

INTERNATIONAL STANDARD

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

ICS 29.060.20

ISBN 978-2-8322-9315-7

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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

**Part 1: Cables for rated voltages of 1 kV
($U_m = 1,2$ kV) and 3 kV ($U_m = 3,6$ kV)**

FOREWORD

- 1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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IEC 60502-1 has been prepared by IEC technical committee 20: Electric cables. It is an International Standard.

This third edition cancels and replaces the second edition published in 2004 and Amendment 1:2009. This edition constitutes a technical revision.

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

- a) references to IEC 60811 (all parts) have been updated and mechanical testing requirements specific to halogen free low-smoke oversheath of material type ST₈ have been considered;
- b) the use of the types of sheathing material to be used is now clearly defined;
- c) the applicability of cables for use in DC systems is now included in the scope;

- d) items which were earlier marked as "under consideration" were studied either for an appropriate solution if found available, or for removal for the time being.

The text of this International Standard is based on the following documents:

Draft	Report on voting
20/1938/FDIS	20/1949/RVD

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

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/standardsdev/publications.

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 1 kV ($U_m = 1,2$ 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 document will remain unchanged until the stability date indicated on the IEC website under "<http://webstore.iec.ch>" in the data related to the specific document. At this date, the document 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 1: Cables for rated voltages of 1 kV ($U_m = 1,2$ kV) and 3 kV ($U_m = 3,6$ kV)

1 Scope

This part of IEC 60502 specifies the construction, dimensions and test requirements of power cables with extruded solid insulation for rated AC voltages of 1 kV ($U_m = 1,2$ kV) and 3 kV ($U_m = 3,6$ kV) for fixed installations such as distribution networks or industrial installations.

Cables of rated AC voltage 1 kV ($U_m = 1,2$ kV) designed and tested in accordance with this document can also be used, if declared by the manufacturer, in DC distribution systems having their nominal voltage ≤ 750 V DC (with a maximum of 900 V DC) between a live conductor and neutral/earth, or $\leq 1\,500$ V DC (with a maximum 1 800 V DC) between two live conductors. Applicable core identification for DC systems are considered in accordance with local installation regulations.

NOTE 1 Recommendations for preferred core colours for line conductors in DC systems are given in IEC 60445. However, local installation regulations for DC systems can already contain specific identification requirements.

This document includes cables which exhibit properties of reduced flame spread, low levels of smoke emission and halogen-free gas emission when exposed to fire.

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), submarine use or shipboard application, or cables directly connected to photovoltaic systems.

NOTE 2 Cables for photovoltaic systems are covered by IEC 62930.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

IEC 60183, *Guidance for the selection of high-voltage A.C. cable systems*

IEC 60228, *Conductors of insulated cables*

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

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 60332-3-24, *Tests on electric and optical cables under fire conditions – Part 3-24: Test for vertical flame spread of vertically-mounted bunched wires or cables – Category C*

IEC 60684-2, *Flexible insulating sleeving – Part 2: Methods of test*

IEC 60724, *Short-circuit temperature limits of electric cables with rated voltages of 1 kV ($U_m = 1,2$ kV) and 3 kV ($U_m = 3,6$ kV)*

IEC 60754-1, *Test on gases evolved during combustion of materials from cables – Part 1: Determination of the halogen acid gas content*

IEC 60754-2, *Test on gases evolved during combustion of materials from cables – Part 2: Determination of acidity (by pH measurement) and conductivity*

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 60811-409, *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 insulations 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 61034-2, *Measurement of smoke density of cables burning under defined conditions – Part 2: Test procedure and requirements*

IEC 62230, *Electric cables – Spark-test method*

ISO 48-2:2018, *Rubber, vulcanized or thermoplastic – Determination of hardness – Part 2: Hardness between 10 IRHD and 100 IRHD*

3 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>

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 document, 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 but 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, middle value if the number of available values is odd, and mean of the two middle values if the number is even

3.1.4

fictitious value

value calculated in accordance with the "fictitious method" described in Annex A

3.2 Definitions relating to tests

3.2.1

routine test

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

3.2.2

sample test

test 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 test

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

Note 1 to entry: Type 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 test after installation

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

4 Voltage designations and materials

4.1 Rated voltages

4.1.1 Rated AC voltages

The rated AC voltages U_0/U (U_m) of the cables considered in this document are 0,6/1 (1,2) kV and 1,8/3 (3,6) kV.

NOTE 1 The voltages given above are the correct designations although in some countries other designations are used, e.g. 1,7/3 kV or 1,9/3,3 kV instead of 1,8/3 kV.

For the voltage designation of cables U_0/U (U_m), the definitions in IEC 60183 apply i.e.:

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

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

U_m is the maximum RMS power frequency voltage between conductors for which the cable is designed.

NOTE 2 U_m is the highest voltage that can be sustained under normal operating conditions at any time and at any point in a system and excludes temporary voltage variations due to fault conditions and sudden disconnection of large loads.

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 according to the duration of time the system can be operated under earth fault conditions (see IEC 60183):

- 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, in accordance with IEC 60183, should, in general, not exceed 1 h. For cables covered by this document, 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 3 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 can 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 AC voltages U_0

Highest system voltage (U_m) kV	Rated voltage (U_0)	
	kV	
	Categories A and B	Category C
1,2	0,6	0,6
3,6	1,8	3,6 ^a
^a This category is covered by 3,6/6 (7,2) kV cables in accordance with IEC 60502-2.		

4.1.2 Rated DC voltages

Under consideration.

4.2 Insulating compounds

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

Table 2 – Insulating compounds

Insulating compound	Abbreviated designation
a) <i>Thermoplastic</i> Polyvinyl chloride intended for cables with rated voltages $U_0/U \leq 1,8/3$ kV	PVC/A ^a
b) <i>Cross-linked:</i> Ethylene propylene rubber or similar (EPM or EPDM) High modulus or hard grade ethylene propylene rubber Cross-linked polyethylene	EPR HEPR XLPE
^a Insulating compound based on polyvinyl chloride intended for cables with rated AC voltages $U_0/U = 3,6/6$ kV is designated PVC/B in IEC 60502-2.	

The maximum conductor temperatures for different types of insulating compound covered by this document 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/A)		
	Conductor cross-section ≤ 300 mm ²	70	160
	Conductor cross-section > 300 mm ²	70	140
Cross-linked polyethylene	(XLPE)	90	250
Ethylene propylene rubber	(EPR and HEPR)	90	250

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

For example, in normal operation, if a cable directly buried in the ground is operated under continuous load (100 % load factor) at the maximum conductor temperature shown in Table 3, 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 the short-circuit temperatures, reference shall be made to IEC 60724.

4.3 Sheathing compounds

The types of sheathing compound covered by this document are listed in Table 4, together with their abbreviated designations.

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

Table 4 – Sheathing compounds and maximum conductor temperatures for different types of sheathing compound

Sheathing compound	Abbreviated designation	Maximum conductor temperature in normal operation °C
a) <i>Thermoplastic:</i>		
Polyvinyl chloride (PVC)	ST ₁	80
	ST ₂	90
Polyethylene	ST ₃	80
	ST ₇	90
Halogen free	ST ₈	90
b) <i>Elastomeric:</i>		
Polychloroprene, chlorosulfonated polyethylene or similar polymers	SE ₁	85

5 Conductors

The conductors shall be either of Class 1 or Class 2 of plain or metal-coated annealed copper or of plain aluminium or aluminium alloy, or of Class 5 of plain or metal-coated copper in accordance with IEC 60228.

6 Insulation

6.1 Material

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

For halogen free cables, the insulation shall also meet the requirements given in Table 23.

6.2 Insulation thickness

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

The thickness of any separator shall not be included in the thickness of the insulation.

Table 5 – Nominal thickness of PVC/A insulation

Nominal cross-sectional area of conductor mm ²	Nominal thickness of insulation at rated voltage $U_0/U (U_m)$	
	0,6/1 (1,2) kV mm	1,8/3 (3,6) kV mm
1,5 and 2,5	0,8	–
4 and 6	1,0	–
10 and 16	1,0	2,2
25 and 35	1,2	2,2
50 and 70	1,4	2,2
95 and 120	1,6	2,2
150	1,8	2,2
185	2,0	2,2
240	2,2	2,2
300	2,4	2,4
400	2,6	2,6
500 to 800	2,8	2,8
1 000	3,0	3,0

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 $U_0/U (U_m)$	
	0,6/1 (1,2) kV mm	1,8/3 (3,6) kV mm
1,5 and 2,5	0,7	–
4 and 6	0,7	–
10 and 16	0,7	2,0
25 and 35	0,9	2,0
50	1,0	2,0
70 and 95	1,1	2,0
120	1,2	2,0
150	1,4	2,0
185	1,6	2,0
240	1,7	2,0
300	1,8	2,0
400	2,0	2,0
500	2,2	2,2
630	2,4	2,4
800	2,6	2,6
1 000	2,8	2,8

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 $U_0/U (U_m)$			
	0,6/1 (1,2) kV		1,8/3 (3,6) kV	
	EPR mm	HEPR mm	EPR mm	HEPR mm
1,5 and 2,5	1,0	0,7	–	–
4 and 6	1,0	0,7	–	–
10 and 16	1,0	0,7	2,2	2,0
25 and 35	1,2	0,9	2,2	2,0
50	1,4	1,0	2,2	2,0
70	1,4	1,1	2,2	2,0
95	1,6	1,1	2,4	2,0
120	1,6	1,2	2,4	2,0
150	1,8	1,4	2,4	2,0
185	2,0	1,6	2,4	2,0
240	2,2	1,7	2,4	2,0
300	2,4	1,8	2,4	2,0
400	2,6	2,0	2,6	2,0
500	2,8	2,2	2,8	2,2
630	2,8	2,4	2,8	2,4
800	2,8	2,6	2,8	2,6
1 000	3,0	2,8	3,0	2,8

7 Assembly of multicore cables, inner coverings and fillers

7.1 General

The assembly of multicore cables depends on the rated voltage and whether a metallic layer is applied to each core.

The following Subclauses 7.2 to 7.4 do not apply to assemblies of sheathed single-core cables.

7.2 Inner coverings and fillers

7.2.1 Construction

The inner coverings may be extruded or lapped.

For cables with circular cores, except cables with more than five 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.

7.2.2 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.

For halogen free cables, the inner covering and fillers shall meet the requirements given in Table 23.

7.2.3 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)
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

7.2.4 Thickness of lapped inner coverings

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.

7.3 Cables with rated voltage 0,6/1 (1,2) kV

7.3.1 General

Cables with a rated voltage of 0,6/1 (1,2) kV may have a metallic layer collectively surrounding the cores.

NOTE The choice between cables having and cables not having a metallic layer depends upon national regulations and installation requirements for the prevention of possible dangers from mechanical damage or direct electrical contact.

7.3.2 Cables having a collective metal layer (see Clause 8)

Cables shall have an inner covering over the laid-up cores. The inner covering and fillers shall comply with 7.2.

Metal tapes may, however, be applied directly over the assembled cores, omitting the inner covering, provided that the nominal thickness of each tape does not exceed 0,3 mm and that the completed cable complies with the special bending test specified in 18.18.

7.3.3 Cables having no collective metal layer (see Clause 8)

The inner covering may be omitted, provided the outer shape of the cable remains practically circular and no adhesion occurs between cores and sheath.

The oversheath may penetrate into the interstices of the cores, except in the case of thermoplastic oversheaths over circular cores exceeding 10 mm².

If, however, an inner covering is applied, its thickness need not comply with 7.2.3 or 7.2.4.

7.4 Cables with rated voltage 1,8/3 (3,6) kV

7.4.1 General

Cables with a rated voltage of 1,8/3 (3,6) kV shall have a metal layer surrounding the cores either individually or collectively.

7.4.2 Cables having only a collective metal layer (see Clause 8)

Cables shall have an inner covering over the laid-up cores. The inner covering and fillers shall comply with 7.2 and shall be non-hygroscopic.

7.4.3 Cables having a metal layer over each individual core (see Clause 9)

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

Cables with an additional collective metal layer (see Clause 8) 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 7.2 and shall be non-hygroscopic.

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 13.2. For lead-sheathed cables, the separation from the underlying individual metal layers may be obtained by an inner covering in accordance with 7.2.

For cables having neither armour, nor concentric conductor, nor other collective metal layer (see Clause 8), the inner covering may be omitted, provided the outer shape of the cable remains practically circular. The oversheath may penetrate into the interstices of the cores, except in the case of thermoplastic oversheaths over circular cores exceeding 10 mm². If, however, an inner covering is applied, its thickness need not comply with 7.2.3 nor 7.2.4.

8 Metal layers for single-core and multicore cables

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

- a) metal screen (see Clause 9);
- b) concentric conductor (see Clause 10);
- c) lead sheath (see Clause 11);
- d) metal armour (see Clause 12).

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 multicore cables.

9 Metal screen

9.1 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 9.2.

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 national regulations and/or standards.

9.2 Requirements

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

10 Concentric conductor

10.1 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.

10.2 Requirements

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

10.3 Application

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

11 Metal 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 using the following formula:

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

where

t_{pb} is the nominal thickness of 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 B).

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

12 Metal armour

12.1 Types of metal armour

The armour types covered by this document are as follows:

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

NOTE For cables with a rated voltage of 0,6/1 (1,2) kV with conductor cross-sectional areas not exceeding 6 mm², galvanized steelwire braid armour can be provided by agreement between the manufacturer and the purchaser.

12.2 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, the possibility of corrosion shall be taken into consideration, 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 AC systems shall consist of non-magnetic material, unless a special construction is chosen.

12.3 Application of armour

12.3.1 Single-core cables

In the case of single-core cables, an inner covering, extruded or lapped, of the thickness specified in 7.2.3 or 7.2.4, shall be applied under the armour.

12.3.2 Multicore cables

In the case of multicore cables, the armour shall be applied on an inner covering complying with 7.2 except for special applications using metallic tapes, see 7.3.2.

12.3.3 Separation sheath

When the underlying metallic layer and the armour are of different materials, they shall be separated by an extruded sheathing compound of one of the types listed in Table 4.

The sheathing compound type shall be suitable for the operation temperature in accordance with Table 4.

For halogen free cables, the separation sheath (ST₈) shall meet the requirements given in Table 23.

When an armour is required for a lead-sheathed cable, it may be applied over a lapped bedding in accordance with 12.3.4.

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

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 B).

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.

12.3.4 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 the case of wire armour, these compounds shall not be applied directly under the wires.

Synthetic tapes may be used 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.

12.4 Dimensions of the armour wires and armour tapes

The nominal dimensions of the armour wires and armour tapes should preferably consist of one of the following values:

Round wires:

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

Flat wires:

0,8 mm thickness;

Tapes of steel:

0,2 or 0,5 or 0,8-mm thickness;

Tapes of aluminium or aluminium alloy:

0,5 or 0,8-mm thickness.

12.5 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 Table 9 and Table 10, respectively.

Table 9 – Nominal diameter of round armour wires

Fictitious diameter under the armour		Nominal diameter of armour wire
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

NOTE This table does not apply to cables having metallic tapes applied directly over the assembled cores (see 7.3.2).

For flat armour wires and fictitious diameters under the 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.

12.6 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 a flat steel wire armour and over a round steel wire armour, if necessary. Tolerances on this steel tape shall comply with 16.7.3.

12.7 Double tape armour

When a tape armour and an inner covering as specified in 7.2 are used, the inner covering shall be reinforced by a taped bedding. The approximate thickness of the inner covering and the additional taped bedding shall be as given in 7.2 and the combined approximate thickness shall be increased by 0,5 mm if the armour tape thickness is 0,2 mm, and increased by 0,8 mm if the armour tape thickness is more than 0,2 mm.

If a separation sheath is required or if the inner covering is extruded and satisfies the requirements of 12.3.3, 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.

13 Oversheath

13.1 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.

If there is concern that the oversheath will be deteriorated by UV radiation, the oversheath shall be protected against UV radiation, which will be mutually agreed with the client. Black polyethylene oversheaths containing the required amount of carbon black (see Table 20) can provide protection against UV radiation depending on geographical regions and meteorological conditions.

13.2 Material

The oversheath shall consist of an extruded sheathing compound of one of the types listed in Table 4.

Halogen free sheathing material shall be used on cables which exhibit properties of reduced flame spread, low levels of smoke emission and halogen free gas emission when exposed to fire. The oversheath (ST₈) of halogen free cables shall meet the requirements given in Table 23.

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

NOTE Chemical additives can be requested for use in the oversheath for special purposes, for example termite protection. Any additive can be permitted by local legislation for manufacture and use in the intended application in the relevant countries.

13.3 Thickness

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

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

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 B).

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.

13.4 Marking

Marking on oversheath is recommended. It shall contain at least an indication of origin (manufacturer's name or trademark (if legally protected)). Inclusion of voltage designation, number of cores and their nominal cross-sectional area into sheath marking is optional.

Marking shall be made by printing, embossing or indenting and it shall be continuous with applicable intervals.

14 Test conditions

14.1 Ambient temperature

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

14.2 Frequency and waveform of power frequency test voltages

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

14.3 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 , and in other respects shall be in accordance with IEC 60060-1.

15 Routine tests

15.1 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 in accordance with agreed quality control procedures.

The routine tests required by this document include:

- a) measurement of the electrical resistance of conductors (see 15.2);
- b) voltage test (see 15.3).

15.2 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 $^\circ\text{C}$ and 1 km length in accordance with the formulae and factors given in IEC 60228.

The DC resistance of each conductor at 20 $^\circ\text{C}$ shall not exceed the appropriate maximum value specified in IEC 60228. For concentric conductors, the resistance shall comply with national regulations and/or standards.

15.3 Voltage test

15.3.1 General

The voltage test shall be made at ambient temperature, using either alternating voltage at power frequency or direct voltage, at the manufacturer's option.

15.3.2 Test procedure for single-core cables

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

Single-core unscreened cables shall be either

- a) immersed in water at room temperature for 1 h and the test voltage then applied for 5 min between the conductor and the water, or
- b) subjected to a spark-test during its manufacturing process in accordance with IEC 62230. This procedure applies for all insulation thicknesses tabled in this document.

15.3.3 Test procedure for multicore cables

For multicore cables with individually screened cores, the test voltage shall be applied for 5 min between each conductor and the metallic layer.

For multicore 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 metallic layers, if any.

The conductors may be suitably connected for successive applications of the test voltage to limit the total testing time, provided that the sequence of connections ensures that the voltage is applied for at least 5 min without interruption between each conductor and each other conductor and between each conductor and the metallic layers, if any.

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

15.3.4 Test voltage

The power frequency test voltage shall be $2,5 U_0 + 2$ kV. Values of single-phase test voltages for the standard rated voltages are given in Table 11.

Table 11 – Routine test voltages

Rated voltage U_0	kV	0,6	1,8
Test voltage	kV	3,5	6,5

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 Table 11.

When a direct voltage is used, the applied voltage shall be 2,4 times the power frequency test voltage.

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

15.3.5 Requirement

No breakdown of the insulation shall occur.

16 Sample tests

16.1 General

The sample tests required by this document include:

- a) conductor examination (see 16.4);
- b) check of dimensions (see 16.5 to 16.8);
- c) hot set test for EPR, HEPR and XLPE insulation and elastomeric sheaths (see 16.9).

16.2 Frequency of sample tests

16.2.1 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.

16.2.2 Physical tests

Physical tests shall be carried out on samples taken from manufactured cables in accordance with agreed quality control procedures. In the absence of such an agreement, for contracts where the total length exceeds 2 km for multicore 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.

16.3 Repetition of tests

If any sample fails in any of the tests in Clause 16, 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 document. If either of the additional samples fails, the batch from which they were taken shall be regarded as failing to comply.

16.4 Conductor examination

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

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

16.5.1 General

The test method shall be in accordance with IEC 60811-201 for insulation and IEC 60811-202 for sheaths.

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.

For cables having more than three cores with conductors of equal nominal cross-section, the number of cores on which the measurement is made shall be limited to either three cores or 10 % of the cores, whichever is larger.

16.5.2 Requirements for the insulation

For each piece of core, the average of the measured values, rounded to 0,1 mm in accordance with Annex B, shall be not less than the nominal thickness, and the smallest value measured shall not fall below 90 % of the nominal value by more than 0,1 mm, i.e.:

$$t_m \geq 0,9 t_n - 0,1$$

where

t_m is the minimum thickness, in millimetres;

t_n is the nominal thickness, in millimetres.

16.5.3 Requirements for non-metallic sheaths

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

$$t_m \geq 0,8 t_n - 0,2$$

16.6 Measurement of thickness of lead sheath

16.6.1 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 value by more than 0,1 mm, i.e.:

$$t_m \geq 0,95 t_n - 0,1$$

16.6.2 Strip method

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

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

16.6.3 Ring method

The measurements shall be made with a micrometer having either one flat nose and one ball nose, or one flat nose and a flat rectangular nose 0,8 mm wide and 2,4 mm long. The ball nose or the flat rectangular nose shall be applied to the inside of the ring. The accuracy of the micrometer shall be $\pm 0,01$ mm.

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

16.7 Measurement of armour wires and tapes

16.7.1 Measurement on wires

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

16.7.2 Measurement on tapes

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

16.7.3 Requirements

The dimensions of armour wires and tapes shall not fall below the nominal values given in 12.5 by more than:

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

16.8 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.

16.9 Hot set test for EPR, HEPR and XLPE insulation and elastomeric sheaths

16.9.1 Procedure

The sampling and test procedure shall be carried out in accordance with IEC 60811-507, employing the conditions given in Table 17 and Table 22.

16.9.2 Requirements

The test results shall comply with the requirements given in Table 17 for EPR, HEPR and XLPE insulation, and in Table 22 for SE₁ sheaths.

17 Type tests, electrical

17.1 General

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 17.2);
- b) insulation resistance measurement at maximum conductor temperature in normal operation (see 17.3);
- c) voltage test for 4 h (see 17.4).

Cables of a rated voltage of 1,8/3 (3,6) kV shall also be subjected to an impulse test on a separate sample of completed cable, 10 m to 15 m in length (see 17.5).

The tests shall be limited to not more than three cores.

17.2 Insulation resistance measurement at ambient temperature

17.2.1 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 DC test voltage shall be between 80 V and 500 V and shall be applied for a sufficient time to reach a reasonably steady measurement, but in any case for not less than 1 min and not more than 5 min.

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

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

17.2.2 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 megaohms $\times$ kilometres [$\text{M}\Omega \cdot \text{km}$] may also be calculated, using the formula:

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

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.

17.2.3 Requirements

The values calculated from the measurements shall be not less than those specified in Table 13.

17.3 Insulation resistance measurement at maximum conductor temperature

17.3.1 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 DC test voltage shall be 80 V to 500 V and shall be applied for a sufficient time to reach a reasonably steady measurement, but in any case for not less than 1 min and not more than 5 min.

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

17.3.2 Calculations

The volume resistivity and/or the insulation resistance constant shall be calculated from the insulation resistance by the formulae given in 17.2.2.

17.3.3 Requirements

The values calculated from the measurements shall be not less than those specified in Table 13.

17.4 Voltage test for 4 h

17.4.1 Procedure

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

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.

17.4.2 Requirements

No breakdown of the insulation shall occur.

17.5 Impulse test for cables of rated voltage 1,8/3 (3,6) kV

17.5.1 Procedure

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

The impulse voltage shall be applied in accordance with the procedure given in IEC 60230 and shall have a peak value of 40 kV.

For multicore cables in which the cores are not individually screened, each series of impulses shall be applied in turn between each phase conductor and all the other conductors connected together and to earth.

17.5.2 Requirements

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

18 Type tests, non-electrical

18.1 General

The non-electrical type tests required by this document are given in Table 14.

18.2 Measurement of thickness of insulation

18.2.1 Sampling

One sample shall be taken from each insulated cable core.

For cables having more than three cores with conductors of equal nominal cross-section, the number of cores on which the measurement is made shall be limited to either three cores or 10 % of the cores, whichever is larger.

18.2.2 Procedure

The measurements shall be made as described in IEC 60811-201.

18.2.3 Requirements

See 16.5.2.

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

18.3.1 Sampling

One sample of cable shall be taken.

18.3.2 Procedure

The measurements shall be made as described in IEC 60811-202.

18.3.3 Requirements

See 16.5.3.

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

18.4.1 Sampling

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

18.4.2 Ageing treatments

The ageing treatments shall be carried out as described in IEC 60811-401 under the conditions specified in Table 15.

The tensile and bending tests after ageing with the copper conductor of Table 15 are only applicable to 0,6/1 (1,2) kV cables. The bending test is only carried out on those cables for which the insulation cannot be subjected to the tensile test.

NOTE The tensile and bending tests, carried out after ageing in the presence of a copper conductor, could be preferred. However, no sufficient information has been obtained to date to make these requirements mandatory, except by agreement between the purchaser and the manufacturer.

18.4.3 Conditioning and mechanical tests

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

18.4.4 Requirements

The test results for aged and unaged test pieces shall comply with the requirements given in Table 15.

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

18.5.1 Sampling

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

18.5.2 Ageing treatments

The ageing treatments shall be carried out as described in IEC 60811-401, under the conditions specified in Table 18.

18.5.3 Conditioning and mechanical tests

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

18.5.4 Requirements

The test results for aged and unaged test pieces shall comply with the requirements given in Table 18.

18.6 Additional ageing test on pieces of completed cables

18.6.1 General

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

The test is applicable to cables of all types.

18.6.2 Sampling

Samples shall be taken from the completed cable as described in IEC 60811-401.

18.6.3 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 15);
- duration: 7×24 h.

18.6.4 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.

18.6.5 Requirements

The variations between the median values of tensile strength and elongation-at-break after ageing and the corresponding values obtained without ageing (see 18.4 and 18.5) shall not exceed the values applying to the test after ageing in an air oven specified in Table 15 for insulation, and Table 18 for non-metallic sheaths.

18.7 Loss of mass test on PVC sheaths of type ST₂

18.7.1 Procedure

The sampling and test procedure shall be in accordance with IEC 60811-409.

18.7.2 Requirements

The test results shall comply with the requirements given in Table 19.

18.8 Pressure test at high temperature on insulation and non-metallic sheaths

18.8.1 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 Table 16, Table 19, Table 20 and Table 21.

18.8.2 Requirements

The test results shall comply with the requirements given in IEC 60811-508.

18.9 Test on PVC insulation and sheaths and halogen free sheaths at low temperatures

18.9.1 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 Table 16, Table 19 and Table 21.

18.9.2 Requirements

The results of the test shall comply with the requirements given in Table 16, Table 19 and Table 21.

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

18.10.1 Procedure

The sampling and test procedure shall be in accordance with IEC 60811-509, the test temperature and duration being in accordance with Table 16 and Table 19.

18.10.2 Requirements

The results of the tests shall comply with the requirements given in IEC 60811-509.

18.11 Ozone resistance test for EPR and HEPR insulation

18.11.1 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 17.

18.11.2 Requirements

The results of the test shall comply with the requirements given in IEC 60811-403.

18.12 Hot set test for EPR, HEPR and XLPE insulation and elastomeric sheaths

The sampling and test procedure shall be carried out in accordance with 16.9 and shall comply with its requirements.

18.13 Oil immersion test for elastomeric sheaths

18.13.1 Procedure

The sampling and test procedure shall be carried out in accordance with IEC 60811-404, employing the conditions given in Table 22.

18.13.2 Requirements

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

18.14 Water absorption test on insulation

18.14.1 Procedure

The sampling and test procedures shall be carried out in accordance with IEC 60811-402, employing the conditions and method specified in Table 16 or Table 17, respectively.

18.14.2 Requirements

The results of the test shall comply with the requirements specified in IEC 60811-402 or Table 17, respectively.

18.15 Fire tests

18.15.1 Flame spread test on single cables

This test shall be carried out on ST₁, ST₂, or SE₁ oversheathed cables only when such a fire performance is specially required or declared.

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

18.15.2 Flame spread test on bunched cables

This test shall be carried out on ST₈ oversheathed halogen free cables.

The test method and requirements shall be those specified in IEC 60332-3-24.

18.15.3 Smoke emission test

This test shall be carried out on ST₈ oversheathed halogen free cables.

The test method and requirements shall be those specified in IEC 61034-2.

18.15.4 Acid gas emission test**18.15.4.1 General**

This test shall be carried out on the non-metallic components of ST₈ oversheathed halogen free cables.

18.15.4.2 Procedure

The test method shall be that specified in IEC 60754-1.

18.15.4.3 Requirements

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

18.15.5 pH and conductivity test**18.15.5.1 General**

This test shall be carried out on the non-metallic components of ST₈ oversheathed halogen free cables.

18.15.5.2 Procedure

The test method shall be that specified in IEC 60754-2.

18.15.5.3 Requirements

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

18.15.6 Fluorine content test**18.15.6.1 General**

This test shall be carried out on the non-metallic components of ST₈ oversheathed halogen free cables.

18.15.6.2 Procedure

The test method shall be that specified in IEC 60684-2.

18.15.6.3 Requirements

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

18.16 Measurement of carbon black content of black PE oversheaths

18.16.1 Procedure

The sampling and test procedure shall be carried out in accordance with IEC 60811-605.

18.16.2 Requirements

The results of the test shall comply with the requirements of Table 20.

18.17 Shrinkage test for XLPE insulation

18.17.1 Procedure

The sampling and test procedure shall be carried out in accordance with IEC 60811-502 under the conditions specified in Table 17.

18.17.2 Requirements

The results of the test shall comply with the requirements of Table 17.

18.18 Special bending test

18.18.1 General

This test shall be made on multicore cables with rated voltages of 0,6/1 (1,2) kV and 1,8/3 (3,6) kV, having a collective metallic layer in the form of metallic tapes applied directly over the assembled cores and omitting the inner covering.

18.18.2 Procedure

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. The diameter of the cylinder shall be $7 D$ with $\pm 5\%$ tolerance, where D is the actual external diameter of the cable sample. The cable shall then be unwound and the process shall be repeated except that the bending of the sample shall be in the reverse direction.

This cycle of operations shall be carried out three times. The sample, left bent around the cylinder shall then be placed in an air oven heated to the maximum conductor temperature in normal operation of the cable for 24 h.

After the cable has cooled down, and while it is still bent, the voltage test shall be carried out in accordance with 15.3.

18.18.3 Requirements

No breakdown shall occur and the oversheath shall show no sign of cracking.

18.19 Determination of hardness of HEPR insulation

18.19.1 Procedure

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

18.19.2 Requirements

The results of the test shall comply with the requirements of Table 17.

18.20 Determination of the elastic modulus of HEPR insulation

18.20.1 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.

18.20.2 Requirements

The results of the test shall comply with the requirements of Table 17.

18.21 Shrinkage test for PE oversheaths

18.21.1 Procedure

The sampling and test procedure shall be carried out in accordance with IEC 60811-503 under the conditions specified in Table 20.

18.21.2 Requirements

The results of the test shall comply with the requirements of Table 20.

18.22 Additional tests on halogen free oversheaths

18.22.1 General

These tests are intended to check that the halogen free oversheaths are not liable to damage during installation and operation.

18.22.2 Water absorption test for halogen free oversheaths

18.22.2.1 Procedure

The sampling and test procedure shall be carried out in accordance with IEC 60811-402 employing the conditions and method specified in Table 21.

18.22.2.2 Requirements

The results of the test shall comply with the requirements of Table 21.

18.22.3 Abrasion test on ST₈ halogen free oversheaths

Test method and requirements are under consideration.

19 Electrical tests after installation

Tests after installation are made, if required, when the installation of the cable and its accessories has been completed.

A DC voltage equal to $4 U_0$ shall be applied for 15 min.

NOTE Electrical tests on repaired installations are subject to installation requirements. The above test is for new installations only.

Table 13 – Electrical type test requirements for insulating compounds

Designation of compounds (see 4.2)	Unit	PVC/A	EPR/ HEPR	XLPE
Maximum conductor temperature in normal operation (see 4.2)	°C	70	90	90
Volume resistivity ρ				
– at 20 °C (see 17.2)	$\Omega \cdot \text{cm}$	10^{13}	–	–
– at maximum conductor temperature in normal operation (see 17.3)	$\Omega \cdot \text{cm}$	10^{10}	10^{12}	10^{12}
Insulation resistance constant K_i				
– at 20 °C (see 17.2)	$\text{M}\Omega \cdot \text{km}$	36,7	–	–
– at maximum conductor temperature in normal operation (see 17.3)	$\text{M}\Omega \cdot \text{km}$	0,037	3,67	3,67

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**Table 14 – Non-electrical type tests
(see Tables 15 to 23)**

	Insulation				Sheaths					
Designation of compounds (see 4.2 and 4.3)	PVC/A	EPR	HEPR	XLPE	PVC		PE			
					ST ₁	ST ₂	ST ₃	ST ₇	ST ₈	SE ₁
<i>Dimensions</i>										
Measurements of thickness	x	x	x	x	x	x	x	X	x	x
<i>Mechanical properties</i> (tensile strength and elongation-at-break)										
Without ageing	x	x	x	x	x	x	x	X	x	x
After ageing in air oven	x	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	x
After immersion in hot oil	—	—	—	—	—	—	—	—	—	x
Thermoplastic properties										
Hot pressure test (indentation)	x	—	—	—	x	x	—	X	x	—
Behaviour at low temperature	x	—	—	—	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
Water absorption	x	x	x	x	—	—	—	—	x	—
Shrinkage test	—	—	—	x	—	—	x	X	—	—
Carbon black content ^a	—	—	—	—	—	—	x	X	—	—
Determination of hardness	—	—	x	—	—	—	—	—	—	—
Determination of elastic modulus	—	—	x	—	—	—	—	—	—	—
Fire tests										
Flame spread test on single cables (if required)	—	—	—	—	x	x	—	—	—	x
Flame spread test on bunched cables	x	—	—	—	—	—	—	—	x	—
Smoke emission test on cables	—	—	—	—	—	—	—	—	x	—
Acid gas emission test	—	b	b	b	—	—	—	—	x	—
pH and conductivity	—	b	b	b	—	—	—	—	x	—
Fluorine content test	—	b	b	b	—	—	—	—	x	—

Key

x indicates that the type test is to be applied.

— indicates that the type test is not to be applied.

^a For black oversheaths only.

^b Indicates that the test is only required for EPR, HEPR and XLPE when the cable is claimed to be halogen free.

Table 15 – Test requirements for mechanical characteristics of insulating compounds (before and after ageing)

	Unit	PVC/A	EPR		HEPR		XLPE	
Designation of compounds (see 4.2)			0,6/1(1,2) kV cables with copper conductors	All other cables	0,6/1(1,2) kV cables with copper conductors	All other cables	0,6/1(1,2) kV cables with copper conductors	All other cables
Maximum conductor temperature in normal operation (see 4.2)	°C	70	90	90	90	90	90	90
<i>Without ageing</i> (IEC 60811-501)								
Tensile strength, minimum	N/mm ²	12,5	4,2	4,2	8,5	8,5	12,5	12,5
Elongation-at-break, minimum	%	150	200	200	200	200	200	200
<i>After ageing in an air oven</i> (IEC 60811-401)								
After ageing without conductor								
Treatment:								
– temperature	°C	100	135	135	135	135	135	135
– tolerance	K	±2	±3	±3	±3	±3	±3	±3
– duration	h	168	168	168	168	168	168	168
Tensile strength								
a) value after ageing, minimum	N/mm ²	12,5	–	–	–	–	–	–
b) variation ^a , maximum	%	±25	±30	±30	±30	±30	±25	±25
Elongation-at-break:								
a) value after ageing, minimum	%	150	–	–	–	–	–	–
b) variation ^a , maximum	%	±25	±30	±30	±30	±30	±25	±25
After ageing with copper conductor followed by the tensile test ^b				–				
Treatment:								
– temperature	°C	–	150	–	150	–	150	–
– tolerance	K	–	±3	–	±3	–	±3	–
– duration	h	–	168	–	168	–	168	–
Tensile strength:								
Variation ^a , maximum	%	–	±30	–	±30	–	±30	–
Elongation-at-break:								
Variation ^a , maximum	%	–	±30	–	±30	–	±30	–
After ageing with copper conductor followed by bending test (only if the tensile test is not practicable) ^b								
Treatment:								
– temperature	°C	–	150	–	150	–	150	–
– tolerance	K	–	±3	–	±3	–	±3	–
– duration	h	–	240	–	240	–	240	–
Results to be obtained		–	No cracks	–	No cracks	–	No cracks	–

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

^b See 18.4.2.

**Table 16 – Test requirements for particular characteristics
of PVC insulating compounds**

Designation of compound (see 4.2)	Unit	PVC/A
Use of the PVC compound		Insulation
<i>Pressure test at high temperature</i> (IEC 60811-508) – temperature (tolerance ± 2 K) – requirement: maximum indentation value	$^{\circ}\text{C}$ %	80 50
<i>Behaviour at low temperature</i> ^a (IEC 60811-504, IEC 60811-505) Test to be carried out without previous ageing: – cold bending test for diameter < 12,5 mm – temperature (tolerance ± 2 K) – requirement	$^{\circ}\text{C}$	–15 no cracks
Cold elongation test on dumb-bells: – temperature (tolerance ± 2 K) – requirement	$^{\circ}\text{C}$ %	–15 ≥ 20
<i>Heat shock test</i> (IEC 60811-509) – temperature (tolerance ± 3 K) – duration – requirement	$^{\circ}\text{C}$ h	150 1 no cracks
<i>Water absorption</i> (IEC 60811-402) Electrical method: – temperature (tolerance ± 2 K) – duration – requirement	$^{\circ}\text{C}$ h	70 240 no breakdown
^a Due to climatic conditions, national standards may require the use of a lower temperature.		

Table 17 – Test requirements for particular characteristics of various cross-linked insulating compounds

Designation of compound (see 4.2)	Unit	EPR	HEPR	XLPE
<i>Ozone resistance</i> (IEC 60811-403)				
Ozone concentration (by volume)	%	0,025 to 0,030	0,025 to 0,030	–
Test duration without cracks	h	24	24	–
<i>Hot set test</i> (IEC 60811-507)				
Treatment:				
– air temperature (tolerance ± 3 K)	$^{\circ}\text{C}$	250	250	200
– mechanical stress	N/cm^2	20	20	20
Maximum elongation under load	%	175	175	175
Maximum permanent elongation after cooling	%	15	15	15
<i>Water absorption</i> (IEC 60811-402)				
Gravimetric method:				
Treatment:				
– temperature (tolerance ± 2 K)	$^{\circ}\text{C}$	85	85	85
– duration	h	336	336	336
Maximum increase of mass	mg/cm^2	5	5	1 ^a
<i>Shrinkage test</i> (IEC 60811-502)				
Distance <i>L</i> between marks	mm	–	–	200
Treatment:				
– temperature (tolerance ± 3 K)	$^{\circ}\text{C}$	–	–	130
– duration	h	–	–	1
Maximum shrinkage	%	–	–	4
<i>Determination of hardness</i> (see Annex C)				
IRHD ^b , minimum		–	80	–
<i>Determination of elastic modulus</i> (see 18.20)				
Modulus at 150 % elongation, minimum	N/mm^2	–	4,5	–
^a An increase greater than 1 mg/cm^2 is being considered for densities of XLPE greater than 1 g/cm^3 .				
^b IRHD: international rubber hardness degree.				

Table 18 – Test requirements for mechanical characteristics of sheathing compounds (before and after ageing)

[illegible]

**Table 19 – Test requirements for particular characteristics
of PVC sheathing compounds**

Designation of compound (see 4.3)	Unit	ST ₁	ST ₂
Use of the PVC compound		Sheath	
<i>Loss of mass in an air oven</i> (IEC 60811-409) Treatment: – temperature (tolerance ± 2 K) – duration Maximum loss of mass	°C h mg/cm ²	– – –	100 168 1,5
<i>Pressure test at high temperature</i> (IEC 60811-508) – temperature (tolerance ± 2 K) – requirement: maximum indentation value	°C %	80 50	90 50
<i>Behaviour at low temperature</i> ^a (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) – requirement Cold elongation test on dumb-bells: – temperature (tolerance ± 2 K) – requirement Cold impact test: – temperature (tolerance ± 2 K) – requirement	°C °C % °C	–15 no cracks –15 ≥ 20 –15 no cracks	–15 no cracks –15 ≥ 20 –15 no cracks
<i>Heat shock test</i> (IEC 60811-509) Treatment: – temperature (tolerance ± 3 K) – duration – requirement	°C h	150 1 no cracks	150 1 no cracks
^a Due to climatic conditions national standards may require the use of a lower temperature.			

Table 20 – Test requirements for particular characteristics of thermoplastic PE sheathing compounds

Designation of compound (see 4.3)	Unit	ST ₃	ST ₇
<i>Density</i> ^a (IEC 60811-606)			
<i>Carbon black content</i> (for black oversheaths only) (IEC 60811-605)			
Nominal value	%	2,5	2,5
Tolerance	%	±0,5	±0,5
<i>Shrinkage test</i> (IEC 60811-503)			
Treatment:			
– temperature (tolerance ±2 K)	°C	80	80
– heating, duration	h	5	5
– heating, cycles		5	5
Maximum shrinkage	%	3	3
<i>Pressure test at high temperature</i> (IEC 60811-508)			
– temperature (tolerance ±2 K)	°C	–	110
– requirement: maximum indentation value	%	–	50
^a The measurement of density is only required for the purpose of other tests.			

Table 21 – Test requirements for particular characteristics of halogen free sheathing compounds

Designation of compound	Unit	ST ₈
<i>Behaviour at low temperature</i> ^a (IEC 60811-504, -505 and -506)		
Test to be carried out without previous ageing:		
– cold bending test for diameter < 12,5 mm	°C	–15
– temperature (tolerance ±2 K)		no cracks
– requirement		
Cold elongation test on dumb-bells:		
– temperature (tolerance ±2 K)	°C	–15
– requirement	%	≥ 20
Cold impact test:		
– temperature (tolerance ±2 K)	°C	–15
– requirement		no cracks
<i>Pressure test at high temperature</i> (IEC 60811-508)		
– temperature (tolerance ±2 K)	°C	80
– requirement: maximum indentation value	%	50
<i>Water absorption</i> (IEC 60811-402)		
Gravimetric method:		
Treatment:		
– temperature (tolerance ±2 K)	°C	70
– duration	h	24
Maximum increase of mass	mg/cm ²	10
^a Due to climatic conditions, national standards may require the use of a lower temperature.		

Table 22 – Test requirements for particular characteristics of elastomeric sheathing compounds

Designation of compound (see 4.3)	Unit	SE ₁
<i>Oil immersion test followed by a determination of the mechanical properties</i> (IEC 60811-404 and IEC 60811-501) Treatment: – oil temperature (tolerance ± 2 K) – duration Maximum variation ^a of: a) tensile strength b) elongation-at-break	°C h % %	100 24 ± 40 ± 40
<i>Hot set test</i> (IEC 60811-507) Treatment: – temperature (tolerance ± 3 K) – mechanical stress Maximum elongation under load Maximum permanent elongation after cooling	°C N/cm ² % %	200 20 175 15
^a Variation: difference between the median value obtained after treatment and the median value without treatment, expressed as a percentage of the latter.		

Table 23 – Test methods and requirements for halogen free compounds

Test method	Unit	Requirement
<i>Acid gas emission test</i> (IEC 60754-1) Bromine and chlorine content (expressed as HCl), maximum	%	0,5
<i>Fluorine content test</i> (IEC 60684-2) Fluorine content, maximum	%	0,1
<i>pH and conductivity test</i> (IEC 60754-2) pH, minimum Conductivity, maximum	µS/mm	4,3 10

Annex A

(normative)

Fictitious calculation method for determination of dimensions of protective coverings

A.1 Overview

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.2 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 in accordance with the rules in Annex B 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.3 Method

A.3.1 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
1,5	1,4	95	11,0
2,5	1,8	120	12,4
4	2,3	150	13,8
6	2,8	185	15,3
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
		1 000	35,7

A.3.2 Cores

The fictitious diameter D_c of any core is given by:

$$D_c = d_L + 2 t_i$$

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

If a metal screen or a concentric conductor is applied, a further addition shall be made in accordance with A.3.5.

A.3.3 Diameter over laid-up cores

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

- a) for cables having all conductors of the same nominal cross-sectional area:

$$D_f = k D_c$$

where the assembly coefficient k is as given in Table A.2.

- b) for four-core cables with one conductor with reduced cross-section:

$$D_f = \frac{2,42 (3 D_{c1} + D_{c2})}{4}$$

where

D_{c1} is the fictitious diameter of the insulated phase conductor, including metallic layer, if any, in millimetres;

D_{c2} is the fictitious diameter of the conductor with reduced cross-section including the insulation or covering, if any, in millimetres.