–	1
Maximum shrinkage	%	–	–	4
Determination of hardness (see Annex E)				
IRHD **, minimum		–	80	–
Determination of elastic modulus (see 19.21)				
Modulus at 150 % elongation, minimum	N/mm²	–	4,5	–

* An increase greater than 1 mg/cm² is being considered for densities of XLPE greater than 1 g/cm³.

** IRHD: international rubber hardness degree.

Table 20 – Test requirements for mechanical characteristics of sheathing compounds (before and after ageing)

Designation of compounds (see 4.3)		**ST_1**	**ST_2**	**ST_3**	**ST_7**	**SE_1**
Maximum conductor temperature in normal operation (see 4.3)	°C	**80**	**90**	**80**	**90**	**85**
Without ageing (~~IEC 60811-1-1, 9.2~~ IEC 60811-501)						
Tensile strength, minimum	N/mm²	12,5	12,5	10,0	12,5	10,0
Elongation-at-break, minimum	%	150	150	300	300	300
After ageing in air oven (~~IEC 60811-1-2, 8.1~~ IEC 60811-401)						
Treatment:						
– temperature (tolerance ±2 ~~°C~~ K) – duration	°C h	100 168	100 168	100 240	110 240	100 168
Tensile strength:						
a) value after ageing, minimum b) variation *, maximum	N/mm² %	12,5 ±25	12,5 ±25	– –	– –	– ±30
Elongation-at-break: a) value after ageing, minimum b) variation *, maximum	 % %	 150 ±25	 150 ±25	 300 –	 300 –	 250 ±40

* Variation: difference between the median value obtained after ageing and the median value obtained without ageing expressed as a percentage of the latter.

Table 21 – Test requirements for particular characteristics for PVC sheathing compounds

Designation of compound (see 4.2 and 4.3)		**ST$_1$**	**ST$_2$**
Use of the PVC compound		**Sheath**	
Loss of mass in air oven (~~IEC 60811-3-2, 8.2~~ IEC 60811-409)			
Treatment:			
– temperature (tolerance ±2 ~~°C~~ K) – duration	°C h	– –	100 168
Maximum loss of mass	mg/cm^2	–	1,5
Pressure test at high temperature (~~IEC 60811-3-1, Clause 8~~ IEC 60811-508)			
Temperature (tolerance ±2 ~~°C~~ K)	°C	80	90
Behaviour at low temperature * (~~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 ±2 ~~°C~~ K)	°C	–15	–15
Cold elongation test on dumb-bells:			
– temperature (tolerance ±2 ~~°C~~ K)	°C	–15	–15
Cold impact test:			
– temperature (tolerance ±2 ~~°C~~ K)	°C	–15	–15
Heat shock test (~~IEC 60811-3-1, Clause 9~~ IEC 60811-509)			
Temperature (tolerance ±3 ~~°C~~ K)	°C	150	150
Duration	h	1	1

* Due to climatic conditions, national standards may require the use of a lower temperature.

Table 22 – Test requirements for particular characteristics of PE (thermoplastic polyethylene) sheathing compounds

Designation of compounds (see 4.3)		**ST$_3$**	**ST$_7$**
Density * (~~IEC 60811-1-3, Clause 8~~ IEC 60811-606)			
Carbon black content (for black oversheaths only) (~~IEC 60811-4-1, Clause 11~~ IEC 60811-605)			
Nominal value	%	2,5	2,5
Tolerance	%	±0,5	±0,5
Shrinkage test (~~IEC 60811-1-3, Clause 11~~ IEC 60811-503)			
Temperature (tolerance ±2 ~~°C~~ K)	°C	80	80
Heating, duration	h	5	5
Heating cycles		5	5
Maximum shrinkage	%	3	3
Pressure test at high temperature (~~IEC 60811-3-1, 8.2~~ IEC 60811-508)			
Temperature (tolerance ±2 ~~°C~~ K)	°C	–	110

* The measurement of density is only required for the purpose of other tests.

Table 23 – Test requirements for particular characteristics of elastomeric sheathing compound

Designation of compound (see 4.3)		**SE_1**
Oil immersion test followed by a determination of the mechanical properties (~~IEC 60811-2-1, Clause 10 and IEC 60811-1-1, Clause 9~~ IEC 60811-404 and IEC 60811-501)		
Treatment:		
– oil temperature (tolerance ±2 ~~°C~~ K)	°C	100
– duration	h	24
Maximum variation * of:		
a) tensile strength	%	±40
b) elongation-at-break	%	±40
Hot set test (~~IEC 60811-2-1, Clause 9~~ IEC 60811-507)		
Treatment:		
– temperature (tolerance ±3 ~~°C~~ K)	°C	200
– time under load	min	15
– mechanical stress	N/cm^2	20
Maximum elongation under load	%	175
Maximum permanent elongation after cooling	%	15

* Variation: difference between the median value obtained after treatment and the median value without treatment, expressed as a percentage of the latter.

Annex A
(normative)

Fictitious calculation method for determination of dimensions of protective coverings

A.1 General

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

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

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

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

~~A.1 General~~

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

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

Holding strips, for example counter helix over armour, if not thicker than 0,3 mm, are neglected in this calculation method.

A.2 Method

A.2.1 Conductors

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

Table A.1 – Fictitious diameter of conductor

Nominal cross-section of conductor mm²	d_L mm	Nominal cross-section of conductor mm²	d_L mm
10	3,6	240	17,5
16	4,5	300	19,5
25	5,6	400	22,6
35	6,7	500	25,2
50	8,0	630	28,3
70	9,4	800	31,9
95	11,0	1 000	35,7
120	12,4	1 200	39,1
150	13,8	1 400	42,2
185	15,3	1 600	45,1

A.2.2 Cores

The fictitious diameter D_c of any core is given by:

a) for cables having cores without semi-conducting layers:

$$D_c = d_L + 2\,t_i$$

b) for cables having cores with semi-conducting layers:

$$D_c = d_L + 2\,t_i + 3{,}0$$

where t_i is the nominal thickness of insulation, in millimetres (see Tables 5 to 7).

If a metal~~lic~~ screen or a concentric conductor is applied, a further addition shall be made in accordance with A.2.5.

A.2.3 Diameter over laid-up cores

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

$$D_f = kD_c$$

where the assembly coefficient k is 2,16 for a three-core cable.

A.2.4 Inner coverings

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

$$D_B = D_f + 2\,t_B$$

where

t_B = 0,4 mm for fictitious diameters over laid-up cores (D_f) up to and including 40 mm;

t_B = 0,6 mm for D_f exceeding 40 mm.

These fictitious values for t_B apply to

a) three-core cables:
   - whether an inner covering is applied or not;
   - whether the inner covering is extruded or lapped;

   unless a separation sheath complying with 13.3.3 is used in place of or in addition to the inner covering, when A.2.7 applies instead;

b) single-core cables:
   - when an inner covering is applied whether it is extruded or lapped.

A.2.5 Concentric conductors and metal~~lic~~ screens

The increase in diameter due to the concentric conductor or metal~~lic~~ screen is given in Table A.2.

Table A.2 – Increase of diameter for concentric conductors and metal~~lic~~ screens

Nominal cross-section of concentric conductor or metal~~lic~~ screen mm²	Increase in diameter mm	Nominal cross-section of concentric conductor or metal~~lic~~ screen mm²	Increase in diameter mm
1,5	0,5	50	1,7
2,5	0,5	70	2,0
4	0,5	95	2,4
6	0,6	120	2,7
10	0,8	150	3,0
16	1,1	185	4,0
25	1,2	240	5,0
35	1,4	300	6,0

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

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

a) tape screen

$$\text{cross-sectional area} = n_t \times t_t \times w_t$$

where

n_t is the number of tapes;

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

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

Where the total thickness of the screen is less than 0,15 mm then the increase in diameter shall be zero:

- for a lapped tape screen made of either two tapes or one tape with overlap, the total thickness is twice the thickness of one tape;

– for a longitudinally applied tape screen:
  - if the overlap is below 30 %, the total thickness is the thickness of the tape;
  - if the overlap is greater than or equal to 30 %, the total thickness is twice the thickness of the tape.

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

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

where

n_w is the number of wires;

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

n_h is the number of a counter helix;

t_h is the thickness of a counter helix, in millimetres, if greater than 0,3 mm;

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

A.2.6 Lead sheath

The fictitious diameter over the lead sheath (D_{pb}) is given by:

$$D_{pb} = D_g + 2\, t_{pb}$$

where

D_g is the fictitious diameter under the lead sheath, in millimetres;

t_{pb} is the thickness calculated in accordance with 12.1, in millimetres.

A.2.7 Separation sheath

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

$$D_s = D_u + 2\, t_s$$

where

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

t_s is the thickness calculated in accordance with 13.3.3, in millimetres.

A.2.8 Lapped bedding

The fictitious diameter over the lapped bedding (D_{lb}) is given by:

$$D_{lb} = D_{ulb} + 2\, t_{lb}$$

where

D_{ulb} is the fictitious diameter under the lapped bedding, in millimetres;

t_{lb} is the thickness of lapped bedding, i.e. 1,5 mm according to 13.3.4.

A.2.9 Additional bedding for tape-armoured cables (provided over the inner covering)

Table A.3 – Increase of diameter for additional bedding

Fictitious diameter under the addition bedding		Increase in diameter for additional bedding
Above mm	**Up to and including** mm	mm
–	29	1,0
29	–	1,6

A.2.10 Armour

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

a) flat or round wire armour by:

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

where

D_A is the diameter under the armour, in millimetres;

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

t_w is the thickness of the counter helix, if any, in millimetres, if greater than 0,3 mm.

b) for double-tape armour by:

$$D_x = D_A + 4\,t_A$$

where

D_A is the diameter under the armour, in millimetres;

t_A is the thickness of the armour tape, in millimetres.

Annex B
(informative)

Tabulated continuous current ratings for cables having extruded insulation and a rated voltage from 3,6/6 kV up to 18/30 kV

B.1 General

This annex deals solely with the steady-state continuous current ratings of single-core and three-core cables having extruded insulation. The tabulated current ratings provided in this annex have been calculated for cables having a rated voltage of 6/10 kV and constructions as detailed in Clause B.2.

These ratings can be applied to cables of similar constructions in the voltage range of 3,6/6 kV to 18/30 kV.

Some parameters such as screen cross-sectional area and oversheath thickness have an influence on the rating of large cables. In addition, the method of screen bonding has to be taken into account in the rating of single-core cables.

The tabulated current ratings have been calculated using the methods set out in the IEC 60287 series.

~~NOTE 1~~ For cyclic current ratings, see the IEC 60853 series.

~~NOTE 2~~ For short-circuit temperature limits, see the IEC 60986 series.

B.2 Cable constructions

The cable constructions and dimensions for which current ratings have been tabulated are based on those given in this standard. The constructions and dimensions used are not related to specific national designs but reflect different model cables. Armoured three-core cables are assumed to have flat wire armour and single-core cables are assumed to be unarmoured. All the cables have copper tape core screens except the single-core XLPE insulated cable, which has a copper wire screen. The nominal cross-sectional areas of the screens for the model cables is given in Table B.1.

Table B.1 – Nominal screen cross-sectional areas

Nominal area of conductor, mm²	16	25	35	50	70	95	120	150	185	240	300	400
Nominal cross-sectional area of screen, per core, mm²												
EPR insulated cable	3	3	4	4	4	5	5	5	6	6	7	8
XLPE insulated cable	16	16	16	16	16	16	16	25	25	25	25	35

The oversheath is taken to be polyethylene for the single core cables and PVC for the three-core cables.

B.3 Temperatures

The maximum conductor temperature for which the tabulated cable ratings have been calculated is 90 °C.

The reference ambient temperatures assumed are as follows:

– for cables in air: 30 °C

– for buried cables, either directly in the soil or in ducts in the ground: 20 °C

Correction factors for other ambient temperatures are given in Tables B.10 and B.11.

The current ratings for cables in air do not take account of the increase, if any, due to solar or other infra-red radiation. Where the cables are subject to such radiation, the current rating should be derived by the methods specified in the IEC 60287 series.

B.4 Soil thermal resistivity

The tabulated current ratings for cables in ducts or direct in the ground relate to a soil thermal resistivity of 1,5 K·m/W. Information on the likely soil thermal resistivity in various countries is given in IEC 60287-3-1. Correction factors for other values of thermal resistivity are given in Tables B.14 to B.17.

It is assumed that the soil properties are uniform, no allowance has been made for the possibility of moisture migration which can lead to a region of high thermal resistivity around the cable. If partial drying-out of the soil is foreseen, the permissible current rating should be derived by the methods specified in the IEC 60287 series.

B.5 Methods of installation

B.5.1 General

Current ratings are tabulated for cables installed in the following conditions.

B.5.2 Single-core cables in air

The cables are assumed to be spaced at least 0,5 times the cable diameter from any vertical surface and installed on brackets or ladder racks as follows:

a) three cables in trefoil formation touching throughout their length;

b) three cables in horizontal flat formation touching throughout their length;

c) three cables in horizontal flat formation with a clearance of one cable diameter.

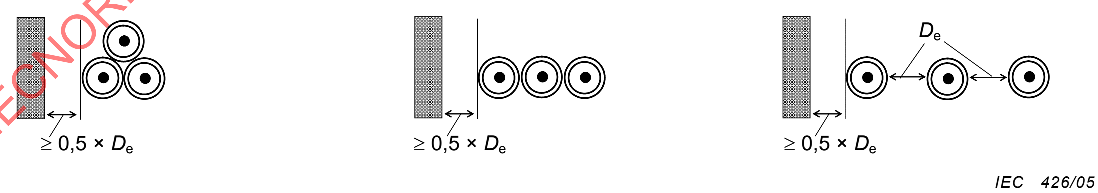


Figure B.1a Figure B.1b Figure B.1c

Key

D_e external diameter of the cable.

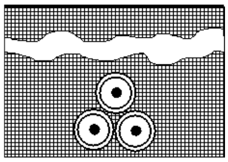
Figure B.1 – Single-core cables in air

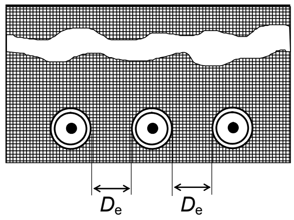
B.5.3 Single-core cables buried direct

Current ratings are given for cables buried direct in the ground at a depth of 0,8 m under the following conditions:

a) three cables in trefoil formation touching throughout their length;

b) three cables in horizontal flat formation with a clearance of one cable diameter, D_e.





IEC 427/05

Figure B.2a

Figure B.2b

Figure B.2 – Single-core cables buried direct

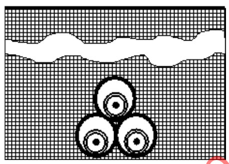
The cable depth is measured to the cable axis or centre of the trefoil group.

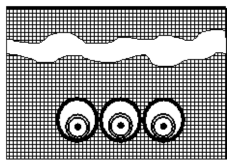
B.5.4 Single-core cables in earthenware ducts

Current ratings are given for cables in earthenware ducts buried at a depth of 0,8 m with one cable per duct as follows:

a) three cables in trefoil ducts touching throughout their length;

b) three cables in horizontal flat formation, ducts touching throughout their length.





IEC 428/05

Figure B.3a

Figure B.3b

Figure B.3 – Single-core cables in earthenware ducts

The ducts are assumed to be earthenware having an inside diameter of 1,5 times the outside diameter of the cable and a wall thickness equal to 6 % of the duct inside diameter. The ratings are based on the assumption that the ducts are air filled. If the ducts have been filled with a material such as Bentonite, then it is usual to adopt the current ratings for cables buried direct.

The tabulated ratings may be applied to cables in ducts having an inside diameter of between 1,2 and 2 times the outside diameter of the cables. For this range of diameters the variation in the rating is less than 2 % of the tabulated value.

B.5.5 Three-core cables

Current ratings are given for three-core cables installed under the following conditions:

a) single cable in air spaced at least 0,3 times the cable diameter from any vertical surface;

b) single cable buried direct in the ground at a depth of 0,8 m;

c) single cable in a buried earthenware duct having dimensions calculated in the same manner as for the single-core cables in ducts. The depth of burial of the duct is 0,8 m.

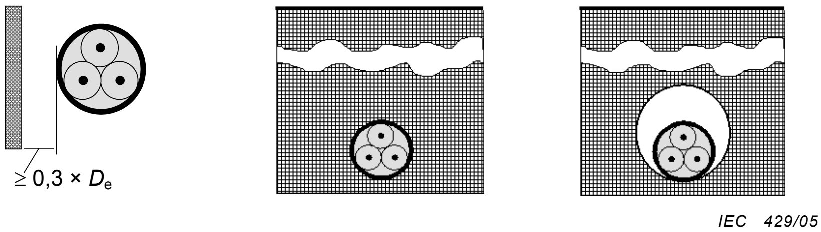


Figure B.4a Figure B.4b Figure B.4c

Figure B.4 – Three-core cables

B.6 Screen bonding

All the tabulated ratings for single-core cables assume that the cable screens are solidly bonded, i.e. bonded at both ends of the cables.

B.7 Cable loading

The tabulated ratings relate to circuits carrying a balanced three-phase load at a rated frequency of 50 Hz.

B.8 Rating factors for grouped circuits

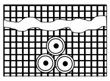
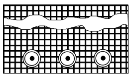
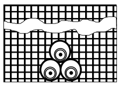
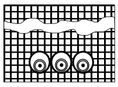
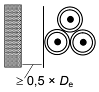
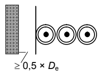
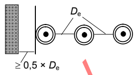
The tabulated current ratings apply to a set of three single-core cables or one three-core cable forming a three-phase circuit. When a number of circuits are installed in close proximity the rating should be reduced by the appropriate factor from Tables B.18 to B.23.

These rating factors should also be applied to groups of parallel cables forming the same circuit. In such cases, attention should also be given to the arrangement of the cables to ensure that the load current is shared equally between the parallel cables.

B.9 Correction factors

The correction factors given in Tables B.10 to B.23 for temperature, installation conditions and grouping are averages over a range of conductor sizes and cable types. For particular cases, the correction factor may be calculated using the methods in IEC 60287-2-1.

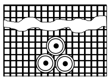
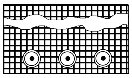
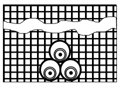
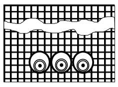
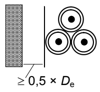
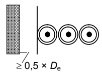
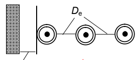
Table B.2 – Current ratings for single-core cables with XLPE insulation – Rated voltage 3,6/6 kV to 18/30 kV * – Copper conductor

Nominal area of conductor	Buried direct in the ground		In single-way ducts		In air		
	Trefoil	Flat spaced	Trefoil ducts	Flat touching ducts	Trefoil	Flat touching	Flat spaced
							
mm^2	A	A	A	A	A	A	A
16	109	113	103	104	125	128	150
25	140	144	132	133	163	167	196
35	166	172	157	159	198	203	238
50	196	203	186	188	238	243	286
70	239	246	227	229	296	303	356
95	285	293	271	274	361	369	434
120	323	332	308	311	417	426	500
150	361	366	343	347	473	481	559
185	406	410	387	391	543	550	637
240	469	470	447	453	641	647	745
300	526	524	504	510	735	739	846
400	590	572	564	571	845	837	938

Maximum conductor temperature	90 °C
Ambient air temperature	30 °C
Ground temperature	20 °C
Depth of laying	0,8 m
Thermal resistivity of soil	1,5 K·m/W
Thermal resistivity of earthenware ducts	1,2 K·m/W
Screens bonded at both ends.	

* Current rating calculated for cables having a rated voltage of 6/10 kV.

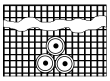
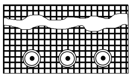
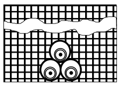
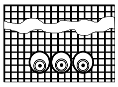
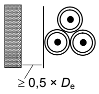
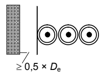
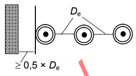
Table B.3 – Current ratings for single-core cables with XLPE insulation – Rated voltage 3,6/6 kV to 18/30 kV * – Aluminium conductor

Nominal area of conductor	Buried direct in the ground		In single-way ducts		In air		
	Trefoil	Flat spaced	Trefoil ducts	Flat touching ducts	Trefoil	Flat touching	Flat spaced
							
mm²	A	A	A	A	A	A	A
16	84	88	80	81	97	99	116
25	108	112	102	103	127	130	153
35	129	134	122	123	154	157	185
50	152	157	144	146	184	189	222
70	186	192	176	178	230	236	278
95	221	229	210	213	280	287	338
120	252	260	240	242	324	332	391
150	281	288	267	271	368	376	440
185	317	324	303	307	424	432	504
240	367	373	351	356	502	511	593
300	414	419	397	402	577	586	677
400	470	466	451	457	673	676	769

Maximum conductor temperature	90 °C
Ambient air temperature	30 °C
Ground temperature	20 °C
Depth of laying	0,8 m
Thermal resistivity of soil	1,5 K·m/W
Thermal resistivity of earthenware ducts	1,2 K·m/W
Screens bonded at both ends.	

* Current rating calculated for cables having a rated voltage of 6/10 kV.

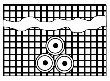
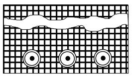
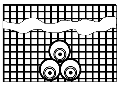
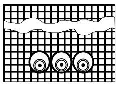
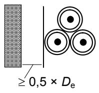
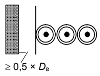
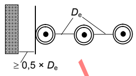
Table B.4 – Current ratings for single-core cables with EPR insulation – Rated voltage 3,6/6 kV to 18/30 kV * – Copper conductor

Nominal area of conductor	Buried direct in the ground		In single-way ducts		In air		
	Trefoil	Flat spaced	Trefoil ducts	Flat touching ducts	Trefoil	Flat touching	Flat spaced
							
mm^2	A	A	A	A	A	A	A
16	106	109	99	100	116	119	138
25	136	140	128	129	153	156	181
35	162	167	153	154	186	190	221
50	192	198	181	183	224	229	266
70	234	242	222	224	280	287	334
95	280	289	266	269	343	352	409
120	319	329	303	306	398	407	474
150	357	369	341	344	454	465	540
185	403	417	386	390	522	534	621
240	467	484	449	454	619	634	736
300	526	545	509	515	712	728	843
400	597	618	580	588	825	843	977

Maximum conductor temperature	90 °C
Ambient air temperature	30 °C
Ground temperature	20 °C
Depth of laying	0,8 m
Thermal resistivity of soil	1,5 K·m/W
Thermal resistivity of earthenware ducts	1,2 K·m/W
Screens bonded at both ends.	

* Current rating calculated for cables having a rated voltage of 6/10 kV.

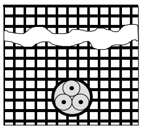
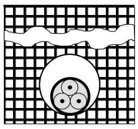
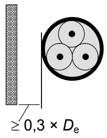
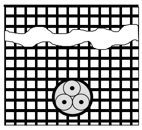
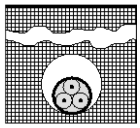
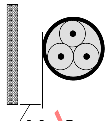
Table B.5 – Current ratings for single-core cables with EPR insulation – Rated voltage 3,6/6 kV to 18/30 kV * – Aluminium conductor

Nominal area of conductor	Buried direct in the ground		In single-way ducts		In air		
	Trefoil	Flat spaced	Trefoil ducts	Flat touching ducts	Trefoil	Flat touching	Flat spaced
							
mm^2	A	A	A	A	A	A	A
16	82	84	77	78	90	92	107
25	105	109	99	100	119	121	141
35	126	130	118	120	144	147	171
50	149	153	140	142	174	178	207
70	182	188	172	174	218	223	259
95	217	224	206	208	266	273	317
120	247	256	235	238	309	317	368
150	277	287	264	267	352	361	419
185	314	325	300	303	406	417	484
240	364	377	350	354	483	495	575
300	411	426	397	401	556	570	659
400	471	487	456	462	651	667	770

Maximum conductor temperature	90 °C
Ambient air temperature	30 °C
Ground temperature	20 °C
Depth of laying	0,8 m
Thermal resistivity of soil	1,5 K·m/W
Thermal resistivity of earthenware ducts	1,2 K·m/W
Screens bonded at both ends.	

* Current rating calculated for cables having a rated voltage of 6/10 kV.

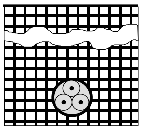
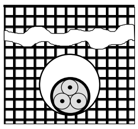
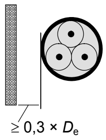
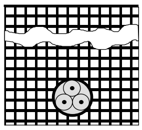
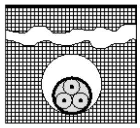
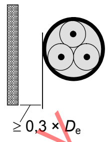
**Table B.6 – Current rating for three-core XLPE insulated cables –
Rated voltage 3,6/6 kV to 18/30 kV * –
Copper conductor, armoured and unarmoured**

Nominal area of conductor	Unarmoured			Armoured		
	Buried direct in ground	In a buried duct	In air	Buried direct in ground	In a buried duct	In air
			 ≥ 0,3 × D_e			 ≥ 0,3 × D_e
mm^2	A	A	A	A	A	A
16	101	87	109	101	88	110
25	129	112	142	129	112	143
35	153	133	170	154	134	172
50	181	158	204	181	158	205
70	221	193	253	220	194	253
95	262	231	304	263	232	307
120	298	264	351	298	264	352
150	334	297	398	332	296	397
185	377	336	455	374	335	453
240	434	390	531	431	387	529
300	489	441	606	482	435	599
400	553	501	696	541	492	683

Maximum conductor temperature	90 °C
Ambient air temperature	30 °C
Ground temperature	20 °C
Depth of laying	0,8 m
Thermal resistivity of soil	1,5 K·m/W
Thermal resistivity of earthenware ducts	1,2 K·m/W

* Current rating calculated for cables having a rated voltage of 6/10 kV.

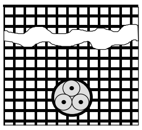
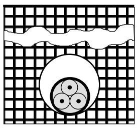
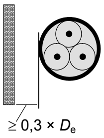
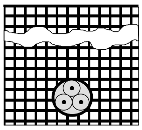
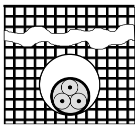
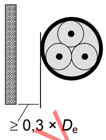
Table B.7 – Current rating for three-core XLPE insulated cables – Rated voltage 3,6/6 kV to 18/30 kV * – Aluminium conductor, armoured and unarmoured

Nominal area of conductor	Unarmoured			Armoured		
	Buried direct in ground	In a buried duct	In air	Buried direct in ground	In a buried duct	In air
						
mm^2	A	A	A	A	A	A
16	78	67	84	78	68	85
25	100	87	110	100	87	111
35	119	103	132	119	104	133
50	140	122	158	140	123	159
70	171	150	196	171	150	196
95	203	179	236	204	180	238
120	232	205	273	232	206	274
150	260	231	309	259	231	309
185	294	262	355	293	262	354
240	340	305	415	338	304	415
300	384	346	475	380	343	472
400	438	398	552	432	393	545

Maximum conductor temperature	90 °C
Ambient air temperature	30 °C
Ground temperature	20 °C
Depth of laying	0,8 m
Thermal resistivity of soil	1,5 K·m/W
Thermal resistivity of earthenware ducts	1,2 K·m/W

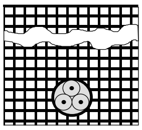
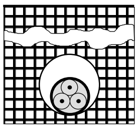
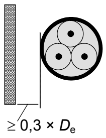
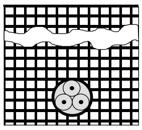
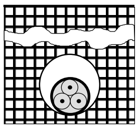
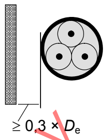
* Current rating calculated for cables having a rated voltage of 6/10 kV.

Table B.8 – Current rating for three-core EPR insulated cables – Rated voltage 3,6/6 kV to 18/30 kV * – Copper conductor, armoured and unarmoured

Nominal area of conductor	Unarmoured			Armoured		
	Buried direct in ground	In a buried duct	In air	Buried direct in ground	In a buried duct	In air
						
mm^2	A	A	A	A	A	A
16	98	84	104	98	85	104
25	125	109	135	125	109	136
35	150	130	164	150	131	164
50	176	154	195	177	155	197
70	216	189	243	216	190	244
95	258	227	296	257	227	296
120	292	258	339	292	259	339
150	328	291	385	327	291	385
185	371	330	441	368	328	439
240	429	384	519	424	381	513
300	482	434	590	475	429	583
400	545	494	678	534	485	666
Maximum conductor temperature			90 °C			
Ambient air temperature			30 °C			
Ground temperature			20 °C			
Depth of laying			0,8 m			
Thermal resistivity of soil			1,5 K·m/W			
Thermal resistivity of earthenware ducts			1,2 K·m/W			

* Current rating calculated for cables having a rated voltage of 6/10 kV.

Table B.9 – Current rating for three-core EPR insulated cables – Rated voltage 3,6/6 kV to 18/30 kV * – Aluminium conductor, armoured and unarmoured

Nominal area of conductor	Unarmoured			Armoured		
	Buried direct in ground	In a buried duct	In air	Buried direct in ground	In a buried duct	In air
						
mm^2	A	A	A	A	A	A
16	76	65	80	76	66	81
25	97	84	105	97	85	105
35	116	101	127	116	101	127
50	137	119	151	137	120	153
70	167	147	189	168	147	190
95	200	176	229	200	176	230
120	227	201	263	227	201	264
150	255	226	299	254	226	300
185	289	257	343	288	257	343
240	335	300	406	332	299	402
300	378	340	462	374	338	459
400	432	392	538	426	387	530

Maximum conductor temperature	90 °C
Ambient air temperature	30 °C
Ground temperature	20 °C
Depth of laying	0,8 m
Thermal resistivity of soil	1,5 K·m/W
Thermal resistivity of earthenware ducts	1,2 K·m/W

* Current rating calculated for cables having a rated voltage of 6/10 kV.

Table B.10 – Correction factors for ambient air temperatures other than 30 °C

Maximum conductor temperature °C	Ambient air temperature °C							
			35	40	45	50	55	60
90								

Table B.11 – Correction factors for ambient ground temperatures other than 20 °C

Maximum conductor temperature °C	**Ambient ground temperature** °C							
			25	30	35	40	45	50
90								

Table B.12 – Correction factors for depths of laying other than 0,8 m for direct buried cables

Depth of laying m	**Single-core cables** **Nominal conductor size** mm²		**Three-core cables**
	≤185 mm²	**>185 mm²**	
0,5	1,04	1,06	1,04
0,6	1,02	1,04	1,03
1	0,98	0,97	0,98
1,25	0,96	0,95	0,96
1,5	0,95	0,93	0,95
1,75	0,94	0,91	0,94
2	0,93	0,90	0,93
2,5	0,91	0,88	0,91
3	0,90	0,86	0,90

Table B.13 – Correction factors for depths of laying other than 0,8 m for cables in ducts

Depth of laying m	**Single-core cables** **Nominal conductor size** mm²		**Three-core cable**
	≤185 mm²	**>185 mm²**	
0,5	1,04	1,05	1,03
0,6	1,02	1,03	1,02
1	0,98	0,97	0,99
1,25	0,96	0,95	0,97
1,5	0,95	0,93	0,96
1,75	0,94	0,92	0,95
2	0,93	0,91	0,94
2,5	0,91	0,89	0,93
3	0,90	0,88	0,92

Table B.14 – Correction factors for soil thermal resistivities other than 1,5 K·m/W for direct buried single-core cables

Nominal area of conductor mm²	Values of soil thermal resistivity K·m/W						
	0,7	**0,8**	**0,9**	**1**	**2**	**2,5**	**3**
16	1,29	1,24	1,19	1,15	0,89	0,82	0,75
25	1,30	1,25	1,20	1,16	0,89	0,81	0,75
35	1,30	1,25	1,21	1,16	0,89	0,81	0,75
50	1,32	1,26	1,21	1,16	0,89	0,81	0,74
70	1,33	1,27	1,22	1,17	0,89	0,81	0,74
95	1,34	1,28	1,22	1,18	0,89	0,80	0,74
120	1,34	1,28	1,22	1,18	0,88	0,80	0,74
150	1,35	1,28	1,23	1,18	0,88	0,80	0,74
185	1,35	1,29	1,23	1,18	0,88	0,80	0,74
240	1,36	1,29	1,23	1,18	0,88	0,80	0,73
300	1,36	1,30	1,24	1,19	0,88	0,80	0,73
400	1,37	1,30	1,24	1,19	0,88	0,79	0,73

Table B.15 – Correction factors for soil thermal resistivities other than 1,5 K·m/W single-core cables in buried ducts

Nominal area of conductor mm²	Values of soil thermal resistivity K·m/W						
	0,7	**0,8**	**0,9**	**1**	**2**	**2,5**	**3**
16	1,20	1,17	1,14	1,11	0,92	0,85	0,79
25	1,21	1,17	1,14	1,12	0,91	0,85	0,79
35	1,21	1,18	1,15	1,12	0,91	0,84	0,79
50	1,21	1,18	1,15	1,12	0,91	0,84	0,78
70	1,22	1,19	1,15	1,12	0,91	0,84	0,78
95	1,23	1,19	1,16	1,13	0,91	0,84	0,78
120	1,23	1,20	1,16	1,13	0,91	0,84	0,78
150	1,24	1,20	1,16	1,13	0,91	0,83	0,78
185	1,24	1,20	1,17	1,13	0,91	0,83	0,78
240	1,25	1,21	1,17	1,14	0,90	0,83	0,77
300	1,25	1,21	1,17	1,14	0,90	0,83	0,77
400	1,25	1,21	1,17	1,14	0,90	0,83	0,77

Table B.16 – Correction factors for soil thermal resistivities other than 1,5 K·m/W for direct buried three-core cables

Nominal area of conductor mm^2	Values of soil thermal resistivity K•m/W						
	0,7	**0,8**	**0,9**	**1**	**2**	**2,5**	**3**
16	1,23	1,19	1,16	1,13	0,91	0,84	0,78
25	1,24	1,20	1,16	1,13	0,91	0,84	0,78
35	1,25	1,21	1,17	1,13	0,91	0,83	0,78
50	1,25	1,21	1,17	1,14	0,91	0,83	0,77
70	1,26	1,21	1,18	1,14	0,90	0,83	0,77
95	1,26	1,22	1,18	1,14	0,90	0,83	0,77
120	1,26	1,22	1,18	1,14	0,90	0,83	0,77
150	1,27	1,22	1,18	1,15	0,90	0,83	0,77
185	1,27	1,23	1,18	1,15	0,90	0,83	0,77
240	1,28	1,23	1,19	1,15	0,90	0,83	0,77
300	1,28	1,23	1,19	1,15	0,90	0,82	0,77
400	1,28	1,23	1,19	1,15	0,90	0,82	0,76

Table B.17 – Correction factors for soil thermal resistivities other than 1,5 K·m/W for three-core cables in ducts

Nominal area of conductor mm^2	Values of soil thermal resistivity K·m/W						
	0,7	**0,8**	**0,9**	**1**	**2**	**2,5**	**3**
16	1,12	1,11	1,09	1,08	0,94	0,89	0,84
25	1,14	1,12	1,10	1,08	0,94	0,89	0,84
35	1,14	1,12	1,10	1,08	0,94	0,88	0,84
50	1,14	1,12	1,10	1,08	0,94	0,88	0,84
70	1,15	1,13	1,11	1,09	0,94	0,88	0,83
95	1,15	1,13	1,11	1,09	0,94	0,88	0,83
120	1,15	1,13	1,11	1,09	0,93	0,88	0,83
150	1,16	1,13	1,11	1,09	0,93	0,88	0,83
185	1,16	1,14	1,11	1,09	0,93	0,87	0,83
240	1,16	1,14	1,12	1,10	0,93	0,87	0,82
300	1,17	1,14	1,12	1,10	0,93	0,87	0,82
400	1,17	1,14	1,12	1,10	0,92	0,86	0,81

Table B.18 – Correction factors for groups of three-core cables in horizontal formation laid direct in the ground

Number of cables in group	Spacing between cable centres mm				
	Touching	200	400	600	800
2	0,80	0,86	0,90	0,92	0,94
3	0,69	0,77	0,82	0,86	0,89
4	0,62	0,72	0,79	0,83	0,87
5	0,57	0,68	0,76	0,81	0,85
6	0,54	0,65	0,74	0,80	0,84
7	0,51	0,63	0,72	0,78	0,83
8	0,49	0,61	0,71	0,78	
9	0,47	0,60	0,70	0,77	–
10	0,46	0,59	0,69	–	–
11	0,45	0,57	0,69	–	–
12	0,43	0,56	0,68	–	–

Table B.19 – Correction factors for groups of three-phase circuits of single-core cables laid direct in the ground

Number of cables in group	Spacing between group centres mm				
	Touching	200	400	600	800
2	0,73	0,83	0,88	0,90	0,92
3	0,60	0,73	0,79	0,83	0,86
4	0,54	0,68	0,75	0,80	0,84
5	0,49	0,63	0,72	0,78	0,82
6	0,46	0,61	0,70	0,76	0,81
7	0,43	0,58	0,68	0,75	0,80
8	0,41	0,57	0,67	0,74	–
9	0,39	0,55	0,66	0,73	–
10	0,37	0,54	0,65	–	–
11	0,36	0,53	0,64	–	–
12	0,35	0,52	0,64	–	–

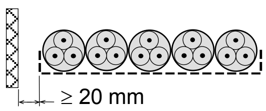
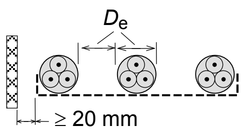
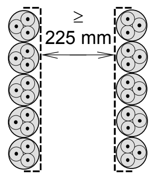
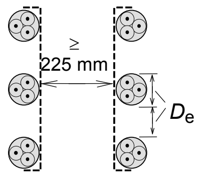
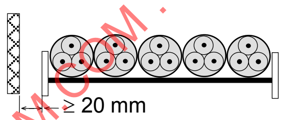
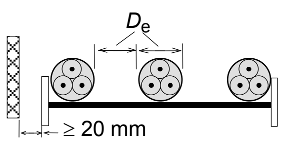
Table B.20 – Correction factors for groups of three-core cables in single way ducts in horizontal formation

Number of cables in group	Spacing between duct centres mm				
	Touching	200	400	600	800
2	0,85	0,88	0,92	0,94	0,95
3	0,75	0,80	0,85	0,88	0,91
4	0,69	0,75	0,82	0,86	0,89
5	0,65	0,72	0,79	0,84	0,87
6	0,62	0,69	0,77	0,83	0,87
7	0,59	0,67	0,76	0,82	0,86
8	0,57	0,65	0,75	0,81	–
9	0,55	0,64	0,74	0,80	–
10	0,54	0,63	0,73	–	–
11	0,52	0,62	0,73	–	–
12	0,51	0,61	0,72	–	–

Table B.21 – Correction factors for groups of three-phase circuits of single-core cables in single-way ducts

Number of cables in group	Spacing between duct group centres mm				
	Touching	200	400	600	800
2	0,78	0,85	0,89	0,91	0,93
3	0,66	0,75	0,81	0,85	0,88
4	0,59	0,70	0,77	0,82	0,86
5	0,55	0,66	0,74	0,80	0,84
6	0,51	0,64	0,72	0,78	0,83
7	0,48	0,61	0,71	0,77	0,82
8	0,46	0,60	0,70	0,76	–
9	0,44	0,58	0,69	0,76	–
10	0,43	0,57	0,68	–	–
11	0,42	0,56	0,67	–	–
12	0,40	0,55	0,67	–	–

Table B.22 – Reduction factors for groups of more than one multi-core cable in air – To be applied to the current-carrying capacity for one multi-core cable in free air

Method of installation		Number of trays	Number of cables					
			1	2	3	4	6	9
Cables on perforated trays	Touching 	1	1,00	0,88	0,82	0,79	0,76	0,73
		2	1,00	0,87	0,80	0,77	0,73	0,68
		3	1,00	0,86	0,79	0,76	0,71	0,66
	Spaced 	1	1,00	1,00	0,98	0,95	0,91	–
		2	1,00	0,99	0,96	0,92	0,87	–
		3	1,00	0,98	0,95	0,91	0,85	–
Cables on vertical perforated trays	 Touching	1	1,00	0,88	0,82	0,78	0,73	0,72
		2	1,00	0,88	0,81	0,76	0,71	0,70
	 Spaced	1	1,00	0,91	0,89	0,88	0,87	–
		2	1,00	0,91	0,88	0,87	0,85	–
Cables on ladder supports, cleats, etc.	Touching 	1	1,00	0,87	0,82	0,80	0,79	0,78
		2	1,00	0,86	0,80	0,78	0,76	0,73
		3	1,00	0,85	0,79	0,76	0,73	0,70
	Spaced 	1	1,00	1,00	1,00	1,00	1,00	–
		2	1,00	0,99	0,98	0,97	0,96	–
		3	1,00	0,98	0,97	0,96	0,93	–

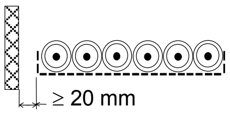
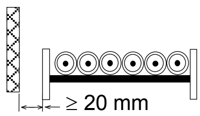
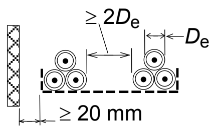
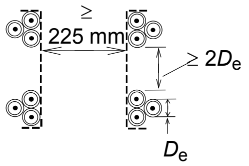
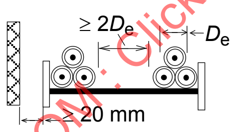
NOTE 1 Values given are averages for the cable types and range of conductor sizes considered. The spread of values is generally less than 5 %.

NOTE 2 Factors apply to single layer groups of cables as shown above and do not apply when cables are installed in more than one layer touching each other. Values for such installations may be significantly lower and must be determined by an appropriate method.

NOTE 3 Values are given for vertical spacings between trays of 300 mm and at least 20 mm between trays and wall. For closer spacing, the factors should be reduced.

NOTE 4 Values are given for horizontal spacing between trays of 225 mm with trays mounted back to back. For closer spacing, the factors should be reduced.

Table B.23 – Reduction factors for groups of more than one circuit of single-core cables (Note 2) – To be applied to the current-carrying capacity for one circuit of single-core cables in free air

Method of installation		Number of trays	Number of three-phase circuits (Note 5) 1	2	3	Use as a multiplier to rating for
Perforated trays (Note 3)	Touching 	1	0,98	0,91	0,87	Three cables in horizontal formation
		2	0,96	0,87	0,81	
		3	0,95	0,85	0,78	
Ladder supports, cleats etc. (Note 3)	Touching 	1	1,00	0,97	0,96	Three cables in horizontal formation
		2	0,98	0,93	0,89	
		3	0,97	0,90	0,86	
Perforated trays (Note 3)		1	1,00	0,98	0,96	Three cables in trefoil formation
		2	0,97	0,93	0,89	
		3	0,96	0,92	0,86	
Vertical perforated trays (Note 4)	 Spaced	1	1,00	0,91	0,89	
		2	1,00	0,90	0,86	
Ladder supports, cleats, etc. (Note 3)		1	1,00	1,00	1,00	
		2	0,97	0,95	0,93	
		3	0,96	0,94	0,90	

NOTE 1 Values given are averages for the cable types and range of conductor sizes considered. The spread of values is generally less than 5 %.

NOTE 2 Factors are given for single layers of cables (or trefoil groups) as shown in the table and do not apply when cables are installed in more than one layer touching each other. Values for such installations may be significantly lower and should be determined by an appropriate method.

NOTE 3 Values are given for vertical spacings between trays of 300 mm. For closer spacing, the factors should be reduced.

NOTE 4 Values are given for horizontal spacing between trays of 225 mm with trays mounted back to back. For closer spacing, the factors should be reduced.

NOTE 5 For circuits having more than one cable in parallel per phase, each three phase set of conductors should be considered as a circuit for the purpose of this table.

Annex C
(normative)

Rounding of numbers

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

The following rules apply when rounding numbers in calculating fictitious diameters and determining dimensions of component layers in accordance with Annex A.

When the calculated value at any stage has more than one decimal place, the value shall be rounded to one decimal place, i.e. to the nearest 0,1 mm. The fictitious diameter at each stage shall be rounded to 0,1 mm and, when used to determine the thickness or dimension of an overlying layer, it shall be rounded before being used in the appropriate formula or table. The thickness calculated from the rounded value of the fictitious diameter shall, in turn, be rounded to 0,1 mm as required in Annex A.

To illustrate these rules, the following practical examples are given:

a) when the figure in the second decimal place before rounding is 0, 1, 2, 3 or 4, then the figure retained in the first decimal place remains unchanged (rounding down);

Examples:

2,12	≈	2,1
2,449	≈	2,4
25,0478	≈	25,0

b) when the figure in the second decimal place before rounding is 9, 8, 7, 6 or 5, then the figure in the first decimal place is increased by one (rounding up).

Examples:

2,17	≈	2,2
2,453	≈	2,5
30,050	≈	30,1

C.2 Rounding of numbers for other purposes

For purposes other than those considered under Clause C.1, it may be required that values are rounded to more than one decimal place. This may occur, for instance, in calculating the average value of several measurement results, or the minimum value by applying a percentage tolerance to a given nominal value. In these cases, rounding shall be carried out to the number of decimal places specified in the relevant clauses.

The method of rounding shall then be as follows:

a) if the last figure to be retained is followed, before rounding, by 0, 1, 2, 3 or 4, it shall remain unchanged (rounding down);

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

Examples:

2,449	≈	2,45	rounded to two decimal places
2,449	≈	2,4	rounded to one decimal place
25,0478	≈	25,048	rounded to three decimal places
25,0478	≈	25,05	rounded to two decimal places
25,0478	≈	25,0	rounded to one decimal place

Annex D
(normative)

Method of measuring resistivity of semi-conducting screens

Each test piece shall be prepared from a 150 mm sample of completed cable.

The conductor screen test piece shall be prepared by cutting a sample of core in half longitudinally and removing the conductor and separator if any (see Figure D.1a). The insulation screen test piece shall be prepared by removing all the coverings from the sample of core (see Figure D.1b).

The procedure for determining the volume resistivity of the screens shall be as follows:

Four silver-painted electrodes A, B, C, and D (see Figures D.1a and D.1b) shall be applied to the semi-conducting surfaces. The two potential electrodes, B and C, shall be 50 mm apart and the two current electrodes, A and D, shall be each placed at least 25 mm beyond the potential electrodes.

Connections shall be made to the electrodes by means of suitable clips. In making connections to the conductor screen electrodes it shall be ensured that the clips are insulated from the insulation screen on the outer surface of the test sample.

The assembly shall be placed in an oven preheated to the specified temperature and, after an interval of at least 30 min, the resistance between the electrodes shall be measured by means of a circuit, the power of which shall not exceed 100 mW.

After the electrical measurements, the diameters over the conductor screen and insulation screen and the thicknesses of the conductor screen and insulation screen shall be measured at ambient temperature, each being the average of six measurements made on the sample shown in Figure D.1b.

The volume resistivity ρ in ohm · metres shall be calculated as follows:

a) conductor screen

$$\rho_c = \frac{R_c \times \pi \times (D_c - T_c) \times T_c}{2L_c}$$

where

ρ_c is the volume resistivity, in ohm · metres;

R_c is the measured resistance, in ohms;

L_c is the distance between potential electrodes, in metres;

D_c is the outer diameter over the conductor screen, in metres;

T_c is the average thickness of conductor screen, in metres.

b) insulation screen

$$\rho_i = \frac{R_i \times \pi \times (D_i - T_i) \times T_i}{L_i}$$

where

ρ_i is the volume resistivity, in ohm · metres;

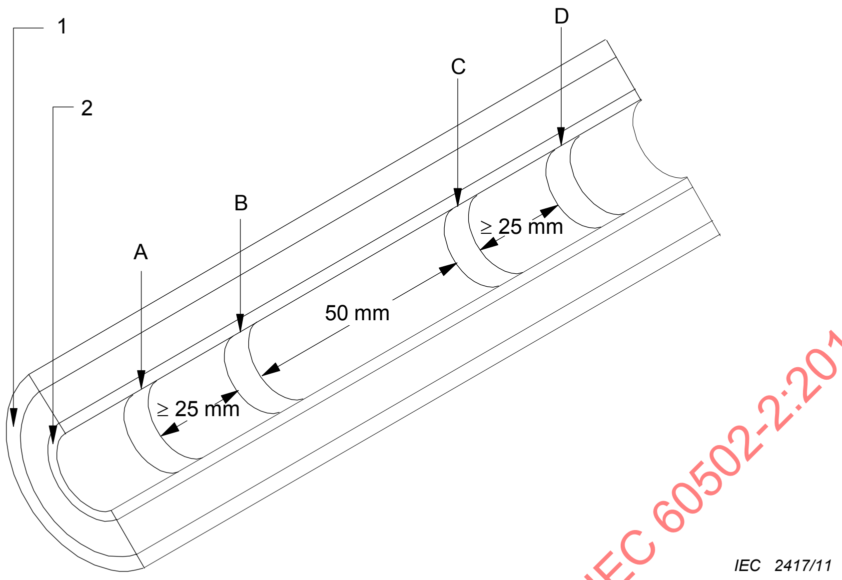
R_i is the measured resistance, in ohms;

L_i is the distance between potential electrodes, in metres;

D_i is the outer diameter over the insulation screen, in metres;

T_i is the average thickness of insulation screen, in metres.

Dimensions in millimetres

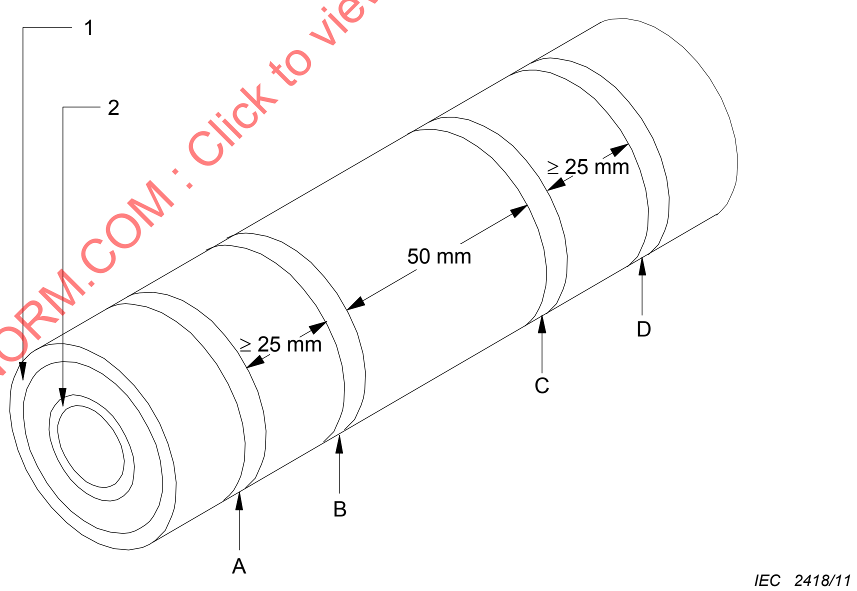


Key

1	insulation screen	B, C	potential electrodes
2	conductor screen	A, D	current electrodes

Figure D.1a – Measurement of the volume resistivity of the conductor screen

Dimensions in millimetres



Key

1	insulation screen	B, C	potential electrodes
2	conductor screen	A, D	current electrodes

Figure D.1b – Measurement of the volume resistivity of the insulation screen

Figure D.1 – Preparation of samples for measurement of resistivity of conductor and insulation screens

Annex E
(normative)

Determination of hardness of HEPR insulations

E.1 Test piece

The test piece shall be a sample of completed cable with all the coverings, external to the HEPR insulation to be measured, carefully removed. Alternatively, a sample of insulated core may be used.

E.2 Test procedure

E.2.1 General

Tests shall be made in accordance with ISO 48 with exceptions as indicated below.

E.2.2 Surfaces of large radius of curvature

The test instrument, in accordance with ISO 48, shall be constructed so as to rest firmly on the HEPR insulation and permit the presser foot and indentor to make vertical contact with this surface. This is done in one of the following ways:

a) the instrument is fitted with feet moveable in universal joints so that they adjust themselves to the curved surface;
b) the base of the instrument is fitted with two parallel rods A and A' at a distance apart depending on the curvature of the surface (see Figure E.1).

These methods may be used on surfaces with radius of curvature down to 20 mm.

When the thickness of HEPR insulation tested is less than 4 mm, an instrument as described in the method in ISO 48 for thin and small test pieces shall be used.

E.2.3 Surfaces of small radius of curvature

On surfaces with too small a radius of curvature for the procedures described in E.2.2, the test piece shall be supported on the same rigid base as the test instrument, in such a way as to minimize bodily movement of the HEPR insulation when the indenting force increment is applied to the indentor and so that the indentor is vertically above the axis of the test piece. Suitable procedures are as follows:

a) by resting the test piece in a grove or trough in a metal jig (see Figure E.2a);
b) by resting the ends of the conductor of the test piece in V-blocks (see Figure E.2b).

The smallest radius of curvature of the surface to be measured by these methods shall be at least 4 mm.

For smaller radii, an instrument as described in the method in ISO 48 for thin and small test pieces shall be used.

E.2.4 Conditioning and test temperature

The minimum time between manufacture, i.e. vulcanization and testing, shall be 16 h.

The test shall be carried out at a temperature of (20 ± 2) °C and the test pieces shall be maintained at this temperature for at least 3 h immediately before testing.

E.2.5 Number of measurements

One measurement shall be made at each of three or five different points distributed around the test piece. The median of the results shall be taken as the hardness of the test piece, reported to the nearest whole number in international rubber hardness degrees (IRHD).

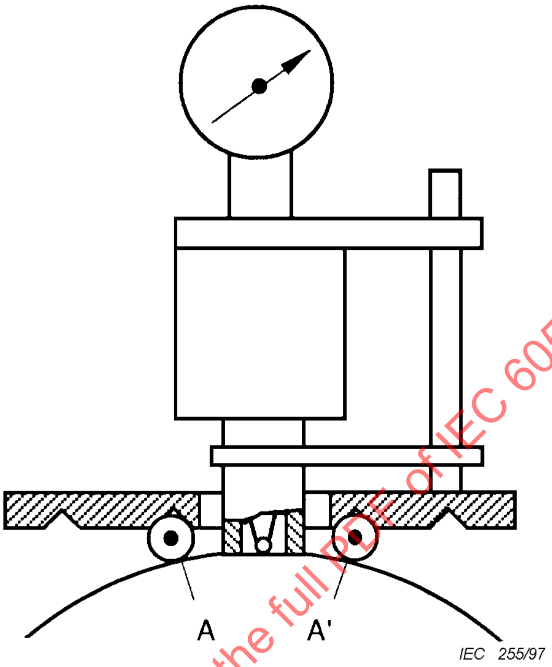


Figure E.1 – Test on surfaces of large radius of curvature

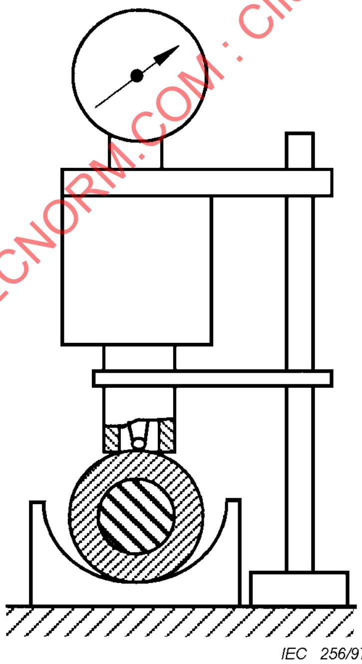


Figure E.2a – Test piece groove

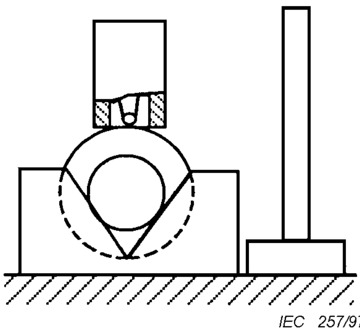


Figure E.2b – Test piece in V-blocks

Figure E.2 – Test on surfaces of small radius of curvature

Annex F
(normative)

Water penetration test

F.1 Test piece

A sample of completed cable at least 6 m in length which has not been subjected to any of the tests described in Clause 18 shall be subjected to a bending test described in 18.2.4 without the additional partial discharge test.

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

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

The surfaces shall be cut so that the interfaces intended to be longitudinally watertight shall be readily exposed to the water. The interfaces not intended to be longitudinally watertight shall be sealed with a suitable material or the outer coverings removed.

Examples of these latter interfaces include:

– when only the conductor of the cable has a barrier;
– the interface between the oversheath and the metal~~lic~~ sheath.

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

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

F.2 Test

The tube is filled within 5 min with water at an ambient temperature of (20 ± 10) °C so that the height of the water in the tube is 1 m above the cable centre (see Figure F.1). The sample shall be allowed to stand for 24 h.

The sample shall then be subjected to 10 heating cycles by passing 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 and which shall not reach 100 °C.

The duration of the heating cycle shall be at least 8 h. 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.

The water head shall be maintained at 1 m.

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

F.3 Requirements

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

Dimensions in millimetres

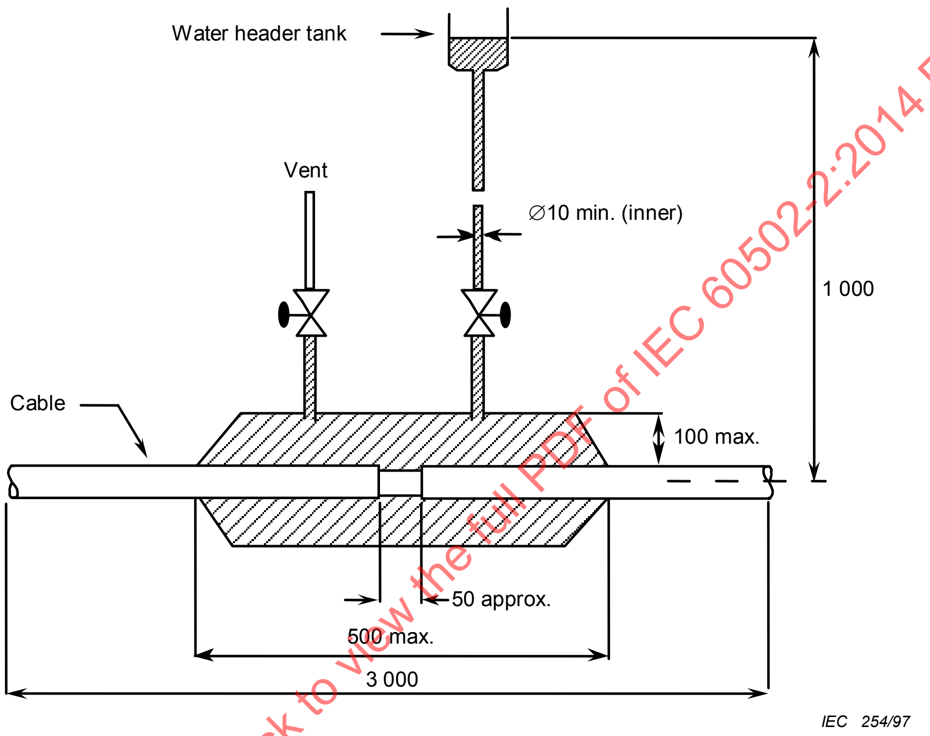


Figure F.1 – Schematic diagram of apparatus for water penetration test

Annex G
(informative)

Determination of the cable conductor temperature

G.1 Purpose

For some tests, it is necessary to raise the cable conductor to a given temperature, typically 5 K to 10 K above the maximum temperature in normal operation, while the cable is energized, either at power frequency or under impulse conditions. It is therefore not possible to have access to the conductor to enable direct measurement of temperature.

In addition, the conductor temperature should be maintained within a restricted range (5 K) whereas the ambient temperature may vary over a wider range.

Although preliminary calibration on the cable under test or calculations may be satisfactory in the first place, the variation of ambient conditions throughout the duration of the test may lead to deviations of the temperature of the conductor outside range.

Therefore, methods should be used in which the conductor temperature can be monitored and controlled throughout the duration of the test.

Guidance is given hereafter on commonly used methods.

G.2 Calibration of the temperature of the main test loop

G.2.1 General

The purpose of the calibration is to determine the conductor temperature by direct measurement for a given current within the temperature range required for the test.

The cable used for calibration (hereafter called reference cable) should be taken from same length as the cable used for the main test loop.

G.2.2 Installation of cable and temperature sensors

The calibration should be performed on a minimum cable length of 5 m, taken from the same cable as tested. The length should be such that the longitudinal heat transfer to the cable ends does not affect the temperature in the centre 2 m of cable by more than 2 K.

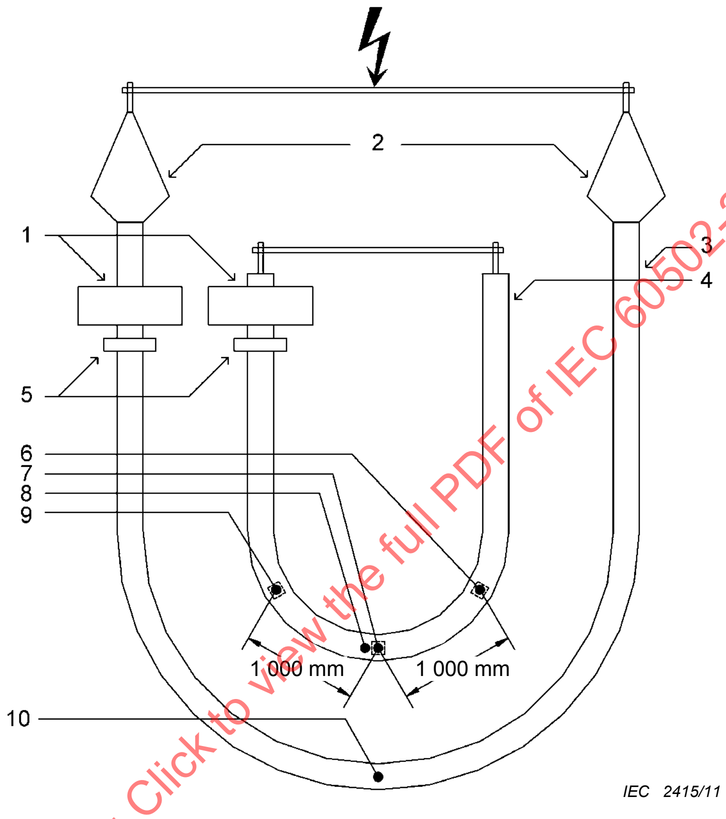
At the middle of the reference cable, two temperature sensors should be attached: one on the conductor (TC_{1c}), and one on the external surface or directly under the external surface (TC_{1s}).

Two other temperature sensors, TC_{2c} and TC_{3c}, should be installed on the conductor of the reference cable (see Figure G.1), each one about 1 m away from the middle.

The temperature sensors should be attached to the conductor by mechanical means since they may move due to vibrations of the cable during heating. Care should be taken to maintain good thermal contact during the tests and to prevent leakage of heat to the ambient. It is recommended to mount the thermocouple(s) as shown in Figure G.2 between two strands of a stranded conductor or between the (solid) conductor and the conductor screen. To enable access to the conductor in the middle of the reference cable, a small hatch should be made by careful removal of the layers above the conductor. After installing the temperature sensor(s), the layers that have been removed may be put back. This may restore the thermal behaviour of the reference cable.

NOTE To prove a negligible heat transfer towards the cable ends, the difference between the readings of TC_{1C}, TC_{2C} and TC_{3C} should be less than 2 K.

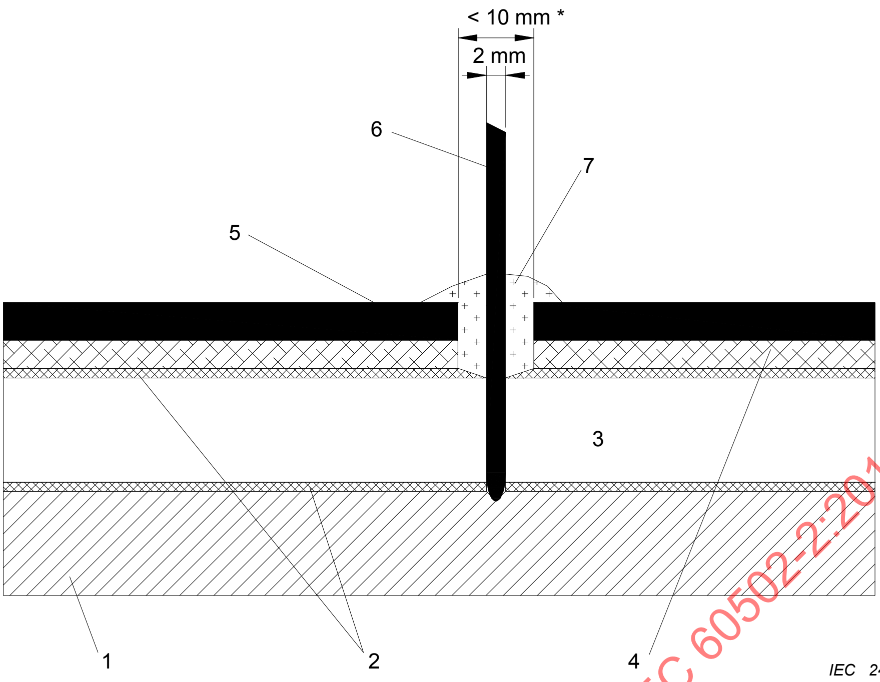
If the main test loop includes several individual cable lengths installed close to each other, these lengths will be subjected to thermal proximity effect. The calibration should therefore be carried out, taking into account the actual test arrangement, measurements being performed on the hottest cable length (usually the middle length).



Key

1	current inducing transformers	6	TC_{3c} (conductor)
2	terminations	7	TC_{1c} (conductor)
3	cable under test	8	TC_{1s} (sheath)
4	reference cable (≥5 m)	9	TC_{2c} (conductor)
5	current measuring transformers	10	TC_{s} (sheath)

Figure G.1 – Typical test set-up for the reference loop and the main test loop



Key

1 conductor
2 semi-conducting screens
3 insulation
4 metal sheath
5 cable oversheath
6 temperature sensor
7 flexible thermal insulating compound
* as small as possible

Figure G.2 – Example of an arrangement of the temperature sensors on the conductor of the reference loop

G.2.3 Calibration method

The calibration should be carried out in a draught-free situation at a temperature of (20 ± 15) °C.

Temperature recorders should be used to measure the conductor, oversheath and ambient temperatures simultaneously.

The cable should be heated until the conductor temperatures, indicated by temperature sensors TC_{1c} of Figure G.1, have stabilized and reached the following temperatures: between 5 K and 10 K above the maximum conductor temperature of the cable in normal operation, as given in Table 1.

When stabilization has been reached, the following should be noted:

– conductor temperature: average value at positions 1, 2 and 3;
– oversheath temperature at position TC_{1s};
– ambient temperature;
– heating current.

G.3 Heating for the test

G.3.1 Method 1 – Test using a reference cable

In this method, a reference cable identical to the cable used for the test is heated with the same current value as the main test loop.

The installation of cable and temperature sensors for both loops should be as given in Clause G.2.

The test arrangement should be such that

– the reference cable carries the same current as the main test loop at any time;
– it is installed in such a way that mutual heating effects are taken into account throughout the test.

The heating current of both loops should be adjusted such that the conductor temperature is kept within the specified limits.

A temperature sensor (TC_S) should be mounted on or under the external surface of the main test loop at the hottest spot, usually in the middle of it, in the same way as temperature sensor TC_{1s} is mounted on the hottest spot of the reference cable.

NOTE 1 The temperature measured with the temperature sensors on or under the oversheath of the main test loop (TC_S) and on the reference loop (TC_{1s}) are used to check whether the oversheath of both loops has the same temperature.

The temperature measured with temperature sensor TC_{1C} on the conductor of the reference loop may be considered as to be representative for the conductor temperature of the energized test loop.

NOTE 2 The temperature of the conductor of the main test loop may be slightly higher than that of the reference loop because of dielectric losses. If necessary, a correction should be made.

All temperature sensors should be connected to a recorder to enable temperature monitoring. The heating current of each loop should also be recorded to prove that the two currents are of the same value throughout the duration of the test. The difference between the heating currents should be kept within ±1 %.

The reference cable may be connected in series with the test cable if the temperature is measured via an optical fibre link or equivalent.

G.3.2 Method 2 – Test using conductor temperature calculations and measurement of the surface temperature

G.3.2.1 Calibration of the test cable conductor temperature

The purpose of the calibration is to determine the conductor temperature by direct measurement for a given current, within the temperature range required for the test.

The cable used for calibration should be identical to that to be used for the test, and the way of heating should be identical.

The installation of cable and temperature sensors for the calibration should be as given in Clause G.2.

The calibration should be carried out in accordance with G.2.3 for the reference cable.

G.3.2.2 Test based on measurement of the external temperature

During calibration and during the test of the main loop, the cable conductor temperature of the main test loop should be calculated in accordance with IEC 60853-2, based on the measured external temperature of the oversheath (TC_S). The measurement should be done with a temperature sensor at the hottest spot, attached to or under the external surface, in the same way as for the reference cable.

NOTE As an alternative, IEC 60287-2 (all parts 2) may be used if demonstrated that asymptotic transient temperature is reached within the specified time

The heating current should be adjusted to obtain the required value of the calculated conductor temperature, based on the measured external temperature of the oversheath.

Bibliography

IEC 60287 (all parts), *Electric cables – Calculation of the current rating*

IEC 60502-1, *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 1: Cables for rated voltages of 1 kV (U_m = 1,2 kV) and 3 kV (U_m = 3,6 kV)*

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

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IEC 60502-2

Edition 3.0 2014-02

INTERNATIONAL STANDARD

NORME INTERNATIONALE

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)

Câbles d'énergie à isolant extrudé et leurs accessoires pour des tensions assignées de 1 kV (*U*m = 1,2 kV) à 30 kV (*U*m = 36 kV) –
Partie 2: Câbles de tensions assignées de 6 kV(*U*m = 7,2 kV) à 30 kV (*U*m = 36 kV)

IEC 60502-2:2014-02(en-fr)

CONTENTS

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.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- 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 (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 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 metal 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.

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) *Thermoplastic*	
polyvinyl chloride intended for cables with rated voltages U_0/U = 3,6/6 kV	PVC/B*
b) *Crosslinked:*	
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 mm²	70	160
	Conductor cross-section >300 mm²	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) *Thermoplastic:*		
polyvinyl chloride (PVC)	ST_1	80
	ST_2	90
polyethylene	ST_3	80
	ST_7	90
b) *Elastomeric:*		
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 mm^2, 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 mm^2, 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 mm^2, 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 metal 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-metal 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-metal, semi-conducting layer in combination with a metal layer.

The non-metal 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 metal 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 metal 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 metal 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 metal layer, the inner covering shall be semi-conducting; the fillers may be semi-conducting.

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

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

Cables with an additional collective metal layer (see Clause 9) of the same material as the underlying individual metal 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 metal layers and the collective metal 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 metal layers may be obtained by an inner covering according to 8.2.

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

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

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

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

The metal 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 metal layers.

10 Metal screen

10.1 Construction

The metal 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 metal screen shall be determined by national regulations and/or standards.

10.3 Metal screens not associated with semi-conducting layers

Where metal 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 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:

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

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 sheaths

Under consideration.

13 Metal armour

13.1 Types of metal 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 metal 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 metal 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 materials[1)] 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 0-442-27373-8.

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).

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 ± 15) °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:

a) conductor examination (see 17.4);
b) check of dimensions (see 17.5 to 17.8);
c) voltage test for cables of rated voltage above 3,6/6 (7,2) kV (see 17.9);
d) 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-metal sheaths (including extruded separation sheaths, but excluding inner extruded coverings)

17.5.1 General

The test method shall be in accordance with 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-metal sheaths

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.

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

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 metal 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 ±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 ±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 ±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 ± 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 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 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 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 SE_1 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 mm^2 are approved when the cross-sectional area of the previously tested cable is in the range of 95 mm^2 to 630 mm^2 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 δ 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 δ 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 ($d + D$) + 5 % for single-core cables;
  - 20 ($d + D$) + 5 % for three-core cables;
- for other cables:
  - 20 ($d + D$) + 5 % for single-core cables;
  - 15 ($d + D$) + 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 metal screen or the conductor or both.

The sample shall be heated until the conductor reaches a temperature which shall be 5 K to 10 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 K to 10 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 K to 10 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 ±2 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 Ω × m,

– insulation screen: 500 Ω × 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 ± 1) °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 × 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 × 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 ±2 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 K to 10 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 IEC 60811-201.

19.2.3 Requirements

See 17.5.2.

19.3 Measurement of thickness of non-metal 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 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 IEC 60811-501.

19.5.2 Ageing treatments

The ageing treatments shall be carried out as described in IEC 60811-401 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 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-metal sheaths before and after ageing

19.6.1 Sampling

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

19.6.2 Ageing treatments

The ageing treatments shall be carried out as described in 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 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-metal 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 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 IEC 60811-401, under the following conditions:

– temperature: (10 ± 2) 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 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-metal sheaths.

19.8 Loss of mass test on PVC sheaths of type ST_2

19.8.1 Procedure

The sampling and test procedure shall be in accordance with 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-metal sheaths

19.9.1 Procedure

The pressure test at high temperature shall be carried out in accordance with 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 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 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 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 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 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 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 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 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 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 ST_1, ST_2 or SE_1 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 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 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 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 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 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 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 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 in accordance with IEC 60060-3 and in accordance with item a), b) or c) as below may be used:

a) test for 15 min with the phase-to-phase voltage U, at a frequency between 20 Hz to 300 Hz shall be applied between the conductor and the metal screen/sheath;

b) test for 24 h with the normal 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 δ 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.

A d.c. test may endanger the insulation system under test. Where possible an a.c. test as described above should be used.

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

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)	Ω × cm	10^{14}	–	–
– at maximum conductor temperature in normal operation (see 18.3.3)	Ω × cm	10^{11}	10^{12}	–
Insulation resistance constant K_i *				
– at 20 °C (see 18.3.2)	MΩ × km	367	–	–
– at maximum conductor temperature in normal operation (see 18.3.3)	MΩ × km	0,37	3,67	–
Tan δ (see 18.2.6)				
– tan δ at maximum conductor temperature in normal operation plus 5 K up to 10 K, maximum	x 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**		
					ST_1	**ST_2**	**ST_3**	**ST_7**	**SE_1**
Dimensions									
Measurements of thicknesses	x	x	x	x	x	x	x	x	x
Mechanical properties									
(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
Thermoplastic properties									
Hot pressure test (indentation)	x	–	–	–	x	x	–	x	–
Behaviour at low temperature	x	–	–	–	x	x	–	–	–
Miscellaneous									
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

Designation of compounds (see 4.2 and 4.3)	Insulations				Sheaths				
	PVC/B	**EPR**	**HEPR**	**XLPE**	**PVC**		**PE**		
					ST_1	**ST_2**	**ST_3**	**ST_7**	**SE_1**
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**
Without ageing (IEC 60811-501)					
Tensile strength, minimum	N/mm²	12,5	4,2	8,5	12,5
Elongation-at-break, minimum	%	125	200	200	200
After ageing in air oven (IEC 60811-401)					
After ageing without conductor					
Treatment:					
– temperature – tolerance – duration	°C K h	100 ±2 168	135 ±3 168	135 ±3 168	135 ±3 168
Tensile strength:					
a) value after ageing, minimum b) variation*, maximum	N/mm² %	12,5 ±25	– ±30	– ±30	– ±25
Elongation-at-break: a) value after ageing, minimum b) variation*, maximum	 % %	 125 ±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**
Pressure test at high temperature (IEC 60811-508)		
Temperature (tolerance ±2 K)	°C	80
Behaviour at low temperature * (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 ±2 K)	°C	–5
Cold elongation test on dumb-bells:		
– temperature (tolerance ±2 K)	°C	–5
Heat shock test (IEC 60811-509)		
Temperature (tolerance ±3 K)	°C	150
Duration	h	1
Thermal stability (IEC 60811-405)		
Temperature (tolerance ±0,5 K)	°C	200
Minimum time	min	100
Water absorption (IEC 60811-402)		
Electrical method:		
Temperature (tolerance ±2 K)	°C	70
Duration	h	240

* Due to climatic conditions, national standards may require the use of a lower temperature.

Table 19 – Test requirements for particular characteristics of various crosslinked insulating compounds

Designation of compounds (see 4.2)		**EPR**	**HEPR**	**XLPE**
Ozone resistance (IEC 60811-403)				
Ozone concentration (by volume)	%	0,025 to 0,030	0,025 to 0,030	–
Test duration without cracks	h	24	24	–
Hot set test (IEC 60811-507)				
Treatment:				
– air temperature (tolerance ±3 K) – time under load – mechanical stress	°C min N/cm²	250 15 20	250 15 20	200 15 20
Maximum elongation under load	%	175	175	175
Maximum permanent elongation after cooling	%	15	15	15
Water absorption (IEC 60811-402) Gravimetric method:				
Temperature (tolerance ±2 K)	°C	85	85	85
Duration	h	336	336	336
Maximum increase of mass	mg/cm²	5	5	1 *
Shrinkage test (IEC 60811-502)				
Distance *L* between marks	mm	–	–	200
Temperature (tolerance ±3 K)	°C	–	–	130
Duration	h	–	–	1
Maximum shrinkage	%	–	–	4
Determination of hardness (see Annex E)				
IRHD **, minimum		–	80	–
Determination of elastic modulus (see 19.21)				
Modulus at 150 % elongation, minimum	N/mm²	–	4,5	–

* An increase greater than 1 mg/cm² is being considered for densities of XLPE greater than 1 g/cm³.

** IRHD: international rubber hardness degree.

Table 20 – Test requirements for mechanical characteristics of sheathing compounds (before and after ageing)

Designation of compounds (see 4.3)		**ST$_1$**	**ST$_2$**	**ST$_3$**	**ST$_7$**	**SE$_1$**
Maximum conductor temperature in normal operation (see 4.3)	°C	**80**	**90**	**80**	**90**	**85**
Without ageing (IEC 60811-501)						
Tensile strength, minimum	N/mm²	12,5	12,5	10,0	12,5	10,0
Elongation-at-break, minimum	%	150	150	300	300	300
After ageing in air oven (IEC 60811-401)						
Treatment:						
– temperature (tolerance ±2 K) – duration	°C h	100 168	100 168	100 240	110 240	100 168
Tensile strength:						
a) value after ageing, minimum b) variation *, maximum	N/mm² %	12,5 ±25	12,5 ±25	– –	– –	– ±30
Elongation-at-break: a) value after ageing, minimum b) variation *, maximum	 % %	 150 ±25	 150 ±25	 300 –	 300 –	 250 ±40

* Variation: difference between the median value obtained after ageing and the median value obtained without ageing expressed as a percentage of the latter.

Table 21 – Test requirements for particular characteristics for PVC sheathing compounds

Designation of compound (see 4.2 and 4.3)		ST_1	ST_2
Use of the PVC compound		**Sheath**	
Loss of mass in air oven (IEC 60811-409)			
Treatment:			
– temperature (tolerance ±2 K) – duration	°C h	– –	100 168
Maximum loss of mass	mg/cm2	–	1,5
Pressure test at high temperature (IEC 60811-508)			
Temperature (tolerance ±2 K)	°C	80	90
Behaviour at low temperature * (IEC 60811-504, IC 60811-505 and IEC 60811-506)			
Test to be carried out without previous ageing:			
– cold bending test for diameter <12,5 mm – temperature (tolerance ±2 K)	°C	–15	–15
Cold elongation test on dumb-bells:			
– temperature (tolerance ±2 K)	°C	–15	–15
Cold impact test:			
– temperature (tolerance ±2 K)	°C	–15	–15
Heat shock test (IEC 60811-509)			
Temperature (tolerance ±3 K)	°C	150	150
Duration	h	1	1
* Due to climatic conditions, national standards may require the use of a lower temperature.			

Table 22 – Test requirements for particular characteristics of PE (thermoplastic polyethylene) sheathing compounds

Designation of compounds (see 4.3)		ST_3	ST_7
Density * (IEC 60811-606)			
Carbon black content (for black oversheaths only) (IEC 60811-605)			
Nominal value	%	2,5	2,5
Tolerance	%	±0,5	±0,5
Shrinkage test (IEC 60811-503)			
Temperature (tolerance ±2 K)	°C	80	80
Heating, duration	h	5	5
Heating cycles		5	5
Maximum shrinkage	%	3	3
Pressure test at high temperature (IEC 60811-508)			
Temperature (tolerance ±2 K)	°C	–	110
* The measurement of density is only required for the purpose of other tests.			

Table 23 – Test requirements for particular characteristics of elastomeric sheathing compound

Designation of compound (see 4.3)		**SE$_1$**
Oil immersion test followed by a determination of the mechanical properties (IEC 60811-404 and IEC 60811-501)		
Treatment:		
– oil temperature (tolerance ±2 K) – duration	°C h	100 24
Maximum variation * of:		
a) tensile strength b) elongation-at-break	% %	±40 ±40
Hot set test (IEC 60811-507)		
Treatment:		
– temperature (tolerance ±3 K) – time under load – mechanical stress	°C min N/cm^2	200 15 20
Maximum elongation under load	%	175
Maximum permanent elongation after cooling	%	15
* Variation: difference between the median value obtained after treatment and the median value without treatment, expressed as a percentage of the latter.		

Annex A
(normative)

Fictitious calculation method for determination of dimensions of protective coverings

A.1 General

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

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

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

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

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

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

Holding strips, for example counter helix over armour, if not thicker than 0,3 mm, are neglected in this calculation method.

A.2 Method

A.2.1 Conductors

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

Table A.1 – Fictitious diameter of conductor

Nominal cross-section of conductor mm^2	d_L mm	Nominal cross-section of conductor mm^2	d_L mm
10	3,6	240	17,5
16	4,5	300	19,5
25	5,6	400	22,6
35	6,7	500	25,2
50	8,0	630	28,3
70	9,4	800	31,9
95	11,0	1 000	35,7
120	12,4	1 200	39,1
150	13,8	1 400	42,2
185	15,3	1 600	45,1

A.2.2 Cores

The fictitious diameter D_c of any core is given by:

a) for cables having cores without semi-conducting layers:

$$D_c = d_L + 2\,t_i$$

b) for cables having cores with semi-conducting layers:

$$D_c = d_L + 2\,t_i + 3{,}0$$

where t_i is the nominal thickness of insulation, in millimetres (see Tables 5 to 7).

If a metal screen or a concentric conductor is applied, a further addition shall be made in accordance with A.2.5.

A.2.3 Diameter over laid-up cores

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

$$D_f = kD_c$$

where the assembly coefficient k is 2,16 for a three-core cable.

A.2.4 Inner coverings

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

$$D_B = D_f + 2\,t_B$$

where

t_B = 0,4 mm for fictitious diameters over laid-up cores (D_f) up to and including 40 mm;

t_B = 0,6 mm for D_f exceeding 40 mm.

These fictitious values for t_B apply to

a) three-core cables:
   - whether an inner covering is applied or not;
   - whether the inner covering is extruded or lapped;

   unless a separation sheath complying with 13.3.3 is used in place of or in addition to the inner covering, when A.2.7 applies instead;

b) single-core cables:
   - when an inner covering is applied whether it is extruded or lapped.

A.2.5 Concentric conductors and metal screens

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

Table A.2 – Increase of diameter for concentric conductors and metal screens

Nominal cross-section of concentric conductor or metal screen mm²	Increase in diameter mm	Nominal cross-section of concentric conductor or metal screen mm²	Increase in diameter mm
1,5	0,5	50	1,7
2,5	0,5	70	2,0
4	0,5	95	2,4
6	0,6	120	2,7
10	0,8	150	3,0
16	1,1	185	4,0
25	1,2	240	5,0
35	1,4	300	6,0

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

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

a) tape screen

$$\text{cross-sectional area} = n_t \times t_t \times w_t$$

where

n_t is the number of tapes;

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

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

Where the total thickness of the screen is less than 0,15 mm then the increase in diameter shall be zero:

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

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

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

where

n_w is the number of wires;

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

n_h is the number of a counter helix;

t_h is the thickness of a counter helix, in millimetres, if greater than 0,3 mm;

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

A.2.6 Lead sheath

The fictitious diameter over the lead sheath (D_{pb}) is given by:

$$D_{pb} = D_g + 2\,t_{pb}$$

where

D_g is the fictitious diameter under the lead sheath, in millimetres;

t_{pb} is the thickness calculated in accordance with 12.1, in millimetres.

A.2.7 Separation sheath

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

$$D_s = D_u + 2\,t_s$$

where

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

t_s is the thickness calculated in accordance with 13.3.3, in millimetres.

A.2.8 Lapped bedding

The fictitious diameter over the lapped bedding (D_{lb}) is given by:

$$D_{lb} = D_{ulb} + 2\,t_{lb}$$

where

D_{ulb} is the fictitious diameter under the lapped bedding, in millimetres;

t_{lb} is the thickness of lapped bedding, i.e. 1,5 mm according to 13.3.4.

A.2.9 Additional bedding for tape-armoured cables (provided over the inner covering)

Table A.3 – Increase of diameter for additional bedding

Fictitious diameter under the addition bedding		Increase in diameter for additional bedding
Above mm	Up to and including mm	mm
–	29	1,0
29	–	1,6

A.2.10 Armour

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

a) flat or round wire armour by:

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

where

D_A is the diameter under the armour, in millimetres;

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

t_w is the thickness of the counter helix, if any, in millimetres, if greater than 0,3 mm.

b) for double-tape armour by:

$$D_x = D_A + 4\ t_A$$

where

D_A is the diameter under the armour, in millimetres;

t_A is the thickness of the armour tape, in millimetres.

Annex B
(informative)

Tabulated continuous current ratings for cables having extruded insulation and a rated voltage from 3,6/6 kV up to 18/30 kV

B.1 General

This annex deals solely with the steady-state continuous current ratings of single-core and three-core cables having extruded insulation. The tabulated current ratings provided in this annex have been calculated for cables having a rated voltage of 6/10 kV and constructions as detailed in Clause B.2.

These ratings can be applied to cables of similar constructions in the voltage range of 3,6/6 kV to 18/30 kV.

Some parameters such as screen cross-sectional area and oversheath thickness have an influence on the rating of large cables. In addition, the method of screen bonding has to be taken into account in the rating of single-core cables.

The tabulated current ratings have been calculated using the methods set out in the IEC 60287 series.

For cyclic current ratings, see the IEC 60853 series.

For short-circuit temperature limits, see the IEC 60986 series.

B.2 Cable constructions

The cable constructions and dimensions for which current ratings have been tabulated are based on those given in this standard. The constructions and dimensions used are not related to specific national designs but reflect different model cables. Armoured three-core cables are assumed to have flat wire armour and single-core cables are assumed to be unarmoured. All the cables have copper tape core screens except the single-core XLPE insulated cable, which has a copper wire screen. The nominal cross-sectional areas of the screens for the model cables is given in Table B.1.

Table B.1 – Nominal screen cross-sectional areas

Nominal area of conductor, mm²	16	25	35	50	70	95	120	150	185	240	300	400
Nominal cross-sectional area of screen, per core, mm²												
EPR insulated cable	3	3	4	4	4	5	5	5	6	6	7	8
XLPE insulated cable	16	16	16	16	16	16	16	25	25	25	25	35

The oversheath is taken to be polyethylene for the single core cables and PVC for the three-core cables.

B.3 Temperatures

The maximum conductor temperature for which the tabulated cable ratings have been calculated is 90 °C.

The reference ambient temperatures assumed are as follows:

– for cables in air: 30 °C

– for buried cables, either directly in the soil or in ducts in the ground: 20 °C

Correction factors for other ambient temperatures are given in Tables B.10 and B.11.

The current ratings for cables in air do not take account of the increase, if any, due to solar or other infra-red radiation. Where the cables are subject to such radiation, the current rating should be derived by the methods specified in the IEC 60287 series.

B.4 Soil thermal resistivity

The tabulated current ratings for cables in ducts or direct in the ground relate to a soil thermal resistivity of 1,5 K·m/W. Information on the likely soil thermal resistivity in various countries is given in IEC 60287-3-1. Correction factors for other values of thermal resistivity are given in Tables B.14 to B.17.

It is assumed that the soil properties are uniform, no allowance has been made for the possibility of moisture migration which can lead to a region of high thermal resistivity around the cable. If partial drying-out of the soil is foreseen, the permissible current rating should be derived by the methods specified in the IEC 60287 series.

B.5 Methods of installation

B.5.1 General

Current ratings are tabulated for cables installed in the following conditions.

B.5.2 Single-core cables in air

The cables are assumed to be spaced at least 0,5 times the cable diameter from any vertical surface and installed on brackets or ladder racks as follows:

a) three cables in trefoil formation touching throughout their length;

b) three cables in horizontal flat formation touching throughout their length;

c) three cables in horizontal flat formation with a clearance of one cable diameter.

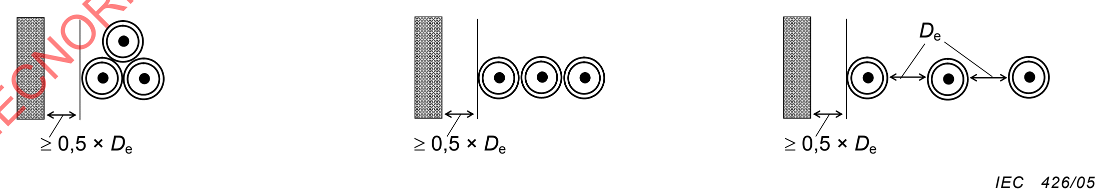


Figure B.1a Figure B.1b Figure B.1c

Key

D_e external diameter of the cable.

Figure B.1 – Single-core cables in air

B.5.3 Single-core cables buried direct

Current ratings are given for cables buried direct in the ground at a depth of 0,8 m under the following conditions:

a) three cables in trefoil formation touching throughout their length;

b) three cables in horizontal flat formation with a clearance of one cable diameter, D_e.

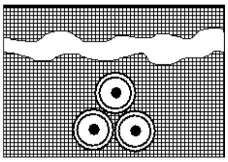
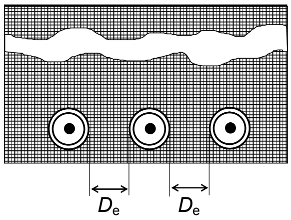


Figure B.2a



IEC 427/05

Figure B.2b

Figure B.2 – Single-core cables buried direct

The cable depth is measured to the cable axis or centre of the trefoil group.

B.5.4 Single-core cables in earthenware ducts

Current ratings are given for cables in earthenware ducts buried at a depth of 0,8 m with one cable per duct as follows:

a) three cables in trefoil ducts touching throughout their length;

b) three cables in horizontal flat formation, ducts touching throughout their length.

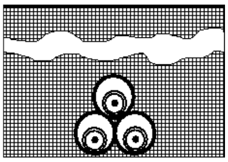
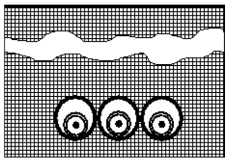


Figure B.3a



IEC 428/05

Figure B.3b

Figure B.3 – Single-core cables in earthenware ducts

The ducts are assumed to be earthenware having an inside diameter of 1,5 times the outside diameter of the cable and a wall thickness equal to 6 % of the duct inside diameter. The ratings are based on the assumption that the ducts are air filled. If the ducts have been filled with a material such as Bentonite, then it is usual to adopt the current ratings for cables buried direct.

The tabulated ratings may be applied to cables in ducts having an inside diameter of between 1,2 and 2 times the outside diameter of the cables. For this range of diameters the variation in the rating is less than 2 % of the tabulated value.

B.5.5 Three-core cables

Current ratings are given for three-core cables installed under the following conditions:

a) single cable in air spaced at least 0,3 times the cable diameter from any vertical surface;

b) single cable buried direct in the ground at a depth of 0,8 m;

c) single cable in a buried earthenware duct having dimensions calculated in the same manner as for the single-core cables in ducts. The depth of burial of the duct is 0,8 m.

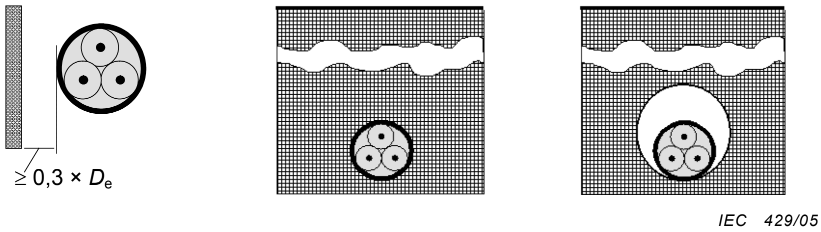


Figure B.4a Figure B.4b Figure B.4c

Figure B.4 – Three-core cables

B.6 Screen bonding

All the tabulated ratings for single-core cables assume that the cable screens are solidly bonded, i.e. bonded at both ends of the cables.

B.7 Cable loading

The tabulated ratings relate to circuits carrying a balanced three-phase load at a rated frequency of 50 Hz.

B.8 Rating factors for grouped circuits

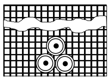
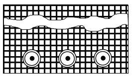
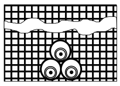
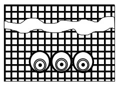
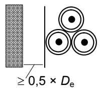
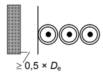
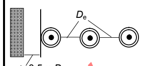
The tabulated current ratings apply to a set of three single-core cables or one three-core cable forming a three-phase circuit. When a number of circuits are installed in close proximity the rating should be reduced by the appropriate factor from Tables B.18 to B.23.

These rating factors should also be applied to groups of parallel cables forming the same circuit. In such cases, attention should also be given to the arrangement of the cables to ensure that the load current is shared equally between the parallel cables.

B.9 Correction factors

The correction factors given in Tables B.10 to B.23 for temperature, installation conditions and grouping are averages over a range of conductor sizes and cable types. For particular cases, the correction factor may be calculated using the methods in IEC 60287-2-1.

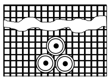
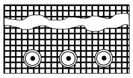
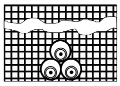
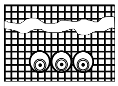
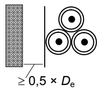
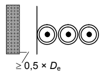
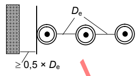
Table B.2 – Current ratings for single-core cables with XLPE insulation – Rated voltage 3,6/6 kV to 18/30 kV * – Copper conductor

Nominal area of conductor	Buried direct in the ground		In single-way ducts		In air		
	Trefoil	Flat spaced	Trefoil ducts	Flat touching ducts	Trefoil	Flat touching	Flat spaced
							
mm²	A	A	A	A	A	A	A
16	109	113	103	104	125	128	150
25	140	144	132	133	163	167	196
35	166	172	157	159	198	203	238
50	196	203	186	188	238	243	286
70	239	246	227	229	296	303	356
95	285	293	271	274	361	369	434
120	323	332	308	311	417	426	500
150	361	366	343	347	473	481	559
185	406	410	387	391	543	550	637
240	469	470	447	453	641	647	745
300	526	524	504	510	735	739	846
400	590	572	564	571	845	837	938

Maximum conductor temperature	90 °C
Ambient air temperature	30 °C
Ground temperature	20 °C
Depth of laying	0,8 m
Thermal resistivity of soil	1,5 K·m/W
Thermal resistivity of earthenware ducts	1,2 K·m/W
Screens bonded at both ends.	

* Current rating calculated for cables having a rated voltage of 6/10 kV.

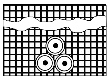
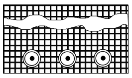
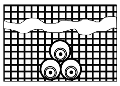
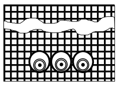
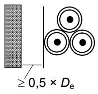
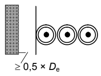
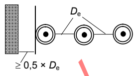
Table B.3 – Current ratings for single-core cables with XLPE insulation – Rated voltage 3,6/6 kV to 18/30 kV * – Aluminium conductor

Nominal area of conductor	Buried direct in the ground		In single-way ducts		In air		
	Trefoil	Flat spaced	Trefoil ducts	Flat touching ducts	Trefoil	Flat touching	Flat spaced
							
mm^2	A	A	A	A	A	A	A
16	84	88	80	81	97	99	116
25	108	112	102	103	127	130	153
35	129	134	122	123	154	157	185
50	152	157	144	146	184	189	222
70	186	192	176	178	230	236	278
95	221	229	210	213	280	287	338
120	252	260	240	242	324	332	391
150	281	288	267	271	368	376	440
185	317	324	303	307	424	432	504
240	367	373	351	356	502	511	593
300	414	419	397	402	577	586	677
400	470	466	451	457	673	676	769

Maximum conductor temperature	90 °C
Ambient air temperature	30 °C
Ground temperature	20 °C
Depth of laying	0,8 m
Thermal resistivity of soil	1,5 K·m/W
Thermal resistivity of earthenware ducts	1,2 K·m/W
Screens bonded at both ends.	

* Current rating calculated for cables having a rated voltage of 6/10 kV.

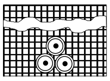
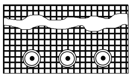
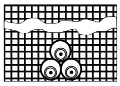
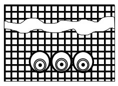
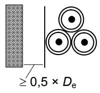
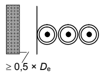
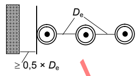
Table B.4 – Current ratings for single-core cables with EPR insulation – Rated voltage 3,6/6 kV to 18/30 kV * – Copper conductor

Nominal area of conductor	Buried direct in the ground		In single-way ducts		In air		
	Trefoil	Flat spaced	Trefoil ducts	Flat touching ducts	Trefoil	Flat touching	Flat spaced
							
mm^2	A	A	A	A	A	A	A
16	106	109	99	100	116	119	138
25	136	140	128	129	153	156	181
35	162	167	153	154	186	190	221
50	192	198	181	183	224	229	266
70	234	242	222	224	280	287	334
95	280	289	266	269	343	352	409
120	319	329	303	306	398	407	474
150	357	369	341	344	454	465	540
185	403	417	386	390	522	534	621
240	467	484	449	454	619	634	736
300	526	545	509	515	712	728	843
400	597	618	580	588	825	843	977

Maximum conductor temperature	90 °C
Ambient air temperature	30 °C
Ground temperature	20 °C
Depth of laying	0,8 m
Thermal resistivity of soil	1,5 K·m/W
Thermal resistivity of earthenware ducts	1,2 K·m/W
Screens bonded at both ends.	

* Current rating calculated for cables having a rated voltage of 6/10 kV.

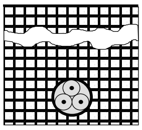
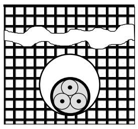
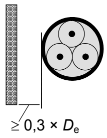
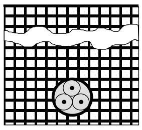
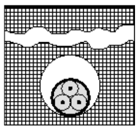
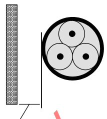
Table B.5 – Current ratings for single-core cables with EPR insulation – Rated voltage 3,6/6 kV to 18/30 kV * – Aluminium conductor

Nominal area of conductor	Buried direct in the ground		In single-way ducts		In air		
	Trefoil	Flat spaced	Trefoil ducts	Flat touching ducts	Trefoil	Flat touching	Flat spaced
							
mm^2	A	A	A	A	A	A	A
16	82	84	77	78	90	92	107
25	105	109	99	100	119	121	141
35	126	130	118	120	144	147	171
50	149	153	140	142	174	178	207
70	182	188	172	174	218	223	259
95	217	224	206	208	266	273	317
120	247	256	235	238	309	317	368
150	277	287	264	267	352	361	419
185	314	325	300	303	406	417	484
240	364	377	350	354	483	495	575
300	411	426	397	401	556	570	659
400	471	487	456	462	651	667	770

Maximum conductor temperature	90 °C
Ambient air temperature	30 °C
Ground temperature	20 °C
Depth of laying	0,8 m
Thermal resistivity of soil	1,5 K·m/W
Thermal resistivity of earthenware ducts	1,2 K·m/W
Screens bonded at both ends.	

* Current rating calculated for cables having a rated voltage of 6/10 kV.

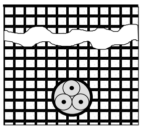
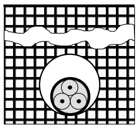
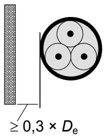
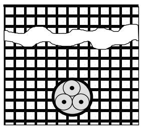
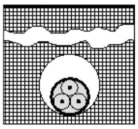
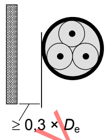
Table B.6 – Current rating for three-core XLPE insulated cables – Rated voltage 3,6/6 kV to 18/30 kV * – Copper conductor, armoured and unarmoured

Nominal area of conductor	Unarmoured			Armoured		
	Buried direct in ground	In a buried duct	In air	Buried direct in ground	In a buried duct	In air
						
mm^2	A	A	A	A	A	A
16	101	87	109	101	88	110
25	129	112	142	129	112	143
35	153	133	170	154	134	172
50	181	158	204	181	158	205
70	221	193	253	220	194	253
95	262	231	304	263	232	307
120	298	264	351	298	264	352
150	334	297	398	332	296	397
185	377	336	455	374	335	453
240	434	390	531	431	387	529
300	489	441	606	482	435	599
400	553	501	696	541	492	683

Maximum conductor temperature	90 °C
Ambient air temperature	30 °C
Ground temperature	20 °C
Depth of laying	0,8 m
Thermal resistivity of soil	1,5 K·m/W
Thermal resistivity of earthenware ducts	1,2 K·m/W

* Current rating calculated for cables having a rated voltage of 6/10 kV.

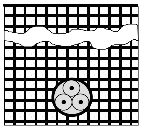
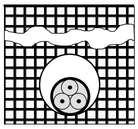
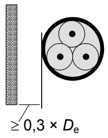
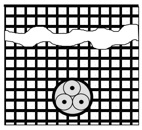
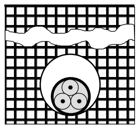
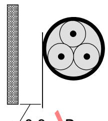
Table B.7 – Current rating for three-core XLPE insulated cables – Rated voltage 3,6/6 kV to 18/30 kV * – Aluminium conductor, armoured and unarmoured

Nominal area of conductor	Unarmoured			Armoured		
	Buried direct in ground	In a buried duct	In air	Buried direct in ground	In a buried duct	In air
						
mm^2	A	A	A	A	A	A
16	78	67	84	78	68	85
25	100	87	110	100	87	111
35	119	103	132	119	104	133
50	140	122	158	140	123	159
70	171	150	196	171	150	196
95	203	179	236	204	180	238
120	232	205	273	232	206	274
150	260	231	309	259	231	309
185	294	262	355	293	262	354
240	340	305	415	338	304	415
300	384	346	475	380	343	472
400	438	398	552	432	393	545

Maximum conductor temperature	90 °C
Ambient air temperature	30 °C
Ground temperature	20 °C
Depth of laying	0,8 m
Thermal resistivity of soil	1,5 K·m/W
Thermal resistivity of earthenware ducts	1,2 K·m/W

* Current rating calculated for cables having a rated voltage of 6/10 kV.

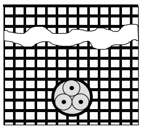
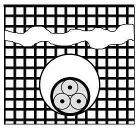
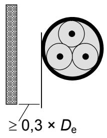
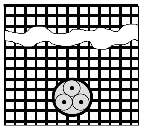
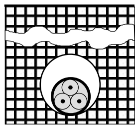
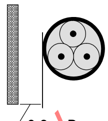
Table B.8 – Current rating for three-core EPR insulated cables – Rated voltage 3,6/6 kV to 18/30 kV * – Copper conductor, armoured and unarmoured

Nominal area of conductor	Unarmoured			Armoured		
	Buried direct in ground	In a buried duct	In air	Buried direct in ground	In a buried duct	In air
						
mm²	A	A	A	A	A	A
16	98	84	104	98	85	104
25	125	109	135	125	109	136
35	150	130	164	150	131	164
50	176	154	195	177	155	197
70	216	189	243	216	190	244
95	258	227	296	257	227	296
120	292	258	339	292	259	339
150	328	291	385	327	291	385
185	371	330	441	368	328	439
240	429	384	519	424	381	513
300	482	434	590	475	429	583
400	545	494	678	534	485	666

Maximum conductor temperature	90 °C
Ambient air temperature	30 °C
Ground temperature	20 °C
Depth of laying	0,8 m
Thermal resistivity of soil	1,5 K·m/W
Thermal resistivity of earthenware ducts	1,2 K·m/W

* Current rating calculated for cables having a rated voltage of 6/10 kV.

Table B.9 – Current rating for three-core EPR insulated cables – Rated voltage 3,6/6 kV to 18/30 kV * – Aluminium conductor, armoured and unarmoured

Nominal area of conductor	Unarmoured			Armoured		
	Buried direct in ground	In a buried duct	In air	Buried direct in ground	In a buried duct	In air
						
mm²	A	A	A	A	A	A
16	76	65	80	76	66	81
25	97	84	105	97	85	105
35	116	101	127	116	101	127
50	137	119	151	137	120	153
70	167	147	189	168	147	190
95	200	176	229	200	176	230
120	227	201	263	227	201	264
150	255	226	299	254	226	300
185	289	257	343	288	257	343
240	335	300	406	332	299	402
300	378	340	462	374	338	459
400	432	392	538	426	387	530

Maximum conductor temperature	90 °C
Ambient air temperature	30 °C
Ground temperature	20 °C
Depth of laying	0,8 m
Thermal resistivity of soil	1,5 K·m/W
Thermal resistivity of earthenware ducts	1,2 K·m/W

* Current rating calculated for cables having a rated voltage of 6/10 kV.

Table B.10 – Correction factors for ambient air temperatures other than 30 °C

Maximum conductor temperature °C	Ambient air temperature °C							
	20	25	35	40	45	50	55	60
90	1,08	1,04	0,96	0,91	0,87	0,82	0,76	0,71

Table B.11 – Correction factors for ambient ground temperatures other than 20 °C

Maximum conductor temperature °C	Ambient ground temperature °C							
	10	15	25	30	35	40	45	50
90	1,07	1,04	0,96	0,93	0,89	0,85	0,80	0,76

Table B.12 – Correction factors for depths of laying other than 0,8 m for direct buried cables

Depth of laying m	Single-core cables Nominal conductor size mm^2		Three-core cables
	≤185 mm^2	>185 mm^2	
0,5	1,04	1,06	1,04
0,6	1,02	1,04	1,03
1	0,98	0,97	0,98
1,25	0,96	0,95	0,96
1,5	0,95	0,93	0,95
1,75	0,94	0,91	0,94
2	0,93	0,90	0,93
2,5	0,91	0,88	0,91
3	0,90	0,86	0,90

Table B.13 – Correction factors for depths of laying other than 0,8 m for cables in ducts

Depth of laying m	Single-core cables Nominal conductor size mm^2		Three-core cable
	≤185 mm^2	>185 mm^2	
0,5	1,04	1,05	1,03
0,6	1,02	1,03	1,02
1	0,98	0,97	0,99
1,25	0,96	0,95	0,97
1,5	0,95	0,93	0,96
1,75	0,94	0,92	0,95
2	0,93	0,91	0,94
2,5	0,91	0,89	0,93
3	0,90	0,88	0,92

Table B.14 – Correction factors for soil thermal resistivities other than 1,5 K·m/W for direct buried single-core cables

Nominal area of conductor mm²	Values of soil thermal resistivity K·m/W						
	0,7	0,8	0,9	1	2	2,5	3
16	1,29	1,24	1,19	1,15	0,89	0,82	0,75
25	1,30	1,25	1,20	1,16	0,89	0,81	0,75
35	1,30	1,25	1,21	1,16	0,89	0,81	0,75
50	1,32	1,26	1,21	1,16	0,89	0,81	0,74
70	1,33	1,27	1,22	1,17	0,89	0,81	0,74
95	1,34	1,28	1,22	1,18	0,89	0,80	0,74
120	1,34	1,28	1,22	1,18	0,88	0,80	0,74
150	1,35	1,28	1,23	1,18	0,88	0,80	0,74
185	1,35	1,29	1,23	1,18	0,88	0,80	0,74
240	1,36	1,29	1,23	1,18	0,88	0,80	0,73
300	1,36	1,30	1,24	1,19	0,88	0,80	0,73
400	1,37	1,30	1,24	1,19	0,88	0,79	0,73

Table B.15 – Correction factors for soil thermal resistivities other than 1,5 K·m/W single-core cables in buried ducts

Nominal area of conductor mm²	Values of soil thermal resistivity K·m/W						
	0,7	0,8	0,9	1	2	2,5	3
16	1,20	1,17	1,14	1,11	0,92	0,85	0,79
25	1,21	1,17	1,14	1,12	0,91	0,85	0,79
35	1,21	1,18	1,15	1,12	0,91	0,84	0,79
50	1,21	1,18	1,15	1,12	0,91	0,84	0,78
70	1,22	1,19	1,15	1,12	0,91	0,84	0,78
95	1,23	1,19	1,16	1,13	0,91	0,84	0,78
120	1,23	1,20	1,16	1,13	0,91	0,84	0,78
150	1,24	1,20	1,16	1,13	0,91	0,83	0,78
185	1,24	1,20	1,17	1,13	0,91	0,83	0,78
240	1,25	1,21	1,17	1,14	0,90	0,83	0,77
300	1,25	1,21	1,17	1,14	0,90	0,83	0,77
400	1,25	1,21	1,17	1,14	0,90	0,83	0,77

Table B.16 – Correction factors for soil thermal resistivities other than 1,5 K·m/W for direct buried three-core cables

Nominal area of conductor mm²	Values of soil thermal resistivity K•m/W						
	0,7	**0,8**	**0,9**	**1**	**2**	**2,5**	**3**
16	1,23	1,19	1,16	1,13	0,91	0,84	0,78
25	1,24	1,20	1,16	1,13	0,91	0,84	0,78
35	1,25	1,21	1,17	1,13	0,91	0,83	0,78
50	1,25	1,21	1,17	1,14	0,91	0,83	0,77
70	1,26	1,21	1,18	1,14	0,90	0,83	0,77
95	1,26	1,22	1,18	1,14	0,90	0,83	0,77
120	1,26	1,22	1,18	1,14	0,90	0,83	0,77
150	1,27	1,22	1,18	1,15	0,90	0,83	0,77
185	1,27	1,23	1,18	1,15	0,90	0,83	0,77
240	1,28	1,23	1,19	1,15	0,90	0,83	0,77
300	1,28	1,23	1,19	1,15	0,90	0,82	0,77
400	1,28	1,23	1,19	1,15	0,90	0,82	0,76

Table B.17 – Correction factors for soil thermal resistivities other than 1,5 K·m/W for three-core cables in ducts

Nominal area of conductor mm²	Values of soil thermal resistivity K·m/W						
	0,7	**0,8**	**0,9**	**1**	**2**	**2,5**	**3**
16	1,12	1,11	1,09	1,08	0,94	0,89	0,84
25	1,14	1,12	1,10	1,08	0,94	0,89	0,84
35	1,14	1,12	1,10	1,08	0,94	0,88	0,84
50	1,14	1,12	1,10	1,08	0,94	0,88	0,84
70	1,15	1,13	1,11	1,09	0,94	0,88	0,83
95	1,15	1,13	1,11	1,09	0,94	0,88	0,83
120	1,15	1,13	1,11	1,09	0,93	0,88	0,83
150	1,16	1,13	1,11	1,09	0,93	0,88	0,83
185	1,16	1,14	1,11	1,09	0,93	0,87	0,83
240	1,16	1,14	1,12	1,10	0,93	0,87	0,82
300	1,17	1,14	1,12	1,10	0,93	0,87	0,82
400	1,17	1,14	1,12	1,10	0,92	0,86	0,81

Table B.18 – Correction factors for groups of three-core cables in horizontal formation laid direct in the ground

Number of cables in group	Spacing between cable centres mm				
	Touching	200	400	600	800
2	0,80	0,86	0,90	0,92	0,94
3	0,69	0,77	0,82	0,86	0,89
4	0,62	0,72	0,79	0,83	0,87
5	0,57	0,68	0,76	0,81	0,85
6	0,54	0,65	0,74	0,80	0,84
7	0,51	0,63	0,72	0,78	0,83
8	0,49	0,61	0,71	0,78	
9	0,47	0,60	0,70	0,77	–
10	0,46	0,59	0,69	–	–
11	0,45	0,57	0,69	–	–
12	0,43	0,56	0,68	–	–

Table B.19 – Correction factors for groups of three-phase circuits of single-core cables laid direct in the ground

Number of cables in group	Spacing between group centres mm				
	Touching	200	400	600	800
2	0,73	0,83	0,88	0,90	0,92
3	0,60	0,73	0,79	0,83	0,86
4	0,54	0,68	0,75	0,80	0,84
5	0,49	0,63	0,72	0,78	0,82
6	0,46	0,61	0,70	0,76	0,81
7	0,43	0,58	0,68	0,75	0,80
8	0,41	0,57	0,67	0,74	–
9	0,39	0,55	0,66	0,73	–
10	0,37	0,54	0,65	–	–
11	0,36	0,53	0,64	–	–
12	0,35	0,52	0,64	–	–

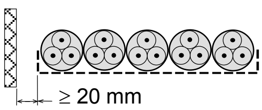
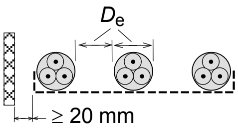
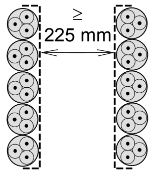
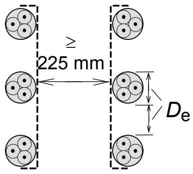
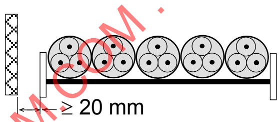
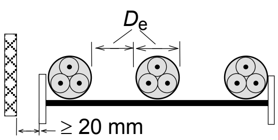
Table B.20 – Correction factors for groups of three-core cables in single way ducts in horizontal formation

Number of cables in group	Spacing between duct centres mm				
	Touching	200	400	600	800
2	0,85	0,88	0,92	0,94	0,95
3	0,75	0,80	0,85	0,88	0,91
4	0,69	0,75	0,82	0,86	0,89
5	0,65	0,72	0,79	0,84	0,87
6	0,62	0,69	0,77	0,83	0,87
7	0,59	0,67	0,76	0,82	0,86
8	0,57	0,65	0,75	0,81	–
9	0,55	0,64	0,74	0,80	–
10	0,54	0,63	0,73	–	–
11	0,52	0,62	0,73	–	–
12	0,51	0,61	0,72	–	–

Table B.21 – Correction factors for groups of three-phase circuits of single-core cables in single-way ducts

Number of cables in group	Spacing between duct group centres mm				
	Touching	200	400	600	800
2	0,78	0,85	0,89	0,91	0,93
3	0,66	0,75	0,81	0,85	0,88
4	0,59	0,70	0,77	0,82	0,86
5	0,55	0,66	0,74	0,80	0,84
6	0,51	0,64	0,72	0,78	0,83
7	0,48	0,61	0,71	0,77	0,82
8	0,46	0,60	0,70	0,76	–
9	0,44	0,58	0,69	0,76	–
10	0,43	0,57	0,68	–	–
11	0,42	0,56	0,67	–	–
12	0,40	0,55	0,67	–	–

Table B.22 – Reduction factors for groups of more than one multi-core cable in air – To be applied to the current-carrying capacity for one multi-core cable in free air

Method of installation		Number of trays	Number of cables					
			1	2	3	4	6	9
Cables on perforated trays	Touching 	1	1,00	0,88	0,82	0,79	0,76	0,73
		2	1,00	0,87	0,80	0,77	0,73	0,68
		3	1,00	0,86	0,79	0,76	0,71	0,66
	Spaced 	1	1,00	1,00	0,98	0,95	0,91	–
		2	1,00	0,99	0,96	0,92	0,87	–
		3	1,00	0,98	0,95	0,91	0,85	–
Cables on vertical perforated trays	 Touching	1	1,00	0,88	0,82	0,78	0,73	0,72
		2	1,00	0,88	0,81	0,76	0,71	0,70
	 Spaced	1	1,00	0,91	0,89	0,88	0,87	–
		2	1,00	0,91	0,88	0,87	0,85	–
Cables on ladder supports, cleats, etc.	Touching 	1	1,00	0,87	0,82	0,80	0,79	0,78
		2	1,00	0,86	0,80	0,78	0,76	0,73
		3	1,00	0,85	0,79	0,76	0,73	0,70
	Spaced 	1	1,00	1,00	1,00	1,00	1,00	–
		2	1,00	0,99	0,98	0,97	0,96	–
		3	1,00	0,98	0,97	0,96	0,93	–

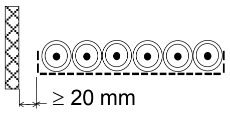
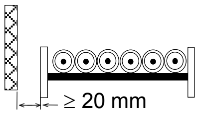
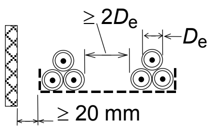
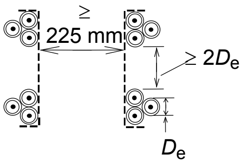
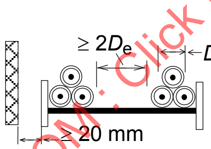
NOTE 1 Values given are averages for the cable types and range of conductor sizes considered. The spread of values is generally less than 5 %.

NOTE 2 Factors apply to single layer groups of cables as shown above and do not apply when cables are installed in more than one layer touching each other. Values for such installations may be significantly lower and must be determined by an appropriate method.

NOTE 3 Values are given for vertical spacings between trays of 300 mm and at least 20 mm between trays and wall. For closer spacing, the factors should be reduced.

NOTE 4 Values are given for horizontal spacing between trays of 225 mm with trays mounted back to back. For closer spacing, the factors should be reduced.

Table B.23 – Reduction factors for groups of more than one circuit of single-core cables (Note 2) – To be applied to the current-carrying capacity for one circuit of single-core cables in free air

Method of installation		Number of trays	Number of three-phase circuits (Note 5) 1	2	3	Use as a multiplier to rating for
Perforated trays (Note 3)	Touching 	1	0,98	0,91	0,87	Three cables in horizontal formation
		2	0,96	0,87	0,81	
		3	0,95	0,85	0,78	
Ladder supports, cleats etc. (Note 3)	Touching 	1	1,00	0,97	0,96	Three cables in horizontal formation
		2	0,98	0,93	0,89	
		3	0,97	0,90	0,86	
Perforated trays (Note 3)		1	1,00	0,98	0,96	Three cables in trefoil formation
		2	0,97	0,93	0,89	
		3	0,96	0,92	0,86	
Vertical perforated trays (Note 4)	 Spaced	1	1,00	0,91	0,89	
		2	1,00	0,90	0,86	
Ladder supports, cleats, etc. (Note 3)		1	1,00	1,00	1,00	
		2	0,97	0,95	0,93	
		3	0,96	0,94	0,90	

NOTE 1 Values given are averages for the cable types and range of conductor sizes considered. The spread of values is generally less than 5 %.

NOTE 2 Factors are given for single layers of cables (or trefoil groups) as shown in the table and do not apply when cables are installed in more than one layer touching each other. Values for such installations may be significantly lower and should be determined by an appropriate method.

NOTE 3 Values are given for vertical spacings between trays of 300 mm. For closer spacing, the factors should be reduced.

NOTE 4 Values are given for horizontal spacing between trays of 225 mm with trays mounted back to back. For closer spacing, the factors should be reduced.

NOTE 5 For circuits having more than one cable in parallel per phase, each three phase set of conductors should be considered as a circuit for the purpose of this table.

Annex C
(normative)

Rounding of numbers

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

The following rules apply when rounding numbers in calculating fictitious diameters and determining dimensions of component layers in accordance with Annex A.

When the calculated value at any stage has more than one decimal place, the value shall be rounded to one decimal place, i.e. to the nearest 0,1 mm. The fictitious diameter at each stage shall be rounded to 0,1 mm and, when used to determine the thickness or dimension of an overlying layer, it shall be rounded before being used in the appropriate formula or table. The thickness calculated from the rounded value of the fictitious diameter shall, in turn, be rounded to 0,1 mm as required in Annex A.

To illustrate these rules, the following practical examples are given:

a) when the figure in the second decimal place before rounding is 0, 1, 2, 3 or 4, then the figure retained in the first decimal place remains unchanged (rounding down);

Examples:

2,12	≈	2,1
2,449	≈	2,4
25,0478	≈	25,0

b) when the figure in the second decimal place before rounding is 9, 8, 7, 6 or 5, then the figure in the first decimal place is increased by one (rounding up).

Examples:

2,17	≈	2,2
2,453	≈	2,5
30,050	≈	30,1

C.2 Rounding of numbers for other purposes

For purposes other than those considered under Clause C.1, it may be required that values are rounded to more than one decimal place. This may occur, for instance, in calculating the average value of several measurement results, or the minimum value by applying a percentage tolerance to a given nominal value. In these cases, rounding shall be carried out to the number of decimal places specified in the relevant clauses.

The method of rounding shall then be as follows:

a) if the last figure to be retained is followed, before rounding, by 0, 1, 2, 3 or 4, it shall remain unchanged (rounding down);

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

Examples:

2,449	≈	2,45	rounded to two decimal places
2,449	≈	2,4	rounded to one decimal place
25,0478	≈	25,048	rounded to three decimal places
25,0478	≈	25,05	rounded to two decimal places
25,0478	≈	25,0	rounded to one decimal place

Annex D
(normative)

Method of measuring resistivity of semi-conducting screens

Each test piece shall be prepared from a 150 mm sample of completed cable.

The conductor screen test piece shall be prepared by cutting a sample of core in half longitudinally and removing the conductor and separator if any (see Figure D.1a). The insulation screen test piece shall be prepared by removing all the coverings from the sample of core (see Figure D.1b).

The procedure for determining the volume resistivity of the screens shall be as follows:

Four silver-painted electrodes A, B, C, and D (see Figures D.1a and D.1b) shall be applied to the semi-conducting surfaces. The two potential electrodes, B and C, shall be 50 mm apart and the two current electrodes, A and D, shall be each placed at least 25 mm beyond the potential electrodes.

Connections shall be made to the electrodes by means of suitable clips. In making connections to the conductor screen electrodes it shall be ensured that the clips are insulated from the insulation screen on the outer surface of the test sample.

The assembly shall be placed in an oven preheated to the specified temperature and, after an interval of at least 30 min, the resistance between the electrodes shall be measured by means of a circuit, the power of which shall not exceed 100 mW.

After the electrical measurements, the diameters over the conductor screen and insulation screen and the thicknesses of the conductor screen and insulation screen shall be measured at ambient temperature, each being the average of six measurements made on the sample shown in Figure D.1b.

The volume resistivity ρ in ohm · metres shall be calculated as follows:

a) conductor screen

$$\rho_c = \frac{R_c \times \pi \times (D_c - T_c) \times T_c}{2L_c}$$

where

ρ_c is the volume resistivity, in ohm · metres;

R_c is the measured resistance, in ohms;

L_c is the distance between potential electrodes, in metres;

D_c is the outer diameter over the conductor screen, in metres;

T_c is the average thickness of conductor screen, in metres.

b) insulation screen

$$\rho_i = \frac{R_i \times \pi \times (D_i - T_i) \times T_i}{L_i}$$

where

ρ_i is the volume resistivity, in ohm · metres;

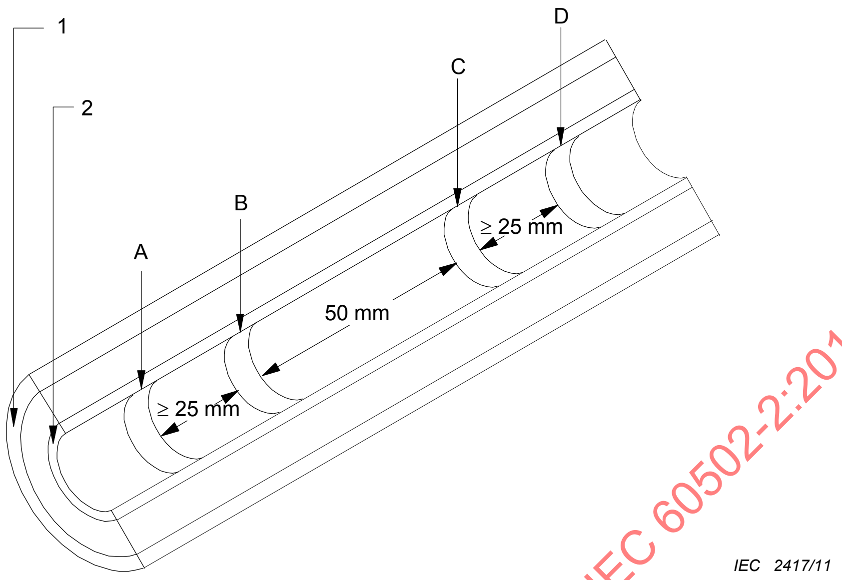
R_i is the measured resistance, in ohms;

L_i is the distance between potential electrodes, in metres;

D_i is the outer diameter over the insulation screen, in metres;

T_i is the average thickness of insulation screen, in metres.

Dimensions in millimetres

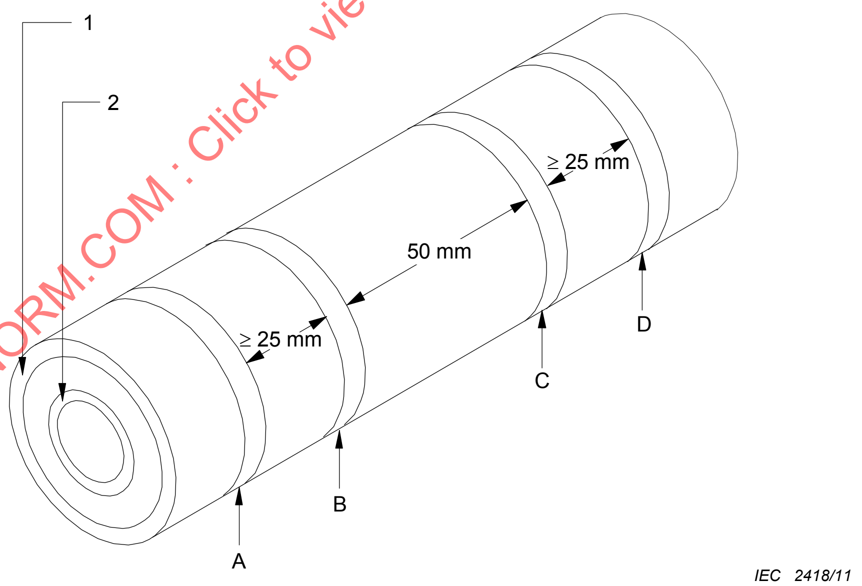


Key

1	insulation screen	B, C	potential electrodes
2	conductor screen	A, D	current electrodes

Figure D.1a – Measurement of the volume resistivity of the conductor screen

Dimensions in millimetres



Key

1	insulation screen	B, C	potential electrodes
2	conductor screen	A, D	current electrodes

Figure D.1b – Measurement of the volume resistivity of the insulation screen

Figure D.1 – Preparation of samples for measurement of resistivity of conductor and insulation screens

Annex E
(normative)

Determination of hardness of HEPR insulations

E.1 Test piece

The test piece shall be a sample of completed cable with all the coverings, external to the HEPR insulation to be measured, carefully removed. Alternatively, a sample of insulated core may be used.

E.2 Test procedure

E.2.1 General

Tests shall be made in accordance with ISO 48 with exceptions as indicated below.

E.2.2 Surfaces of large radius of curvature

The test instrument, in accordance with ISO 48, shall be constructed so as to rest firmly on the HEPR insulation and permit the presser foot and indentor to make vertical contact with this surface. This is done in one of the following ways:

a) the instrument is fitted with feet moveable in universal joints so that they adjust themselves to the curved surface;

b) the base of the instrument is fitted with two parallel rods A and A' at a distance apart depending on the curvature of the surface (see Figure E.1).

These methods may be used on surfaces with radius of curvature down to 20 mm.

When the thickness of HEPR insulation tested is less than 4 mm, an instrument as described in the method in ISO 48 for thin and small test pieces shall be used.

E.2.3 Surfaces of small radius of curvature

On surfaces with too small a radius of curvature for the procedures described in E.2.2, the test piece shall be supported on the same rigid base as the test instrument, in such a way as to minimize bodily movement of the HEPR insulation when the indenting force increment is applied to the indentor and so that the indentor is vertically above the axis of the test piece. Suitable procedures are as follows:

a) by resting the test piece in a grove or trough in a metal jig (see Figure E.2a);

b) by resting the ends of the conductor of the test piece in V-blocks (see Figure E.2b).

The smallest radius of curvature of the surface to be measured by these methods shall be at least 4 mm.

For smaller radii, an instrument as described in the method in ISO 48 for thin and small test pieces shall be used.

E.2.4 Conditioning and test temperature

The minimum time between manufacture, i.e. vulcanization and testing, shall be 16 h.

The test shall be carried out at a temperature of (20 ± 2) °C and the test pieces shall be maintained at this temperature for at least 3 h immediately before testing.

E.2.5 Number of measurements

One measurement shall be made at each of three or five different points distributed around the test piece. The median of the results shall be taken as the hardness of the test piece, reported to the nearest whole number in international rubber hardness degrees (IRHD).

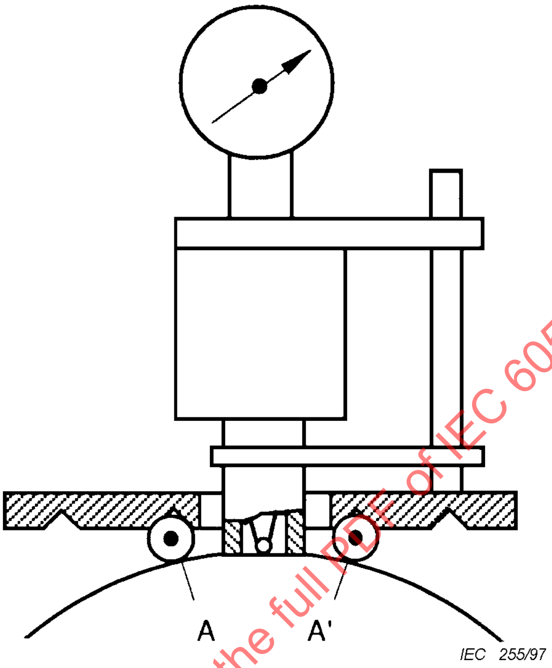


Figure E.1 – Test on surfaces of large radius of curvature

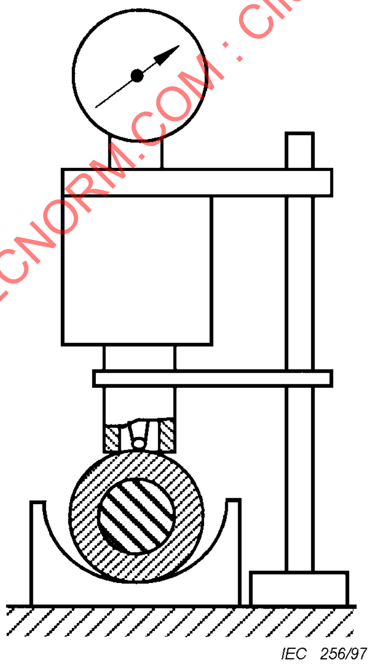


Figure E.2a – Test piece groove

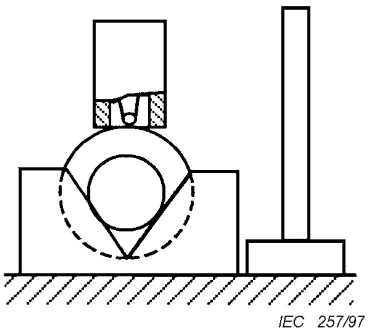


Figure E.2b – Test piece in V-blocks

Figure E.2 – Test on surfaces of small radius of curvature

Annex F
(normative)

Water penetration test

F.1 Test piece

A sample of completed cable at least 6 m in length which has not been subjected to any of the tests described in Clause 18 shall be subjected to a bending test described in 18.2.4 without the additional partial discharge test.

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

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

The surfaces shall be cut so that the interfaces intended to be longitudinally watertight shall be readily exposed to the water. The interfaces not intended to be longitudinally watertight shall be sealed with a suitable material or the outer coverings removed.

Examples of these latter interfaces include:

– when only the conductor of the cable has a barrier;
– the interface between the oversheath and the metal sheath.

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

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

F.2 Test

The tube is filled within 5 min with water at an ambient temperature of (20 ± 10) °C so that the height of the water in the tube is 1 m above the cable centre (see Figure F.1). The sample shall be allowed to stand for 24 h.

The sample shall then be subjected to 10 heating cycles by passing current through the conductor, until the conductor reaches a steady temperature 5 K to 10 K above the maximum conductor temperature in normal operation and which shall not reach 100 °C.

The duration of the heating cycle shall be at least 8 h. 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.

The water head shall be maintained at 1 m.

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

F.3 Requirements

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

Dimensions in millimetres

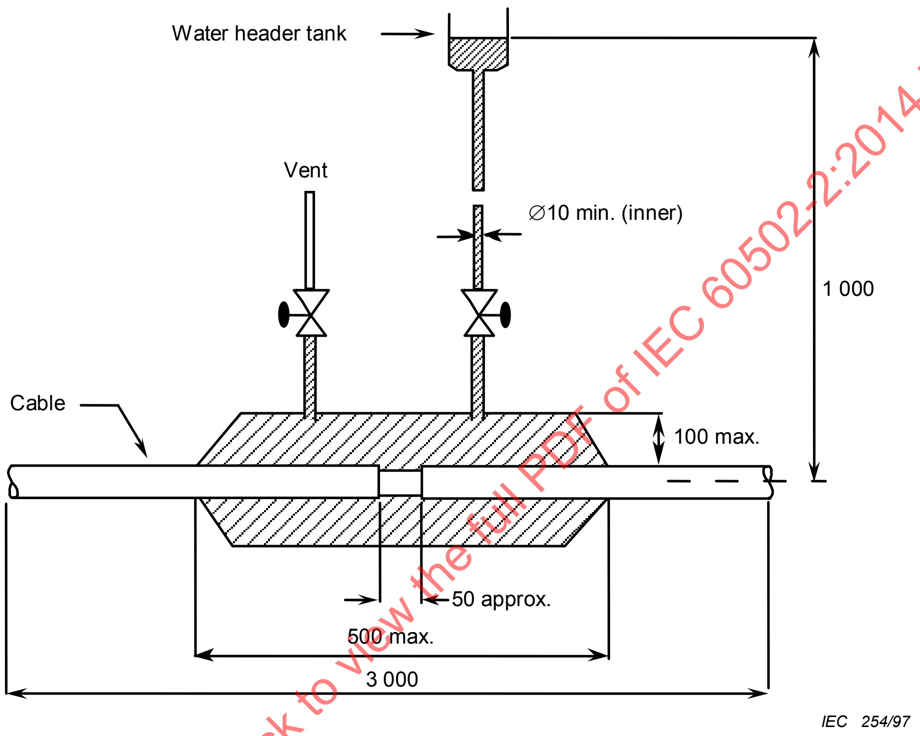


Figure F.1 – Schematic diagram of apparatus for water penetration test

Annex G
(informative)

Determination of the cable conductor temperature

G.1 Purpose

For some tests, it is necessary to raise the cable conductor to a given temperature, typically 5 K to 10 K above the maximum temperature in normal operation, while the cable is energized, either at power frequency or under impulse conditions. It is therefore not possible to have access to the conductor to enable direct measurement of temperature.

In addition, the conductor temperature should be maintained within a restricted range (5 K) whereas the ambient temperature may vary over a wider range.

Although preliminary calibration on the cable under test or calculations may be satisfactory in the first place, the variation of ambient conditions throughout the duration of the test may lead to deviations of the temperature of the conductor outside range.

Therefore, methods should be used in which the conductor temperature can be monitored and controlled throughout the duration of the test.

Guidance is given hereafter on commonly used methods.

G.2 Calibration of the temperature of the main test loop

G.2.1 General

The purpose of the calibration is to determine the conductor temperature by direct measurement for a given current within the temperature range required for the test.

The cable used for calibration (hereafter called reference cable) should be taken from same length as the cable used for the main test loop.

G.2.2 Installation of cable and temperature sensors

The calibration should be performed on a minimum cable length of 5 m, taken from the same cable as tested. The length should be such that the longitudinal heat transfer to the cable ends does not affect the temperature in the centre 2 m of cable by more than 2 K.

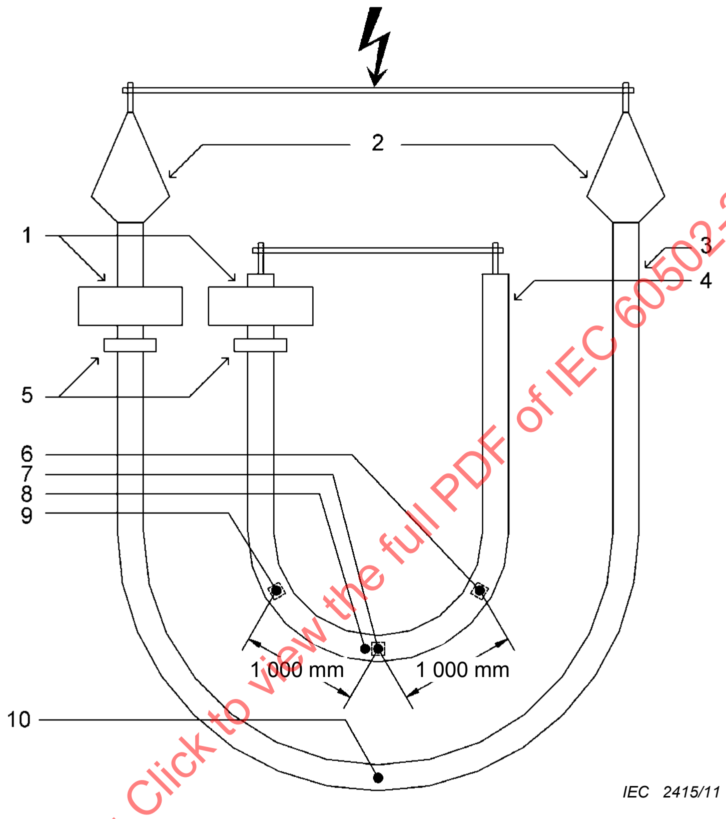
At the middle of the reference cable, two temperature sensors should be attached: one on the conductor (TC_{1c}), and one on the external surface or directly under the external surface (TC_{1s}).

Two other temperature sensors, TC_{2c} and TC_{3c}, should be installed on the conductor of the reference cable (see Figure G.1), each one about 1 m away from the middle.

The temperature sensors should be attached to the conductor by mechanical means since they may move due to vibrations of the cable during heating. Care should be taken to maintain good thermal contact during the tests and to prevent leakage of heat to the ambient. It is recommended to mount the thermocouple(s) as shown in Figure G.2 between two strands of a stranded conductor or between the (solid) conductor and the conductor screen. To enable access to the conductor in the middle of the reference cable, a small hatch should be made by careful removal of the layers above the conductor. After installing the temperature sensor(s), the layers that have been removed may be put back. This may restore the thermal behaviour of the reference cable.

NOTE To prove a negligible heat transfer towards the cable ends, the difference between the readings of TC_{1C}, TC_{2C} and TC_{3C} should be less than 2 K.

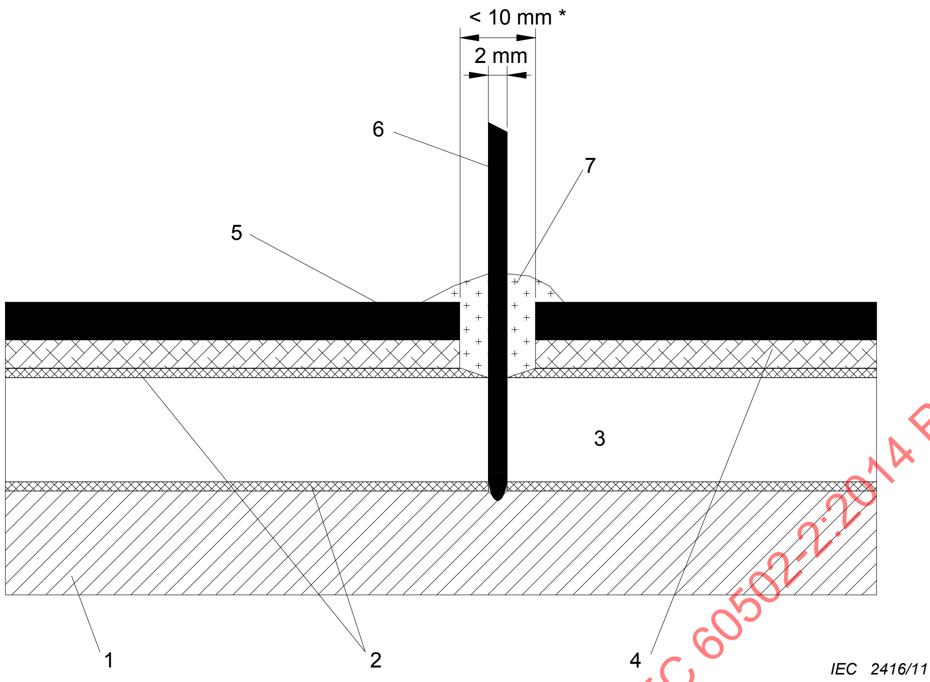
If the main test loop includes several individual cable lengths installed close to each other, these lengths will be subjected to thermal proximity effect. The calibration should therefore be carried out, taking into account the actual test arrangement, measurements being performed on the hottest cable length (usually the middle length).



Key

1	current inducing transformers	6	TC_{3c} (conductor)
2	terminations	7	TC_{1c} (conductor)
3	cable under test	8	TC_{1s} (sheath)
4	reference cable (≥5 m)	9	TC_{2c} (conductor)
5	current measuring transformers	10	TC_s (sheath)

Figure G.1 – Typical test set-up for the reference loop and the main test loop



Key

1 conductor
2 semi-conducting screens
3 insulation
4 metal sheath
5 cable oversheath
6 temperature sensor
7 flexible thermal insulating compound
* as small as possible

Figure G.2 – Example of an arrangement of the temperature sensors on the conductor of the reference loop

G.2.3 Calibration method

The calibration should be carried out in a draught-free situation at a temperature of (20 ± 15) °C.

Temperature recorders should be used to measure the conductor, oversheath and ambient temperatures simultaneously.

The cable should be heated until the conductor temperatures, indicated by temperature sensors TC_{1c} of Figure G.1, have stabilized and reached the following temperatures: between 5 K and 10 K above the maximum conductor temperature of the cable in normal operation, as given in Table 1.

When stabilization has been reached, the following should be noted:

– conductor temperature: average value at positions 1, 2 and 3;
– oversheath temperature at position TC_{1s};
– ambient temperature;
– heating current.

G.3 Heating for the test

G.3.1 Method 1 – Test using a reference cable

In this method, a reference cable identical to the cable used for the test is heated with the same current value as the main test loop.

The installation of cable and temperature sensors for both loops should be as given in Clause G.2.

The test arrangement should be such that

– the reference cable carries the same current as the main test loop at any time;
– it is installed in such a way that mutual heating effects are taken into account throughout the test.

The heating current of both loops should be adjusted such that the conductor temperature is kept within the specified limits.

A temperature sensor (TC_S) should be mounted on or under the external surface of the main test loop at the hottest spot, usually in the middle of it, in the same way as temperature sensor TC_{1s} is mounted on the hottest spot of the reference cable.

NOTE 1 The temperature measured with the temperature sensors on or under the oversheath of the main test loop (TC_S) and on the reference loop (TC_{1s}) are used to check whether the oversheath of both loops has the same temperature.

The temperature measured with temperature sensor TC_{1C} on the conductor of the reference loop may be considered as to be representative for the conductor temperature of the energized test loop.

NOTE 2 The temperature of the conductor of the main test loop may be slightly higher than that of the reference loop because of dielectric losses. If necessary, a correction should be made.

All temperature sensors should be connected to a recorder to enable temperature monitoring. The heating current of each loop should also be recorded to prove that the two currents are of the same value throughout the duration of the test. The difference between the heating currents should be kept within ±1 %.

The reference cable may be connected in series with the test cable if the temperature is measured via an optical fibre link or equivalent.

G.3.2 Method 2 – Test using conductor temperature calculations and measurement of the surface temperature

G.3.2.1 Calibration of the test cable conductor temperature

The purpose of the calibration is to determine the conductor temperature by direct measurement for a given current, within the temperature range required for the test.

The cable used for calibration should be identical to that to be used for the test, and the way of heating should be identical.

The installation of cable and temperature sensors for the calibration should be as given in Clause G.2.

The calibration should be carried out in accordance with G.2.3 for the reference cable.

G.3.2.2 Test based on measurement of the external temperature

During calibration and during the test of the main loop, the cable conductor temperature of the main test loop should be calculated in accordance with IEC 60853-2, based on the measured external temperature of the oversheath (TC_S). The measurement should be done with a temperature sensor at the hottest spot, attached to or under the external surface, in the same way as for the reference cable.

NOTE As an alternative, IEC 60287-2 (all parts 2) may be used if demonstrated that asymptotic transient temperature is reached within the specified time

The heating current should be adjusted to obtain the required value of the calculated conductor temperature, based on the measured external temperature of the oversheath.

Bibliography

IEC 60287 (all parts), *Electric cables – Calculation of the current rating*

IEC 60502-1, *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 1: Cables for rated voltages of 1 kV (U_m = 1,2 kV) and 3 kV (U_m = 3,6 kV)*

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SOMMAIRE

COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

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CÂBLES D'ÉNERGIE À ISOLANT EXTRUDÉ ET LEURS ACCESSOIRES POUR DES TENSIONS ASSIGNÉES DE 1 kV (U_m = 1,2 kV) À 30 kV (U_m = 36 kV) –

Partie 2: Câbles de tensions assignées de 6 kV (U_m = 7,2 kV) à 30 kV (U_m = 36 kV)

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La Norme internationale CEI 60502-2 a été établie par le comité d'études 20 de la CEI: Câbles électriques.

Cette troisième édition annule et remplace la deuxième édition publiée en 2005 et constitue une révision technique.

Des changements techniques significatifs ont été apportés par rapport à la deuxième édition:

a) une procédure de calcul simplifié pour l'épaisseur de la gaine de plomb et de la gaine extérieure;
b) un nouveau paragraphe concernant la détermination de la température de l'âme du câble;

c) une procédure modifiée des essais individuels de tension;

d) un nouveau paragraphe concernant l'essai individuel électrique de la gaine extérieure;

e) les exigences modifiées pour les gaines non métalliques y compris une couche semi-conductrice;

f) les tolérances modifiées concernant l'essai d'enroulement d'un cylindre d'essai;

g) l'ajout d'un essai sous 0,1 Hz après l'installation.

De plus, la structure modifiée de la série CEI 60811 est adoptée dans cette troisième édition.

Les deux remplacements «metallic» par «metal» et «thermosetting» par «crossliked» ne concernent que la version anglaise.

Le texte de cette norme est issu des documents suivants:

FDIS	Rapport de vote
20/1469A/FDIS	20/1472/RVD

Le rapport de vote indiqué dans le tableau ci-dessus donne toute information sur le vote ayant abouti à l'approbation de cette norme.

Cette publication a été rédigée selon les Directives ISO/CEI, Partie 2.

Une liste de toutes les parties de la série CEI 60502, publiées sous le titre général *Câbles électriques à isolant extrudé et leurs accessoires pour des tensions assignées de 1 kV (U_m = 1,2 kV) à 30 kV (U_m = 36 kV)*, peut être consultée sur le site web de la CEI.

Le comité a décidé que le contenu de cette publication ne sera pas modifié avant la date de maintenance indiquée sur le site web de la CEI sous «http://webstore.iec.ch» dans les données relatives à la publication recherchée. A cette date, la publication sera

- reconduite;
- supprimée;
- remplacée par une édition révisée, ou
- amendée.

CÂBLES D'ÉNERGIE À ISOLANT EXTRUDÉ ET LEURS ACCESSOIRES POUR DES TENSIONS ASSIGNÉES DE 1 kV (U_m = 1,2 kV) À 30 kV (U_m = 36 kV) –

Partie 2: Câbles de tensions assignées de 6 kV (U_m = 7,2 kV) à 30 kV (U_m = 36 kV)

1 Domaine d'application

La présente partie de la CEI 60502 spécifie la constitution, les dimensions et les exigences d'essais des câbles d'énergie à isolation extrudée par diélectriques massifs, de tensions assignées de 6 kV à 30 kV, pour installations fixes telles que les réseaux de distribution ou les installations industrielles.

Pour la conception des câbles, il est recommandé de tenir compte du risque possible d'une entrée d'eau radiale. Les câbles dont la conception est déclarée comporter une barrière d'étanchéité longitudinale à l'eau et les essais qui y correspondent sont inclus dans cette partie de la CEI 60502.

Les câbles destinés à des conditions particulières d'installations et de service ne sont pas inclus, par exemple, les câbles pour réseaux aériens, pour l'industrie minière, pour les centrales nucléaires (à l'intérieur et à l'extérieur de l'enceinte de confinement), les câbles sous-marins ou les câbles de bord des navires.

2 Références normatives

Les documents suivants sont cités en référence de manière normative, en intégralité ou en partie, dans le présent document et sont indispensables pour son application. Pour les références datées, seule l'édition citée s'applique. Pour les références non datées, la dernière édition du document de référence s'applique (y compris les éventuels amendements).

CEI 60038, *Tensions normales de la CEI*

CEI 60060-1, *Techniques des essais à haute tension –Partie 1: Définitions et exigences générales*

IEC 60060-3, *High-voltage test techniques – Part 3: Definitions and requirements for on-site testing* (disponible en anglais seulement)

CEI 60183, *Guide pour le choix des câbles à haute tension*

CEI 60228, *Ames des câbles isolés*

CEI 60229:2007, *Câble électriques – Essais sur les gaines extérieures extrudées avec fonction spéciale de protection*

CEI 60230, *Essais de choc des câbles et de leurs accessoires*

CEI 60287-3-1, *Câbles électriques – Calcul du courant admissible – Partie 3: Sections concernant les conditions de fonctionnement – Section 1: Conditions de fonctionnement de référence et sélection du type de câble*

CEI 60332-1-2, *Essais des câbles électriques soumis au feu – Partie 1-2: Essai de propagation verticale de la flamme sur conducteur ou câble isolé – Procédure pour flamme à prémélange de 1 kW*

CEI 60811 (toutes les parties), *Câbles électriques et à fibres optiques – Méthodes d'essai pour les matériaux non-métalliques*

CEI 60811-201, *Câbles électriques et à fibres optiques – Méthodes d'essai pour les matériaux non-métalliques – Partie 201: Essais généraux – Mesure de l'épaisseur des enveloppes isolantes*

CEI 60811-202, *Câbles électriques et à fibres optiques – Méthodes d'essai pour les matériaux non-métalliques – Partie 202: Essais généraux – Mesure de l'épaisseur des gaines non métalliques*

CEI 60811-203, *Câbles électriques et à fibres optiques – Méthodes d'essai pour les matériaux non-métalliques – Partie 203: Essais généraux – Mesure des dimensions extérieures*

CEI 60811-401, *Câbles électriques et à fibres optiques – Méthodes d'essai pour les matériaux non-métalliques – Partie 401: Essais divers – Méthodes de vieillissement thermique – Vieillissement en étuve à air*

CEI 60811-402, *Câbles électriques et à fibres optiques – Méthodes d'essai pour les matériaux non-métalliques – Partie 402: Essais divers – Essais d'absorption d'eau*

CEI 60811-403, *Câbles électriques et à fibres optiques – Méthodes d'essai pour les matériaux non-métalliques – Partie 403: Essais divers – Essai de résistance à l'ozone sur les mélanges réticulés*

CEI 60811-404, *Câbles électriques et à fibres optiques – Méthodes d'essai pour les matériaux non-métalliques – Partie 404: Essais divers – Essais de résistance à l'huile minérale pour les gaines*

CEI 60811-405, *Câbles électriques et à fibres optiques – Méthodes d'essai pour les matériaux non-métalliques – Partie 405: Essais divers – Essai de stabilité thermique pour les enveloppes isolantes et gaines en PVC*

CEI 60811-409, *Câbles électriques et à fibres optiques – Méthodes d'essai pour les matériaux non-métalliques – Partie 409: Essais divers – Essai de perte de masse des enveloppes isolantes et gaines thermoplastiques*

CEI 60811-501, *Câbles électriques et à fibres optiques – Méthodes d'essai pour les matériaux non-métalliques – Partie 501: Essais mécaniques – Détermination des propriétés mécaniques des mélanges pour les enveloppes isolantes et les gaines*

CEI 60811-502, *Câbles électriques et à fibres optiques – Méthodes d'essai pour les matériaux non-métalliques – Partie 502: Essais mécaniques – Essai de rétraction des enveloppes isolantes*

CEI 60811-503, *Câbles électriques et à fibres optiques – Méthodes d'essai pour les matériaux non-métalliques – Partie 503: Essais mécaniques – Essai de rétraction des gaines*

CEI 60811-504, *Câbles électriques et à fibres optiques – Méthodes d'essai pour les matériaux non-métalliques – Partie 504: Essais mécaniques – Essai d'enroulement à basse température pour les enveloppes isolantes et les gaines*

CEI 60811-505, *Câbles électriques et à fibres optiques – Méthodes d'essai pour les matériaux non-métalliques – Partie 503: Essais mécaniques – Essai d'allongement à basse température pour les enveloppes isolantes et les gaines*

CEI 60811-506, *Câbles électriques et à fibres optiques – Méthodes d'essai pour les matériaux non-métalliques – Partie 506: Essais mécaniques – Essai de choc à basse température pour les enveloppes isolantes et les gaines*

CEI 60811-507, *Câbles électriques et à fibres optiques – Méthodes d'essai pour les matériaux non-métalliques – Partie 507: Essais mécaniques – Essai d'allongement à chaud pour les matériaux réticulés*

CEI 60811-508, *Câbles électriques et à fibres optiques – Méthodes d'essai pour les matériaux non-métalliques – Partie 508: Essais mécaniques – Essai de pression à température élevée pour les enveloppes isolantes et les gaines*

CEI 60811-509, *Câbles électriques et à fibres optiques – Méthodes d'essai pour les matériaux non-métalliques – Partie 509: Essais mécaniques – Essai de résistance à la fissuration des enveloppes isolantes et des gaines (essai de choc thermique)*

CEI 60811-605, Câbles électriques et à fibres optiques – Méthodes d'essai pour les matériaux non-métalliques – Partie 605: Essais physiques – Mesure du taux de noir de carbone et/ou des charges minérales dans les mélanges en polyéthylène

CEI 60811-606, *Câbles électriques et à fibres optiques – Méthodes d'essai pour les matériaux non-métalliques – Partie 606: Essais physiques – Méthodes de détermination de la masse volumique*

CEI 60853 (toutes les parties), *Calcul des capacités de transport des câbles pour les régimes de charge cycliques et de surcharge de secours*

CEI 60853-2, *Calcul des capacités de transport des câbles pour les régimes de charge cycliques et de surcharge de secours – Partie 2: Régime cyclique pour des câbles de tensions supérieures à 18/30 (36) kV et régimes de secours pour des câbles de toutes tensions*

CEI 60885-3, *Méthodes d'essais électriques pour les câbles électriques – Partie 3: Méthodes d'essais pour mesures de décharges partielles sur longueurs de câbles de puissance extrudés*

CEI 60986, *Limites de température de court-circuit des câbles électriques de tensions assignées de 6 kV (U_m = 7,2 kV) à 30 kV (U_m = 36 kV)*

ISO 48, *Caoutchouc vulcanisé ou thermoplastique – Détermination de la dureté (dureté comprise entre 10 DIDC et 100 DIDC)*

3 Termes et définitions

Pour les besoins du présent document, les termes et définitions suivants s'appliquent.

3.1 Définitions de valeurs dimensionnelles (épaisseurs, sections, etc.)

3.1.1
valeur nominale
valeur par laquelle une grandeur est dénommée et qui est souvent utilisée dans les tableaux

Note 1 à l'article: Régulièrement, dans cette norme, les valeurs nominales correspondent à des valeurs qui sont vérifiées par des mesures, compte tenu des tolérances spécifiées.

3.1.2
valeur approximative
valeur qui n'est ni garantie ni vérifiée; elle est utilisée, par exemple, pour le calcul d'autres dimensions

3.1.3
valeur médiane
quand plusieurs résultats d'essais sont obtenus et classés par ordre de valeurs croissantes (ou décroissantes), la valeur médiane est la valeur du milieu de la série si le nombre de

valeurs disponibles est impair, et la moyenne arithmétique des deux valeurs centrales de la série si le nombre est pair

3.1.4
valeur fictive
valeur calculée suivant la «méthode du calcul fictif» définie à l'Annexe A

3.2 Définitions relatives aux essais

3.2.1
essais individuels
essais effectués par le fabricant sur chacune des longueurs de câble produit afin de vérifier que chaque longueur répond aux caractéristiques spécifiées

3.2.2
essais sur prélèvements
essais effectués par le fabricant sur des échantillons de câble complet ou sur des constituants prélevés sur câble complet, à une fréquence spécifiée, afin de vérifier que le produit fini répond aux caractéristiques spécifiées

3.2.3
essais de type
essais effectués avant la livraison sur une base commerciale générale d'un type de câble concerné par cette norme, afin de démontrer que ses caractéristiques répondent aux applications prévues

Note 1 à l'article: Ces essais sont de telle nature qu'après avoir été effectués, il n'est pas nécessaire de les répéter, à moins que des modifications n'aient été introduites dans les matériaux, dans la conception du câble ou dans le procédé de fabrication, susceptibles d'en modifier les caractéristiques.

3.2.4
essais électriques après pose
essais effectués pour vérifier l'intégrité du câble et de ses accessoires après la pos

4 Désignation des tensions et des matériaux

4.1 Tensions assignées

Les tensions assignées U_0/U (U_m) des câbles concernés par cette norme sont les suivantes:

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

NOTE Les tensions indiquées ci-dessus constituent les désignations correctes, bien que d'autres désignations soient utilisées dans certains pays, par exemple 3,5/6 – 5,8/10 – 11,5/20 – 17,3/30 kV.

Dans la désignation des tensions des câbles U_0/U (U_m):

U_0 est la tension assignée à fréquence industrielle entre chacun des conducteurs et la terre, ou l'écran métallique, pour laquelle le câble est conçu;

U est la tension assignée à fréquence industrielle entre conducteurs, pour laquelle le câble est conçu;

U_m est la valeur maximale de la «tension la plus élevée du réseau» pour laquelle le matériel peut être utilisé (voir CEI 60038).

Pour une application donnée, la tension assignée d'un câble doit être adaptée aux conditions d'exploitation du réseau dans lequel il est utilisé. Pour faciliter le choix du câble, les réseaux sont divisés en trois catégories:

– catégorie A: cette catégorie comprend les réseaux dans lesquels tout conducteur de phase qui entre en contact avec la terre ou avec un conducteur de terre est déconnecté du réseau en moins de 1 min;

– catégorie B: cette catégorie comprend les réseaux qui, en régime de défaut, continuent à être exploités pendant un temps limité avec une phase à la terre. Selon la CEI 60183, il convient que cette durée ne dépasse pas 1 h. Pour les câbles concernés par cette norme, une durée plus longue peut être tolérée, ne dépassant cependant 8 h en aucun cas. Il convient que la durée cumulée des défauts à la terre sur une année quelconque ne dépasse pas 125 h;

– catégorie C: cette catégorie comprend tous les réseaux qui n'entrent pas dans l'une des catégories A ou B.

Il convient d'avoir à l'esprit que, dans un réseau où un défaut à la terre n'est pas éliminé automatiquement et rapidement, les contraintes supplémentaires supportées par l'isolation des câbles pendant la durée du défaut réduisent la vie de ceux-ci dans une certaine proportion. S'il est prévu que le réseau fonctionne assez souvent avec un défaut permanent à la terre, il peut être prudent de classer le réseau dans la catégorie C.

Les valeurs recommandées de U_0 pour les câbles utilisés dans les réseaux triphasés sont indiquées au Tableau 1.

Tableau 1 – Tensions assignées recommandées U_0

Tension la plus élevée du réseau (U_m) kV	**Tension assignée (U_0)** kV	
	Catégories A et B	**Catégorie 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 Mélanges isolants

Les types de mélanges isolants concernés par cette norme sont énumérés dans le Tableau 2, ainsi que leurs désignations abrégées.

Tableau 2 – Mélanges isolants

Mélange isolant	**Désignation abrégée**
a) *Thermoplastique:*	
polychlorure de vinyle pour les câbles de tension assignée U_0/U = 3,6/6 kV	PVC/B *
b) *Réticulé:*	
caoutchouc d'éthylène propylène ou matériau similaire (EPM ou EPDM)	EPR
caoutchouc d'éthylène propylène dur ou à module élevé	HEPR
polyéthylène réticulé	PR
* Le mélange isolant à base de polychlorure de vinyle destiné aux câbles de tension assignée $U_0/U \leq$ 1,8/3 kV est désigné PVC/A dans la CEI 60502-1.	

Pour les différents types de mélanges isolants concernés par cette norme, les températures maximales de l'âme sont données dans le Tableau 3.

Tableau 3 – Températures maximales de l'âme pour les différents types de mélanges isolants

Mélange isolant		Température maximale de l'âme °C	
		Service normal	Court-circuit (durée maximale 5 s)
Polychlorure de vinyle	(PVC/B)		
	Section d'âme ≤300 mm²	70	160
	Section d'âme >300 mm²	70	140
Polyéthylène réticulé	(PR)	90	250
Caoutchouc d'éthylène propylène	(EPR et HEPR)	90	250

Les températures indiquées dans le Tableau 3 sont basées sur les propriétés intrinsèques des matériaux isolants. Il est important de prendre en compte d'autres facteurs lorsque ces valeurs sont utilisées pour le calcul d'intensités admissibles.

Par exemple, en service normal, si un câble enterré directement dans le sol est exploité en régime permanent (facteur de charge de 100 %) à la température maximale de l'âme conductrice indiquée dans le tableau, la résistivité thermique du sol environnant peut, à la longue, dépasser sa valeur initiale par l'effet du dessèchement qui en résulte. La température de l'âme risque alors de dépasser largement la valeur maximale. Si de telles conditions de service sont envisagées, des précautions appropriées doivent être prises.

Pour des indications sur les courants admissibles en régime permanent, il convient de se référer à l'Annexe B, qui comprend les Tableaux B.2 à B.9, concernant les courants admissibles dans des conditions de pose normales et les Tableaux B.10 à B.23, concernant les facteurs de correction pour des conditions de pose particulières.

Pour des indications sur les températures de court-circuit, il convient de se référer à la CEI 60986.

4.3 Mélanges pour gaine

Pour les différents types de mélanges pour gaine concernés par cette norme, les températures maximales de l'âme sont données dans le Tableau 4.

Tableau 4 – Températures maximales de l'âme pour les différents types de mélanges pour gaine

Mélange pour gaine	Désignation abrégée	Température maximale de l'âme en service normal °C
a) *Thermoplastique:*		
polychlorure de vinyle (PVC)	ST_1	80
	ST_2	90
polyéthylène	ST_3	80
	ST_7	90
b) *Elastomère:*		
polychloroprène, polyéthylène chlorosulfoné ou polymères similaires	SE_1	85

5 Ames conductrices

Les âmes doivent être soit de classe 1 soit de classe 2 en cuivre recuit, nu ou revêtu d'une couche métallique, ou en aluminium nu ou en alliage d'aluminium conformément à la CEI 60228. Pour les âmes de classe 2, des dispositions peuvent être prises pour rendre celles-ci étanches longitudinalement.

6 Enveloppe isolante

6.1 Matériau

L'enveloppe isolante doit être constituée d'un diélectrique massif extrudé, de l'un des types énumérés dans le Tableau 2.

6.2 Épaisseur de l'enveloppe isolante

Les épaisseurs nominales de l'enveloppe isolante sont spécifiées dans les Tableaux 5 à 7.

L'épaisseur d'un éventuel séparateur, ou d'un écran semiconducteur sur âme ou sur enveloppe isolante, ne doit pas être comprise dans celle de l'enveloppe isolante.

Tableau 5 – Epaisseur nominale de l'enveloppe isolante en PVC/B

Section nominale de l'âme mm²	Epaisseur nominale de l'enveloppe isolante à la tension assignée 3,6/6 (7,2) kV mm
10 à 1 600	3,4

NOTE 1 L'emploi d'âmes conductrices de section inférieure à celles indiquées dans ce tableau n'est pas conseillé. Toutefois, si une âme de section inférieure est nécessaire, il faut soit augmenter le diamètre de l'âme par un écran sur âme (voir 7.2), soit majorer l'épaisseur de l'enveloppe isolante de manière à limiter le gradient électrique maximal, appliqué à l'enveloppe isolante sous la tension d'essai, aux valeurs calculées pour la plus petite section d'âme indiquée dans ce tableau.

NOTE 2 Pour des âmes de sections supérieures à 1 000 mm², l'épaisseur de l'enveloppe isolante peut être augmentée afin d'éviter un quelconque dommage mécanique pendant l'installation et en exploitation.

Tableau 6 – Epaisseur nominale de l'enveloppe isolante en polyéthylène réticulé (PR)

Section nominale de l'âme mm²	Epaisseur nominale de l'enveloppe isolante à la tension assignée 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 à 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 à 1 600	3,2	3,4	4,5	5,5	8,0

NOTE 1 L'emploi d'âmes conductrices de section inférieure à celles indiquées dans ce tableau n'est pas conseillé. Toutefois, si une âme de section inférieure est nécessaire, il convient soit d'augmenter le diamètre de l'âme par un écran sur âme (voir 7.2), soit de majorer l'épaisseur de l'enveloppe isolante de manière à limiter le gradient électrique maximal, appliqué à l'enveloppe isolante sous la tension d'essai, aux valeurs calculées pour la plus petite section d'âme indiquée dans ce tableau.

NOTE 2 Pour des âmes de sections supérieures à 1 000 mm², l'épaisseur de l'enveloppe isolante peut être augmentée afin d'éviter un quelconque dommage mécanique pendant l'installation et en exploitation.

Tableau 7 – Epaisseur nominale de l'enveloppe isolante en caoutchouc d'éthylène propylène (EPR) et caoutchouc d'éthylène propylène dur (HEPR)

Section nominale de l'âme	Epaisseur nominale de l'enveloppe isolante à la tension assignée 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
mm²	Sans écran mm	Avec écran 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 à 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 à 1 600	3,2	3,2	3,4	4,5	5,5	8,0

NOTE 1 L'emploi d'âmes conductrices de section inférieure à celles indiquées dans ce tableau n'est pas conseillé. Toutefois, si une âme de section inférieure est nécessaire, il convient soit d'augmenter le diamètre de l'âme par un écran sur âme (voir 7.2), soit de majorer l'épaisseur de l'enveloppe isolante de manière à limiter le gradient électrique maximal, appliqué à l'enveloppe isolante sous la tension d'essai, aux valeurs calculées pour la plus petite section d'âme indiquée dans ce tableau.

NOTE 2 Pour des âmes de sections supérieures à 1 000 mm², l'épaisseur de l'enveloppe isolante peut être augmentée afin d'éviter un quelconque dommage mécanique pendant l'installation et en exploitation.

7 Ecrans

7.1 Généralités

Tous les câbles doivent comporter un revêtement métallique, soit individuel sur chaque conducteur, soit collectif.

S'ils sont prescrits, les écrans sur conducteurs de câbles unipolaires ou tripolaires doivent consister en un écran sur âme et un écran sur enveloppe isolante. Ceux-ci sont obligatoires sur tous les câbles, avec les exceptions suivantes:

a) les câbles de tension assignée 3,6/6 (7,2) kV isolés à l'EPR ou au HEPR peuvent ne pas comporter d'écrans, à condition d'utiliser l'épaisseur d'enveloppe isolante la plus forte du Tableau 7;

b) les câbles de tension assignée 3,6/6 (7,2) kV isolés au PVC ne doivent pas comporter d'écrans.

7.2 Ecran sur âme

L'écran sur âme doit être non métallique et être constitué d'un mélange semiconducteur extrudé, qui peut être appliqué sur un ruban semiconducteur. Le mélange semiconducteur extrudé doit adhérer fermement à l'enveloppe isolante.

7.3 Ecran sur enveloppe isolante

L'écran sur enveloppe isolante doit être constitué d'une couche semiconductrice non métallique associée à un revêtement métallique.

La couche non métallique doit être extrudée directement sur l'enveloppe isolante de chacun des conducteurs et consister en un mélange semiconducteur soit adhérent, soit pelable.

Un ruban ou un mélange semiconducteur peut ensuite être appliqué sur les conducteurs individuels, ou sur l'assemblage des conducteurs.

Le revêtement métallique doit être appliqué soit sur chaque conducteur individuel soit sur l'assemblage des conducteurs, et satisfaire aux exigences de l'Article 10.

8 Assemblage des câbles tripolaires, revêtements internes et bourrages

8.1 Généralités

L'assemblage des câbles tripolaires dépend de la tension assignée et de l'écran métallique éventuellement appliqué sur chaque conducteur.

Les paragraphes 8.2 à 8.4 ne s'appliquent pas aux torsades de câbles unipolaires comportant une gaine individuelle.

8.2 Revêtements internes et bourrages

8.2.1 Constitution

Les revêtements internes peuvent être extrudés ou rubanés.

Pour les câbles à conducteurs circulaires, un revêtement interne rubané ne doit être admis que si les interstices entre conducteurs sont convenablement remplis.

L'emploi d'un lien approprié est permis avant l'application d'un revêtement interne extrudé.

8.2.2 Matériau

Les matériaux utilisés pour les revêtements internes et les bourrages doivent être adaptés à la température de service du câble et compatibles avec le matériau d'isolation.

8.2.3 Epaisseur du revêtement interne extrudé

L'épaisseur approximative des revêtements internes extrudés doit être conforme aux valeurs du Tableau 8.

Tableau 8 – Epaisseur du revêtement interne extrudé

Diamètre fictif sur l'assemblage des conducteurs		Epaisseur du revêtement interne extrudé (valeurs approximatives) mm
Supérieur à mm	**Inférieur ou égal à** 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 Epaisseur des revêtements internes rubanés

L'épaisseur approximative des revêtements rubanés doit être de 0,4 mm pour les diamètres fictifs sur assemblage des conducteurs inférieurs ou égaux à 40 mm et de 0,6 mm pour les diamètres supérieurs.

8.3 Câbles avec revêtement métallique collectif (voir Article 9)

Les câbles doivent comporter un revêtement interne sur l'assemblage des conducteurs. Le revêtement interne et les bourrages doivent satisfaire à 8.2 et doivent être non hygroscopiques, sauf si le câble est réputé étanche longitudinalement.

Pour les câbles comportant un écran semiconducteur sur chaque conducteur individuel ainsi qu'un revêtement métallique collectif, le revêtement interne doit être semiconducteur; les bourrages peuvent être semiconducteurs.

8.4 Câbles comportant un revêtement métallique individuel sur chaque conducteur (voir Article 10)

Les revêtements métalliques de chacun des conducteurs doivent être en contact entre eux.

Les câbles ayant en outre un revêtement métallique collectif (voir Article 9) du même matériau que les revêtements individuels doivent comporter un revêtement interne sur l'assemblage des conducteurs. Le revêtement interne et les bourrages doivent satisfaire à 8.2 et doivent être non hygroscopiques, sauf si le câble est réputé étanche longitudinalement. Le revêtement interne et les bourrages peuvent être semiconducteurs.

Lorsque les revêtements métalliques individuels et le revêtement métallique collectif sont constitués de matériaux différents, ils doivent être séparés par une gaine extrudée constituée de l'un des matériaux spécifiés en 14.2. Pour les câbles sous gaine de plomb, la séparation avec les revêtements métalliques individuels peut être obtenue par un revêtement interne conforme à 8.2.

Pour les câbles ne comportant pas de revêtement métallique collectif (voir Article 9), le revêtement interne peut être omis pour autant que la forme extérieure du câble reste pratiquement cylindrique.

9 Revêtements métalliques des câbles unipolaires et tripolaires

Les types de revêtements métalliques suivants sont inclus dans cette norme:

a) écran métallique (voir Article 10);

b) âme concentrique (voir Article 11);

c) gaine métallique (voir Article 12);

d) armure métallique (voir Article 13).

Le ou les revêtements métalliques doivent correspondre à un ou plusieurs des types énumérés ci-dessus et ne doivent pas être magnétiques quand ils sont appliqués sur des câbles unipolaires ou sur les conducteurs individuels de câbles tripolaires.

Des dispositions peuvent être prises pour assurer une étanchéité longitudinale au niveau des revêtements métalliques.

10 Ecran métallique

10.1 Constitution

L'écran métallique doit être constitué d'un ou de plusieurs rubans, ou d'une tresse, ou d'une nappe concentrique de fils, ou d'une combinaison de fils et de ruban(s).

Il peut aussi être constitué d'une gaine ou, dans le cas d'un écran collectif, d'une armure satisfaisant à 10.2.

Dans le choix du matériau constituant l'écran, il est nécessaire d'apporter une attention particulière aux risques de corrosion, non seulement du point de vue de la sécurité mécanique, mais aussi du point de vue de la sécurité électrique.

Les vides dans l'écran doivent être conformes aux règlements nationaux et/ou aux normes nationales.

10.2 Exigences

Les exigences relatives aux dimensions et aux caractéristiques physiques et électriques de l'écran métallique doivent être définies par les règlements nationaux et/ou les normes nationales.

10.3 Ecrans métalliques non associés à une couche semiconductrice

Il n'est pas nécessaire d'associer une couche semiconductrice aux écrans métalliques utilisés à la tension assignée de 3,6/6 (7,2) kV pour les enveloppes isolantes en PVC, EPR et HEPR.

11 Ame concentrique

11.1 Constitution

Les vides dans l'âme concentrique doivent être conformes aux règlements nationaux et/ou aux normes nationales.

Dans le choix du matériau constituant l'âme concentrique, il est nécessaire d'apporter une attention particulière aux risques de corrosion, non seulement du point de vue de la sécurité mécanique, mais aussi du point de vue de la sécurité électrique.

11.2 Exigences

Les exigences relatives aux dimensions, aux caractéristiques physiques et à la résistance électrique de l'âme concentrique, doivent être définies par les règlements nationaux et/ou les normes nationales.

11.3 Application

Quand une âme concentrique est prescrite, elle doit être appliquée sur le revêtement interne dans le cas des câbles tripolaires. Dans le cas des câbles unipolaires, elle doit être appliquée soit directement sur l'enveloppe isolante, soit sur l'écran semiconducteur sur enveloppe isolante, soit sur un revêtement interne approprié.

12 Gaine métallique

12.1 Gaine de plomb

Cette gaine doit être constituée de plomb ou d'alliage de plomb et être appliquée sous forme d'un tube sans soudure, raisonnablement serré.

L'épaisseur nominale doit être calculée à l'aide de la formule suivante:

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

où

t_{pb} est l'épaisseur nominale de la gaine de plomb, en millimètres;

D_g est le diamètre fictif sous la gaine de plomb, en millimètres (arrondi à la première décimale, selon l'Annexe C).

Dans tous les cas, la plus petite épaisseur nominale ne doit pas être inférieure à 1,2 mm. Les valeurs calculées doivent être arrondies à la première décimale (voir Annexe C).

12.2 Autres gaines métalliques

A l'étude.

13 Armure métallique

13.1 Types d'armures métalliques

Les types d'armures concernés par cette norme sont les suivantes:

a) armure de fils méplats;

b) armure de fils ronds;

c) armure constituée de deux rubans.

13.2 Matériaux

Les fils ronds et méplats doivent être en acier galvanisé, en cuivre nu ou étamé, en aluminium ou en alliage d'aluminium.

Les rubans doivent être en acier, en acier galvanisé, en aluminium ou en alliage d'aluminium. Les rubans d'acier doivent être laminés à froid ou à chaud, de qualité commerciale.

Dans le cas des câbles munis d'une armure de fils d'acier devant satisfaire à une conductance minimale, il est admis d'ajouter des fils de cuivre ou de cuivre étamé en nombre suffisant, afin de satisfaire aux exigences requises.

Dans le choix du matériau constituant l'armure, une attention particulière doit être portée aux risques de corrosion, non seulement du point de vue de la sécurité mécanique, mais aussi du point de vue de la sécurité électrique, surtout lorsque l'armure est utilisée comme écran.

L'armure des câbles unipolaires utilisés dans des réseaux à courant alternatif doit être constituée d'un matériau non magnétique, à moins qu'une constitution spéciale ne soit adoptée.

13.3 Disposition de l’armure

13.3.1 Câbles unipolaires

Dans le cas des câbles unipolaires, un revêtement interne extrudé ou rubané, dont l'épaisseur est spécifiée en 8.2.3 ou en 8.2.4, doit être disposé sous l'armure s'il n'y a pas d'écran.

13.3.2 Câbles tripolaires

Lorsqu'une armure est prescrite dans le cas des câbles tripolaires, elle doit être disposée sur un revêtement interne conforme à 8.2.

13.3.3 Gaine de séparation

Lorsque l’écran métallique sous-jacent et l’armure sont constitués de matériaux différents, ils doivent être séparés par une gaine extrudée constituée de l'un des matériaux indiqués en 14.2.

Lorsqu’une armure est prévue sur un câble comportant une gaine de plomb, elle peut être disposée sur une gaine de séparation ou un matelas rubané comme indiqué en 13.3.4.

Si une gaine de séparation est utilisée, elle doit être appliquée sous l'armure, à la place ou en plus du revêtement interne.

Une gaine de séparation n’est pas nécessaire lorsque des dispositions ont été prises pour assurer une étanchéité longitudinale au niveau des revêtements métalliques.

L'épaisseur nominale de cette gaine de séparation T_s exprimée en millimètres doit être calculée à l’aide de la formule suivante:

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

où D_u est le diamètre fictif sous cette gaine, en millimètres, calculé comme indiqué dans l'Annexe A.

La valeur calculée à l’aide de la formule doit être arrondie à 0,1 mm près (voir Annexe C).

Pour les câbles ne comportant pas de gaine de plomb, l'épaisseur nominale ne doit pas être inférieure à 1,2 mm. Pour les câbles pour lesquels la gaine de séparation est appliquée directement sur la gaine de plomb, l'épaisseur nominale ne doit pas être inférieure à 1,0 mm.

13.3.4 Matelas rubané sous armure pour les câbles sous plomb

Le matelas rubané disposé sur la gaine de plomb enduite doit être constitué soit de rubans de papier imprégné et enduit de mélange, soit d’une combinaison de deux couches de papier imprégné de mélange, puis d’une ou de plusieurs couches de matériau fibreux imprégné de mélange.

L’imprégnation des matériaux constituant le matelas peut être à base de mélanges bitumineux ou d’autres matériaux protecteurs. Dans le cas de fils d’armure, ces mélanges ne doivent pas être appliqués directement sous les fils.

Des rubans synthétiques peuvent être utilisés à la place des rubans de papier imprégné.

L'épaisseur totale du matelas rubané entre la gaine de plomb et l'armure, après application de l'armure, doit avoir une valeur approximative de 1,5 mm.

13.4 Dimensions des fils et des rubans d'armure

Les dimensions nominales des fils et des rubans d'armure doivent être de préférence choisies parmi les valeurs suivantes:

fils ronds:

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

fils méplats:

0,8 mm d'épaisseur;

rubans en acier:

0,2 – 0,5 – 0,8 mm d'épaisseur;

rubans en aluminium ou en alliage d'aluminium:

0,5 – 0,8 mm d'épaisseur.

13.5 Correspondance entre les diamètres des câbles et les dimensions des armures

Les diamètres nominaux des fils d'armure ronds et les épaisseurs nominales des rubans d'armure ne doivent pas être inférieurs aux valeurs indiquées respectivement dans les Tableaux 9 et 10.

Tableau 9 – Diamètre nominal des fils d'armure ronds

Diamètre fictif sous armure		Diamètre nominal du fil d'armure mm
Supérieur à mm	**Inférieur ou égal à** mm	
–	10	0,8
10	15	1,25
15	25	1,6
25	35	2,0
35	60	2,5
60	–	3,15

Tableau 10 – Epaisseur nominale des rubans d'armure

Diamètre fictif sous armure		Epaisseur nominale du ruban	
Supérieur à mm	**Inférieur ou égal à** mm	**Acier ou acier galvanisé** mm	**Aluminium ou alliage d'aluminium** mm
–	30	0,2	0,5
30	70	0,5	0,5
70	–	0,8	0,8

Pour les fils d'armure méplats et les diamètres fictifs sous armure supérieurs à 15 mm, l'épaisseur nominale des fils d'acier méplats doit être de 0,8 mm. Les câbles de diamètre fictif sous armure inférieur ou égal à 15 mm ne doivent pas recevoir de fils d'armure méplats.

13.6 Armure de fils ronds ou méplats

Les fils d'armure doivent être jointifs, c'est-à-dire avec un jeu minimal entre fils adjacents. Un ruban d'acier galvanisé d'épaisseur nominale d'au moins 0,3 mm peut être disposé en forme d'hélice ouverte sur une armure de fils d'acier méplats ou ronds, si cela est nécessaire. Les tolérances données en 17.7.3 s'appliquent à ce ruban d'acier.

13.7 Armure constituée de deux rubans

Quand une armure de rubans et un revêtement interne conformes à 8.2 sont utilisés, le revêtement interne doit être renforcé par un matelas rubané. L'épaisseur totale du revêtement interne et du matelas rubané supplémentaire doit être celle donnée en 8.2, augmentée de 0,5 mm si l'épaisseur des rubans d'armure est de 0,2 mm, et de 0,8 mm si l'épaisseur des rubans d'armure est supérieure à 0,2 mm.

L'épaisseur totale du revêtement interne et du matelas rubané supplémentaire ne doit pas être inférieure à ces valeurs de plus de 0,2 mm avec une tolérance de +20 %.

Si une gaine de séparation est prescrite ou si le revêtement interne est extrudé et satisfait aux exigences de 13.3.3, le matelas rubané supplémentaire n'est pas prescrit.

Les rubans d'armure doivent être posés en hélice, en deux couches, de façon que le ruban externe soit approximativement centré sur l'intervalle entre spires du ruban interne. L'intervalle entre deux spires adjacentes de chaque ruban ne doit pas dépasser 50 % de la largeur du ruban.

14 Gaine extérieure

14.1 Généralités

Tous les câbles doivent comporter une gaine extérieure.

La gaine extérieure est normalement de couleur noire, mais une autre couleur peut être fournie selon accord entre le fabricant et l'acheteur, sous réserve qu'elle convienne pour les conditions particulières d'emploi du câble.

NOTE Un essai de stabilité aux rayons UV est à l'étude.

14.2 Matériau

La gaine extérieure doit être constituée d'un mélange thermoplastique (PVC ou polyéthylène) ou élastomérique (polychloroprène, polyéthylène chlorosulfoné ou matériaux analogues).

Le matériau de la gaine doit convenir à la température de service comme indiqué au Tableau 4.

Des additifs chimiques peuvent être nécessaires dans la gaine extérieure pour des applications spéciales, par exemple protection contre les termites, mais il convient que ces additifs ne contiennent pas de produits nocifs pour l'homme et/ou pour l'environnement.

NOTE Des exemples de matériaux[1] considérés comme indésirables sont les suivants:

- Aldrin:1,2,3,4,10,10-hexachloro-1,4,4a,5,8,8a-hexahydro-1,4,5,8-diméthanonaphtalène
- Dieldrin: 1,2,3,4,10,10-hexachloro-6,7-époxy-1,4,4a,5,6,7,8,8a-octahydro-1,4,5,8-diméthanonaphtalène
- Lindane: isomère gamma du 1,2,3,4,5,6-hexachloro-cyclohexane.

[1] Source: *Dangerous properties of industrial materials*, N.I. Sax, fifth edition, Van Nostrand Reinhold, ISBN 0-442-27373-8.

14.3 Epaisseur

Sauf spécification contraire, l'épaisseur nominale t_s exprimée en millimètres doit être calculée à l'aide de la formule suivante:

$$t_s = 0{,}035\ D + 1{,}0$$

où D est le diamètre fictif immédiatement sous la gaine, en millimètres (voir Annexe A).

La valeur calculée à l'aide de la formule doit être arrondie à 0,1 mm près (voir Annexe C).

L'épaisseur nominale ne doit pas être inférieure à 1,4 mm pour les câbles unipolaires et à 1,8 mm pour les câbles multipolaires.

15 Conditions d'essais

15.1 Température ambiante

Sauf spécification contraire précisée pour chaque essai particulier, les essais doivent être effectués à une température ambiante de (20 ± 15) °C.

15.2 Fréquence et forme d'onde des tensions d'essai à fréquence industrielle

La fréquence des tensions alternatives d'essai ne doit être ni inférieure à 49 Hz ni supérieure à 61 Hz. La forme d'onde de ces tensions doit être pratiquement sinusoïdale. Les valeurs indiquées sont des valeurs efficaces.

15.3 Forme d'onde des tensions d'essai de choc

Conformément à la CEI 60230, la durée conventionnelle du front d'onde doit être comprise entre 1 µs et 5 µs et la durée jusqu'à la moitié de la valeur de crête comprise entre 40 µs et 60 µs. Les autres caractéristiques doivent être conformes à la CEI 60060-1.

15.4 Détermination de la température de l'âme du câble

Il est recommandé que l'une des méthodes décrites à l'Annexe G soit utilisée pour déterminer la température réelle.

16 Essais individuels

16.1 Généralités

Les essais individuels sont normalement effectués sur toutes les longueurs de câble fabriqué (voir 3.2.1). Toutefois, le nombre de longueurs essayées peut être réduit ou une méthode alternative adoptée, selon des procédures agréées de contrôle de la qualité.

Les essais individuels prescrits par cette norme sont les suivants:

a) la mesure de la résistance électrique des âmes (voir 16.2);
b) l'essai de décharges partielles (voir 16.3) pour les câbles comportant des écrans sur âme et sur enveloppe isolante comme indiqué en 7.2 et 7.3;
c) l'essai de tension (voir 16.4).

d) essai électrique sur la gaine extérieure, s'il est exigé (voir 16.5).

16.2 Résistance électrique des âmes

Les mesures de résistance doivent être effectuées sur toutes les âmes de chaque longueur de câble soumise aux essais individuels, y compris l'âme concentrique éventuelle.

La longueur de câble complète, ou un échantillon prélevé sur elle, doit être placée dans le local d'essai, maintenu à une température sensiblement constante pendant au moins 12 h avant l'essai. En cas de doute sur la coïncidence entre la température de l'âme et celle du local, la résistance de l'âme doit être mesurée après un séjour de 24 h dans le local d'essai. En variante, la résistance peut être mesurée sur un échantillon d'âme conditionné pendant au moins 1 h dans un bain de liquide à température régulée.

La résistance mesurée doit être ramenée à une température de 20 °C et à 1 km de câble au moyen des formules et facteurs indiqués dans la CEI 60228.

La résistance de chaque âme en courant continu à 20 °C ne doit pas être supérieure à la valeur maximale correspondante spécifiée dans la CEI 60228. Pour les âmes concentriques, la résistance doit être conforme aux règlements nationaux et/ou aux normes nationales.

16.3 Essai de décharges partielles

L'essai de décharges partielles doit être effectué comme indiqué dans la CEI 60885-3, excepté que la sensibilité telle que définie dans la CEI 60885-3 doit être de 10 pC ou mieux.

Dans le cas des câbles tripolaires, l'essai doit être effectué sur tous les conducteurs isolés en appliquant la tension entre chaque âme et l'écran métallique.

La tension d’essai doit être augmentée progressivement et maintenue à 2 U_0 pendant 10 s puis ramenée lentement à 1,73 U_0.

Il ne doit pas y avoir de décharge détectable provenant de l’objet en essai au-delà de la sensibilité déclarée à 1,73 U_0.

NOTE Une quelconque décharge provenant de l’objet en essai peut être dangereuse.

16.4 Essai de tension

16.4.1 Généralités

L'essai de tension doit être effectué à la température ambiante en appliquant une tension alternative à fréquence industrielle.

16.4.2 Méthode d’essai pour les câbles unipolaires

Pour les câbles unipolaires, la tension d'essai doit être appliquée pendant 5 min entre l’âme et l'écran métallique.

16.4.3 Méthode d'essai pour les câbles tripolaires

Pour les câbles tripolaires avec écran métallique individuel sur chaque conducteur, la tension d'essai doit être appliquée pendant 5 min entre chaque âme et le revêtement métallique.

Pour les câbles tripolaires sans écran métallique individuel sur chaque conducteur, la tension d'essai doit être appliquée pendant 5 min successivement entre chaque conducteur isolé et tous les autres conducteurs et les revêtements métalliques collectifs.

Les câbles tripolaires peuvent être essayés en une seule opération en utilisant un transformateur triphasé.

16.4.4 Tension d'essai

La tension d'essai à fréquence industrielle doit être de 3,5 U_0. Les valeurs des tensions d'essai monophasées pour les tensions assignées normalisées sont indiquées dans le Tableau 11.

Tableau 11 – Tension des essais individuels

Tension assignée U_0	kV	3,6	6	8,7	12	18
Tension d'essai	kV	12,5	21	30,5	42	63

Dans le cas des câbles tripolaires, si la tension d'essai est appliquée par un transformateur triphasé, la tension d'essai entre les phases du transformateur doit être de 1,73 fois les valeurs indiquées dans ce tableau.

Dans tous les cas, la tension d'essai doit être élevée progressivement à la valeur spécifiée.

16.4.5 Exigence

Il ne doit pas se produire de perforation de l'enveloppe isolante.

16.5 Essai électrique sur la gaine extérieure du câble

Par accord convenu entre le client et le fournisseur, le câble doit être soumis à l'essai électrique spécifié en 3.2 de la CEI 60229:2007.

Les câbles ayant des couches semi-conductrices extrudées sur la gaine extérieure doivent être exclus et l'essai de tension continue spécifié en 3.1 de la CEI 60229:2007 peut être appliqué.

17 Essais sur prélèvements

17.1 Généralités

Les essais sur prélèvements prescrits par cette norme sont les suivants:

a) l'examen de l'âme (voir 17.4);
b) les vérifications dimensionnelles (voir 17.5 à 17.8);
c) l'essai de tension pour les câbles de tension assignée supérieure à 3,6/6 (7,2) kV (voir 17.9);
d) l'essai d'allongement à chaud des enveloppes isolantes en EPR, HEPR et PR et des gaines en matériau élastomérique (voir 17.10).

17.2 Fréquence des essais sur prélèvements

17.2.1 Examen de l'âme et vérifications dimensionnelles

L'examen de l'âme, les mesures d'épaisseurs d'enveloppe isolante et de gaine et les mesures du diamètre extérieur doivent être effectués sur une longueur de chaque série de fabrication de câble du même type et de même section nominale, le nombre de longueurs étant toutefois limité à 10 % du nombre total des longueurs stipulées dans la commande.

17.2.2 Essais électriques et physiques

Les essais électriques et physiques doivent être effectués sur des échantillons de câbles prélevés sur les câbles fabriqués, selon des procédures agréées de contrôle de la qualité. En l'absence de procédures agréées, pour les commandes dont la longueur totale dépasse 2 km pour les câbles tripolaires ou 4 km pour les câbles unipolaires, les essais doivent être réalisés selon le Tableau 12.

Tableau 12 – Nombre d'échantillons pour essais sur prélèvements

Longueur de câble				Nombre d'échantillons
Câbles multipolaires		Câbles unipolaires		
Supérieure à km	Inférieure ou égale à km	Supérieure à km	Inférieure ou égale à km	
2	10	4	20	1
10	20	20	40	2
20	30	40	60	3
etc.		etc.		etc.

17.3 Répétition des essais

Si l'un des échantillons ne satisfait pas aux essais de l'Article 17, deux nouveaux échantillons doivent être prélevés sur le même lot de câbles et soumis à l'essai ou aux essais pour lesquels le résultat n'a pas été satisfaisant. Si les deux contre-essais sont satisfaisants, l'ensemble des câbles du lot est considéré comme conforme aux exigences de cette norme. Si l'un ou l'autre des contre-essais n'est pas satisfaisant, le lot de câbles est considéré comme non conforme.

17.4 Examen de l'âme

La conformité aux exigences de la CEI 60228 concernant la constitution de l'âme doit être vérifiée par examen et par mesure, lorsque cela est possible.

17.5 Mesure de l'épaisseur des enveloppes isolantes et des gaines non métalliques (y compris les gaines de séparation extrudées, mais à l'exclusion des revêtements internes extrudés)

17.5.1 Généralités

La méthode d'essai doit être conforme à la CEI 60811-201 et la CEI 60811-202.

Chaque longueur de câble choisie pour l'essai est représentée par un morceau de câble prélevé à une extrémité après élimination éventuelle des parties endommagées.

17.5.2 Exigences pour les enveloppes isolantes

Pour chaque échantillon de conducteur, la plus petite valeur mesurée ne doit pas être inférieure à 90 % de l'épaisseur nominale, diminuée de 0,1 mm, à savoir:

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

en outre:

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

où

t_{max} est l'épaisseur maximale, en millimètres;

t_{min} est l'épaisseur minimale, en millimètres;

t_n est l'épaisseur nominale, en millimètres.

NOTE t_{max} et t_{min} sont mesurés sur la même section de câble.

17.5.3 Exigences pour les gaines non métalliques

S'il est utilisé une couche semi-conductrice extrudée qui est totalement adhérente à la gaine non métallique, une épaisseur pouvant atteindre 0,3 mm de la couche semi-conductrice peut être acceptée comme faisant partie de l'épaisseur de la gaine. Une gaine telle que décrite précédemment doit satisfaire aux exigences mécaniques relatives au type du matériau de gaine, quelle que soit la façon dont les éprouvettes haltères ont été préparées.

L'épaisseur minimale de la gaine non métallique ne doit pas être inférieure à 80 % de la valeur nominale diminuée de 0,2 mm, à savoir:

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

17.6 Mesure de l'épaisseur de la gaine de plomb

17.6.1 Généralités

L'épaisseur minimale de la gaine de plomb doit être déterminée par l'une des deux méthodes suivantes, au choix du fabricant, et ne doit pas être inférieure à 95 % de l'épaisseur nominale, diminuée de 0,1 mm, à savoir:

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

NOTE Les méthodes de mesure de l'épaisseur des autres types de gaines métalliques sont à l'étude.

17.6.2 Méthode «à plat»

La mesure doit être effectuée à l'aide d'un micromètre à faces planes, de touches de diamètre compris entre 4 mm et 8 mm et de précision ±0,01 mm.

La mesure doit être faite sur un échantillon de gaine de 50 mm de longueur environ, prélevé sur le câble complet. L'échantillon doit être fendu longitudinalement, puis soigneusement redressé. Après nettoyage de l'éprouvette, l'épaisseur de l'échantillon est mesurée en un certain nombre de points, le long de la périphérie de la gaine, à 10 mm au moins du bord de l'éprouvette redressée, afin d'être sûr que l'épaisseur minimale est mesurée.

17.6.3 Méthode de l'anneau

Les mesures doivent être faites à l'aide d'un micromètre ayant soit une touche plane et une touche sphérique, soit une touche plane et une touche rectangulaire de 0,8 mm de largeur et 2,4 mm de longueur. La touche sphérique ou la touche rectangulaire doit être appliquée sur la face intérieure de l'anneau. La précision du micromètre doit être de ±0,01 mm.

Les mesures doivent être prises sur un anneau de gaine soigneusement prélevé sur l'échantillon. L'épaisseur doit être mesurée en un nombre de points suffisant, sur la périphérie de l'anneau, afin d'être sûr d'obtenir l'épaisseur minimale.

17.7 Mesure sur les fils et rubans d'armure

17.7.1 Mesure sur les fils

Le diamètre des fils ronds et l'épaisseur des fils méplats doivent être mesurés à l'aide d'un micromètre ayant deux touches planes et une précision de ±0,01 mm. Pour les fils ronds, deux mesures doivent être effectuées à angle droit sur le même diamètre et la moyenne des deux valeurs est prise comme diamètre du fil.

17.7.2 Mesure sur les rubans

Les mesures doivent être faites avec un micromètre ayant deux touches planes d'un diamètre approximatif de 5 mm, et une précision de ±0,01 mm. Pour les rubans de largeur inférieure ou égale à 40 mm, l'épaisseur doit être mesurée au milieu de la largeur. Pour les rubans plus larges, les mesures doivent être faites à 20 mm de chaque bord du ruban et la moyenne des deux valeurs est prise comme épaisseur du ruban.

17.7.3 Exigences

Les dimensions des fils et des rubans d'armure ne doivent pas être inférieures aux valeurs nominales indiquées en 13.5 de plus de:

– 5 % pour les fils ronds;
– 8 % pour les fils méplats;
– 10 % pour les rubans.

17.8 Mesure du diamètre extérieur

Si la mesure du diamètre extérieur du câble est prescrite à titre d'essai sur prélèvements, elle doit être effectuée conformément à la CEI 60811-203.

17.9 Essai de tension pendant 4 h

Cet essai n'est applicable qu'aux câbles de tension assignée supérieure à 3,6/6 (7,2) kV.

17.9.1 Echantillonnage

L'échantillon doit être un tronçon de câble complet d'au moins 5 m de longueur entre les extrémités d'essai.

17.9.2 Mode opératoire

Une tension à fréquence industrielle doit être appliquée pendant 4 h à la température ambiante, entre chaque âme et le ou les revêtements métalliques.

17.9.3 Tension d'essai

La tension d'essai doit être de 4 U_0. Les valeurs de tension d'essai pour les tensions assignées normalisées sont données dans le Tableau 13.

Tableau 13 – Tension des essais sur prélèvements

Tension assignée U_0	kV	6	8,7	12	18
Tension d'essai	kV	24	35	48	72

La tension d'essai doit être élevée progressivement à la valeur spécifiée et maintenue pendant 4 h.

17.9.4 Exigences

Il ne doit pas se produire de perforation de l'enveloppe isolante.

17.10 Essai d'allongement à chaud des enveloppes isolantes en EPR, HEPR et PR et des gaines en matériau élastomérique

17.10.1 Mode opératoire

L'échantillonnage et la méthode d'essai doivent être conformes à la CEI 60811-507, dans les conditions indiquées dans les Tableaux 19 et 23.

17.10.2 Exigences

Les résultats des essais doivent être conformes aux valeurs indiquées dans le Tableau 19 pour les enveloppes isolantes en EPR, HEPR et PR, et dans le Tableau 23 pour les gaines du type SE_1.

18 Essais de type électriques

18.1 Généralités

Lorsque les essais de type ont été réalisés avec succès sur un type de câble concerné par la présente norme, de section et de tension assignée spécifiques, l'acceptation de type doit être considérée comme valable pour des câbles du même type avec d'autres sections et/ou tensions assignées, si les trois conditions suivantes sont toutes remplies:

a) les mêmes matériaux d'isolation et d'écrans semiconducteurs et le même procédé de fabrication sont utilisés;
b) la section de l'âme n'est pas supérieure à celle du câble essayé, avec l'exception que toutes les sections jusqu'à 630 mm² inclus sont acceptées lorsque la section du câble préalablement essayé est dans la gamme de 95 mm² à 630 mm² inclus.
c) la tension assignée n'est pas supérieure à celle du câble essayé.

L'acceptation doit être indépendante de la matière de l'âme.

18.2 Câbles comportant des écrans sur âme et sur enveloppe isolante

18.2.1 Généralités

Un échantillon de câble complet, de 10 m à 15 m de longueur, doit être soumis aux essais énumérés en 18.2.2.

Avec les exceptions indiquées en 18.2.3, tous les essais indiqués en 18.2.2 doivent être effectués successivement sur le même échantillon.

Dans le cas des câbles tripolaires, chaque essai ou chaque mesure doit être effectué sur tous les conducteurs.

La mesure de la résistivité des écrans semiconducteurs, indiquée en 18.2.10, doit être effectuée sur un échantillon distinct.

18.2.2 Série d'essais

La série normale d'essais doit être la suivante:

a) essai d'enroulement, suivi d'un essai de décharges partielles (voir 18.2.4 et 18.2.5);
b) mesure de tan δ (voir 18.2.3 et 18.2.6);
c) essai de cycles de chauffage, suivi d'un essai de décharges partielles (voir 18.2.7);
d) essai aux ondes de choc, suivi d'un essai de tension (voir 18.2.8);
e) essai de tension pendant 4 h (voir 18.2.9).

18.2.3 Dispositions particulières

La mesure de tan δ peut être effectuée sur un échantillon distinct de celui utilisé pour la série normale d'essais énumérée en 18.2.2.

La mesure de tan δ n'est pas prescrite pour les câbles de tension assignée inférieure à 6/10 (12) kV.

Un nouvel échantillon peut être utilisé pour l'essai e), à condition qu'il ait été préalablement soumis aux essais a) et c) énumérés en 18.2.2.

18.2.4 Essai d'enroulement

L'échantillon doit être enroulé autour d'un cylindre d'essai (par exemple, le tambour d'un touret) à la température ambiante sur un tour complet au moins. Ensuite, l'échantillon doit être déroulé et l'opération répétée, sauf que la courbure de l'échantillon doit être de sens contraire et sans rotation axiale.

Ce cycle d'opérations doit être effectué trois fois.

Le diamètre du cylindre d'essai ne doit pas être supérieur à ce qui suit:

- pour les câbles comportant une gaine de plomb ou un ruban disposé longitudinalement avec recouvrement:
  - 25 $(d + D) + 5$ % pour les câbles unipolaires;
  - 20 $(d + D) + 5$ % pour les câbles tripolaires;
- pour les autres câbles:
  - 20 $(d + D) + 5$ % pour les câbles unipolaires;
  - 15 $(d + D) + 5$ % pour les câbles tripolaires.

  où

  D est le diamètre externe réel du tronçon de câble, en millimètres, mesuré conformément à 17.8;

  d est le diamètre réel de l'âme, en millimètres.

Si le conducteur n'est pas circulaire:

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

où S est la section nominale, en millimètres carrés.

A l'issue de cet essai, l'échantillon doit être soumis à un essai de décharges partielles et doit satisfaire aux exigences données en 18.2.5.

18.2.5 Essai de décharges partielles

L'essai de décharges partielles doit être effectué conformément à la CEI 60885-3, la sensibilité étant de 5 pC ou mieux.

La tension d'essai doit être augmentée progressivement et maintenue à 2 U_0 pendant 10 s puis ramenée lentement à 1,73 U_0.

Il ne doit pas y avoir de décharge détectable provenant de l'objet en essai au-delà de la sensibilité déclarée à 1,73 U_0.

NOTE Une quelconque décharge provenant de l'objet en essai peut être dangereuse.

18.2.6 Mesure de tan δ pour les câbles de tension assignée supérieure ou égale à 6/10 (12) kV

L'échantillon de câble complet doit être chauffé selon l'une des méthodes suivantes: l'échantillon doit être placé soit dans une cuve de liquide, soit dans une étuve, soit chauffé par un courant circulant dans l'écran métallique ou dans l'âme, ou dans les deux.

L'échantillon doit être chauffé jusqu'à ce que l'âme atteigne une température dépassant de 5 K à 10 K la température maximale de l'âme en service normal.

Pour chaque méthode, la température de l'âme doit être déterminée soit en mesurant la résistance de l'âme, soit à l'aide d'un dispositif de mesure de température approprié placé dans le bain ou dans l'étuve, ou à la surface de l'écran, ou sur un câble de référence chauffé de façon identique.

La tan δ doit être mesurée sous une tension alternative d'au moins 2 kV à la température spécifiée ci-dessus.

Les valeurs mesurées ne doivent pas être supérieures à celles données au Tableau 15.

18.2.7 Essai de cycles de chauffage

L'échantillon ayant subi les essais précédents doit être disposé sur le sol de la salle d'essais, et être chauffé en faisant passer un courant dans l'âme, jusqu'à ce que celle-ci atteigne une température constante dépassant de 5 K à 10 K la température maximale de l'âme en service normal.

Pour les câbles tripolaires, le courant de chauffage doit être appliqué à toutes les âmes.

Le cycle de chauffage doit durer au moins 8 h. La température de l'âme doit être maintenue entre les limites prescrites pendant au moins 2 h de chaque période de chauffage. On doit laisser ensuite l'échantillon refroidir naturellement à l'air pendant au moins 3 h jusqu'à ce que l'âme ait atteint une température ne dépassant pas la température ambiante de plus de 10 K.

Ce cycle doit être réalisé 20 fois.

A l'issue du dernier cycle, l'échantillon doit être soumis à un essai de décharges partielles et doit satisfaire aux exigences indiquées en 18.2.5.

18.2.8 Essai aux ondes de choc suivi d'un essai de tension

Cet essai doit être effectué sur l'échantillon dont l'âme doit être portée à une température dépassant de 5 K à 10 K la température maximale de l'âme en service normal.

La tension de choc doit être appliquée conformément au mode opératoire indiqué dans la CEI 60230 et doit avoir une valeur de crête indiquée au Tableau 14.

Tableau 14 – Tensions d'essai aux ondes de choc

Tension assignée 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)
Tension d'essai (crête)	kV	60	75	95	125	170

Chaque conducteur du câble doit résister sans perforation à 10 chocs positifs et 10 chocs négatifs.

Après l'essai aux ondes de choc, chaque conducteur de l'échantillon de câble doit être soumis à un essai de tension à fréquence industrielle à la température ambiante, pendant 15 min. La valeur de la tension d'essai est indiquée au Tableau 11. Il ne doit pas se produire de perforation de l'enveloppe isolante.

18.2.9 Essai de tension pendant 4 h

Cet essai doit être effectué à la température ambiante. Une tension à fréquence industrielle doit être appliquée à l'échantillon pendant 4 h, entre l'âme ou les âmes et le ou les écrans.

La tension d'essai doit être égale à 4 U_0. Elle doit être portée graduellement jusqu'à la valeur spécifiée. Il ne doit pas se produire de perforation de l'enveloppe isolante.

18.2.10 Résistivité des écrans semiconducteurs

18.2.10.1 Généralités

La résistivité des écrans semiconducteurs extrudés appliqués sur l'âme et sur l'enveloppe isolante, doit être déterminée par des mesures sur des éprouvettes prélevées sur le conducteur d'un échantillon de câble en l'état de livraison, et d'un échantillon de câble ayant subi l'essai de vieillissement spécifié en 19.7, destiné à vérifier la compatibilité des matériaux constitutifs.

18.2.10.2 Mode opératoire

Le mode opératoire doit être conforme à l'Annexe D.

Les mesures doivent être effectuées à la température maximale de l'âme en service normal, à ±2 K près.

18.2.10.3 Exigences

Avant et après vieillissement, la résistivité ne doit pas être supérieure aux valeurs suivantes:

– écran sur âme: 1 000 Ω × m,
– écran sur enveloppe isolante: 500 Ω × m.

18.3 Câbles de tension assignée 3,6/6 (7,2) kV sans écran sur enveloppe isolante

18.3.1 Généralités

Chaque conducteur d'un échantillon de câble complet, de 10 m à 15 m de longueur, est soumis aux essais suivants effectués dans l'ordre:

a) mesure de la résistance d'isolement à la température ambiante (voir 18.3.2);
b) mesure de la résistance d'isolement à la température maximale de l'âme en service normal (voir 18.3.3);
c) essai de tension pendant 4 h (voir 18.3.4).

Les câbles doivent, en outre, être soumis à un essai aux ondes de choc sur un échantillon de câble complet distinct, de 10 m à 15 m de longueur (voir 18.3.5).

18.3.2 Mesure de la résistance d'isolement à la température ambiante

18.3.2.1 Mode opératoire

Cet essai doit être effectué sur la longueur de l'échantillon avant tout autre essai électrique.

Tous les revêtements extérieurs doivent être ôtés, puis les conducteurs isolés doivent être immergés dans de l'eau à la température ambiante, pendant au moins 1 h avant l'essai.

La tension continue d'essai doit être comprise entre 80 V et 500 V et doit être appliquée pendant une durée suffisante, égale à 1 min au moins et à 5 min au plus, afin d'obtenir une lecture stable.

La mesure doit être faite entre chaque âme et l'eau.

Si nécessaire, la mesure peut être confirmée à la température de (20 ± 1) °C.

18.3.2.2 Calculs

La résistivité transversale doit être calculée, en partant de la valeur mesurée de la résistance d'isolement, par la formule suivante:

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

où

- ρ est la résistivité transversale, en ohms × centimètres;
- R est la résistance d'isolement mesurée, en ohms;
- l est la longueur du câble, en centimètres;
- D est le diamètre extérieur de l'enveloppe isolante, en millimètres;
- d est le diamètre intérieur de l'enveloppe isolante, en millimètres.

On peut aussi calculer la «constante d'isolement K_i», exprimée en mégohms × kilomètres, au moyen de la formule suivante:

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

NOTE Pour les conducteurs à âmes sectorales, le rapport *D/d* est le rapport du périmètre de l'enveloppe isolante à celui de l'âme.

18.3.2.3 Exigences

Les valeurs calculées à partir des mesures effectuées ne doivent pas être inférieures à celles indiquées dans le Tableau 15.

18.3.3 Mesure de la résistance d'isolement à la température maximale de l'âme

18.3.3.1 Mode opératoire

Les conducteurs de l'échantillon de câble doivent être immergés dans de l'eau à la température maximale de l'âme en service normal, à ±2 K près, pendant au moins 1 h avant l'essai.

La tension continue d'essai doit être comprise entre 80 V et 500 V et doit être appliquée pendant une durée suffisante, égale à 1 min au moins et à 5 min au plus, afin d'obtenir une lecture stable.

La mesure doit être faite entre chaque âme et l'eau.

18.3.3.2 Calculs

La résistivité transversale et/ou la constante d'isolement doivent être calculées à partir de la résistance d'isolement par les formules données en 18.3.2.2.

18.3.3.3 Exigences

Les valeurs calculées à partir des mesures effectuées ne doivent pas être inférieures à celles indiquées dans le Tableau 15.

18.3.4 Essai de tension pendant 4 h

18.3.4.1 Mode opératoire

Les conducteurs de l'échantillon de câble doivent être immergés dans de l'eau à la température ambiante pendant au moins 1 h.

Une tension d'essai à fréquence industrielle égale à 4 U_0 doit ensuite être appliquée progressivement entre chaque âme et l'eau, et maintenue pendant 4 h.

18.3.4.2 Exigences

Il ne doit pas se produire de perforation de l'enveloppe isolante.

18.3.5 Essai aux ondes de choc

18.3.5.1 Mode opératoire

Cet essai doit être réalisé sur un échantillon à une température d'âme supérieure de 5 K à 10 K à la température maximale de l'âme en service normal.

La tension de choc doit être appliquée conformément au mode opératoire indiqué dans la CEI 60230 et avoir une valeur de crête de 60 kV.

Chaque série de chocs doit être appliquée successivement entre chaque conducteur de phase et tous les autres conducteurs reliés entre eux et à la terre.

18.3.5.2 Exigences

Chaque conducteur du câble doit résister, sans perforation, à 10 chocs positifs et 10 chocs négatifs.

19 Essais de type non électriques

19.1 Généralités

Les essais de type non électriques exigés par cette norme sont indiqués dans le Tableau 16.

19.2 Mesure de l'épaisseur de l'enveloppe isolante

19.2.1 Echantillonnage

Un échantillon doit être prélevé sur chaque conducteur de câble isolé.

19.2.2 Mode opératoire

Le mode opératoire doit être celui décrit dans la CEI 60811-201.