

# 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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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

**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

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**This redline version of the official IEC Standard allows the user to identify the changes made to the previous edition IEC 60502-1:2004+AMD1:2009 CSV. A vertical bar appears in the margin wherever a change has been made. Additions are in green text, deletions are in strikethrough red text.**

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 ST<sub>8</sub> 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](http://www.iec.ch/members_experts/refdocs). The main document types developed by IEC are described in greater detail at [www.iec.ch/standardsdev/publications](http://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.

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# 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  $\leq 750$  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 60038:1983, IEC standard voltages~~

IEC 60060-1:~~1989~~, *High-voltage test techniques – Part 1: General definitions and test requirements*

IEC 60183:~~1984~~, *Guidance for the selection of high-voltage A.C. cable systems*

IEC 60228:~~1978~~, *Conductors of insulated cables*

IEC 60230:~~1966~~, *Impulse tests on cables and their accessories*

~~IEC 60332-1:1993, Tests on electric cables under fire conditions – Part 1: Test on a single vertical insulated wire or cable~~

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 60332-3-24:2000, 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 60502-2:1997, 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)~~

IEC 60684-2:1987, Flexible insulating sleeving – Part 2: Methods of test

IEC 60724:2000, 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 60754-1:1994, Test on gases evolved during combustion of materials from cables – Part 1: Determination of the ~~amount of~~ halogen acid gas content

IEC 60754-2:1994, Test on gases evolved during combustion of ~~electric materials~~ from cables – Part 2: Determination of ~~degree of acidity of gases evolved during the combustion of materials taken from electric cables by measuring pH~~ (by pH measurement) and conductivity

~~IEC 60811-1-1:1993, Common test methods for insulating and sheathing materials of electric cables – Part 1: Methods for general application – Section 1: Measurement of thickness and overall dimensions – Tests for determining the mechanical properties~~

~~IEC 60811-1-2:1985, Common test methods for insulating and sheathing materials of electric cables – Part 1: Methods for general application – Section 2: Thermal ageing methods~~

~~IEC 60811-1-3:1993, Common test methods for insulating and sheathing materials of electric cables – Part 1: Methods for general application – Section 3: Methods for determining the density – Water absorption tests – Shrinkage test~~

~~IEC 60811-1-4:1985, Common test methods for insulating and sheathing materials of electric cables – Part 1: Methods for general application – Section 4: Tests at low temperature~~

~~IEC 60811-2-1:1998, Insulating and sheathing materials of electric and optical cables – Common test methods – Part 2-1: Methods specific to elastomeric compounds – Ozone resistance, hot set and mineral oil immersion tests~~

~~IEC 60811-3-1:1985, 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 60811-3-2:1985, 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 60811-4-1:1985, Common test methods for insulating and sheathing materials of electric cables – Part 4: Methods specific to polyethylene and polypropylene compounds – Section 1: Resistance to environmental stress cracking – Wrapping test after thermal ageing in air – Measurement of the melt flow index – Carbon black and/or mineral content measurement in PE~~

~~IEC 61034-2: 1997, Measurement of smoke density of cables burning under defined conditions – Part 2: Test procedure and requirements~~

~~ISO 48:1994, Rubber, vulcanized or thermoplastic – Determination of hardness (hardness between 10 IRHD and 100 IRHD)~~

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: ~~These~~ 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 metallic 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 ~~value of the "highest system voltage" for which the equipment may be used (see IEC 60038)~~ 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 ~~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~~ **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<br>( $U_m$ )<br>kV                                                      | Rated voltage ( $U_0$ )<br>kV |                  |
|------------------------------------------------------------------------------------------------|-------------------------------|------------------|
|                                                                                                | Categories A and B            | Category C       |
| 1,2                                                                                            | 0,6                           | 0,6              |
| 3,6                                                                                            | 1,8                           | 3,6 <sup>a</sup> |
| <sup>a</sup> 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><br>Polyvinyl chloride intended for cables with rated voltages $U_0/U \leq 1,8/3$ kV                                                           | PVC/A <sup>a</sup>      |
| b) <i>Cross-linked:</i><br>Ethylene propylene rubber or similar (EPM or EPDM)<br>High modulus or hard grade ethylene propylene rubber<br>Cross-linked polyethylene    | EPR<br>HEPR<br>XLPE     |
| <sup>a</sup> Insulating compound based on polyvinyl chloride intended for cables with rated <b>AC</b> 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<br>°C |                                         |
|---------------------------|-------------------------------------------------|-------------------------------------|-----------------------------------------|
|                           |                                                 | Normal operation                    | Short-circuit<br>(5 s maximum duration) |
| Polyvinyl chloride        | (PVC/A)                                         |                                     |                                         |
|                           | Conductor cross-section $\leq 300 \text{ mm}^2$ | 70                                  | 160                                     |
|                           | Conductor cross-section $> 300 \text{ mm}^2$    | 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 ~~should~~ 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<br>°C |
|--------------------------------------------------------------------|-------------------------|---------------------------------------------------------|
| a) <i>Thermoplastic:</i>                                           |                         |                                                         |
| Polyvinyl chloride (PVC)                                           | ST <sub>1</sub>         | 80                                                      |
|                                                                    | ST <sub>2</sub>         | 90                                                      |
| Polyethylene                                                       | ST <sub>3</sub>         | 80                                                      |
|                                                                    | ST <sub>7</sub>         | 90                                                      |
| Halogen free                                                       | ST <sub>8</sub>         | 90                                                      |
| b) <i>Elastomeric:</i>                                             |                         |                                                         |
| Polychloroprene, chlorosulfonated polyethylene or similar polymers | SE <sub>1</sub>         | 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<br><br>mm <sup>2</sup>                                    | Nominal thickness of insulation at rated voltage<br>$U_0/U (U_m)$ |                      |
|-----------------------------------------------------------------------------------------------------|-------------------------------------------------------------------|----------------------|
|                                                                                                     | 0,6/1 (1,2) kV<br>mm                                              | 1,8/3 (3,6) kV<br>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                  |
| <b>NOTE</b> —Any conductor cross-section smaller than those given in this table is not recommended. |                                                                   |                      |

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

| Nominal cross-sectional area of conductor<br><br>mm <sup>2</sup>                                    | Nominal thickness of insulation at rated voltage<br>$U_0/U (U_m)$ |                      |
|-----------------------------------------------------------------------------------------------------|-------------------------------------------------------------------|----------------------|
|                                                                                                     | 0,6/1 (1,2) kV<br>mm                                              | 1,8/3 (3,6) kV<br>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                  |
| <b>NOTE</b> —Any conductor cross-section smaller than those given in this table is not recommended. |                                                                   |                      |

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

| Nominal cross-sectional area of conductor<br><br>mm <sup>2</sup> | Nominal thickness of insulation at rated voltage<br><br>$U_0/U (U_m)$ |            |                |            |
|------------------------------------------------------------------|-----------------------------------------------------------------------|------------|----------------|------------|
|                                                                  | 0,6/1 (1,2) kV                                                        |            | 1,8/3 (3,6) kV |            |
|                                                                  | EPR<br>mm                                                             | HEPR<br>mm | EPR<br>mm      | HEPR<br>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        |

**NOTE** – Any conductor cross-section smaller than those given in this table is not recommended.

## 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<br>(approximate values) |
|----------------------------------------|---------------------------|--------------------------------------------------------------|
| Above<br>mm                            | Up to and including<br>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 metallic 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.

Metallic 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 metallic 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 mm<sup>2</sup>.

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~~lic~~ layer surrounding the cores either individually or collectively.

### 7.4.2 Cables having only a collective metal~~lic~~ 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~~lic~~ layer over each individual core (see Clause 9)

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 8) 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 7.2 and shall be non-hygroscopic.

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 13.2. For lead-sheathed cables, the separation from the underlying individual metal~~lic~~ 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~~lic~~ 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 mm<sup>2</sup>. If, however, an inner covering is applied, its thickness need not comply with 7.2.3 nor 7.2.4.

## 8 Metal~~lic~~ layers for single-core and multicore cables

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

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

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 multicore cables.

## 9 Metal~~lic~~ screen

### 9.1 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 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 metallic 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 Metallic sheath

### ~~11.1 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 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).

## ~~11.2 Other metallic sheaths~~

~~Under consideration.~~

## 12 Metallic armour

### 12.1 Types of metallic 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 mm<sup>2</sup>, galvanized steelwire braid armour ~~may~~ 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, ~~special consideration shall be given to~~ 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 materials specified in 13.2~~ 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 (ST<sub>8</sub>) 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 ~~shall~~ 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<br>mm                          | Up to and including<br>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<br>mm                          | Up to and including<br>mm | Steel or galvanized steel<br>mm | Aluminium or aluminium alloy<br>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 7.1 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 7.1 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 %.~~

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.

~~NOTE—A UV stability test is under consideration.~~

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 a thermoplastic compound (PVC or polyethylene or halogen free) or an elastomeric compound (polychloroprene, chlorosulfonated polyethylene or similar polymers).~~

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 (ST<sub>8</sub>) 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.

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

~~NOTE—Examples of materials<sup>1)</sup> considered to be undesirable include:~~

<sup>1)</sup>—Source: *Dangerous properties of industrial materials*, N.I. Sax, fifth edition, Van Nostrand Reinhold, ISBN 0-442-27373-6.

~~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~~

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  $\mu\text{s}$  and 5  $\mu\text{s}$  and a nominal time to half the peak value between 40  $\mu\text{s}$  and 60  $\mu\text{s}$ , 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 °C and 1 km length in accordance with the formulae and factors given in IEC 60228.

The DC 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.

### 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 metallic 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

~~NOTE—A spark test is under consideration for single-core cables without any metallic layer.~~

- 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            | Up to and including | Above              | Up to and including |                   |
| km               | km                  | km                 | 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 ~~Clause 8 of IEC 60811-1-1~~ 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 ~~Clause 8 of IEC 60811-1-1~~ 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 ~~Clause 9 of IEC 60811-2-1~~ 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 SE<sub>1</sub> 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

$\rho$  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  $\pm 2 ^\circ\text{C}$  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  $5\text{ }^{\circ}\text{C}$  K and  $10\text{ }^{\circ}\text{C}$  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 ~~8.1 of IEC 60811-1-1~~ 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 ~~8.2 of IEC 60811-1-1~~ 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 ~~9.1 of IEC 60811-1-1~~ IEC 60811-501.

### 18.4.2 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 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, ~~are recommended~~ 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 ~~9.1 of IEC 60811-1-1~~ 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 ~~9.2 of IEC 60811-1-1~~ IEC 60811-501.

### 18.5.2 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 18.

### 18.5.3 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.

### 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 ~~8.1.4 of IEC 60811-1-2~~ 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 ~~8.1.4 of IEC 60811-1-2~~ IEC 60811-401, under the following conditions:

- temperature:  $(10 \pm 2) \text{ }^{\circ}\text{C}$  above the maximum conductor temperature of the cable in normal operation (see Table 15);
- duration:  $7 \times 24 \text{ h}$ .

### 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 ~~8.1.4 of IEC 60811-1-2~~ 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 ST<sub>2</sub>

### 18.7.1 Procedure

The sampling and test procedure shall be in accordance with ~~8.2 of IEC 60811-3-2~~ 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 Clause 8 of IEC 60811-3-1, employing the test conditions given in the test method and in Tables 16 and 20.~~

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 ~~Clause 8 of IEC 60811-3-1~~ 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 Clause 8 of IEC 60811-1-4, employing the test temperature specified in Tables 16, 19 and 21.~~

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 ~~Clause 8 of IEC 60811-1-4~~ 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 ~~Clause 9 of IEC 60811-3-1~~ 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 ~~Clause 9 of IEC 60811-3-1~~ 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 ~~Clause 8 of IEC 60811-2-4~~ 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 ~~Clause 8 of IEC 60811-2-1~~ 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 ~~Clause 10 of IEC 60811-2-1~~ 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 ~~9.1 or 9.2 of IEC 60811-1-3~~ 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 ~~9.1 of IEC 60811-1-3~~ 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 ST<sub>1</sub>, ST<sub>2</sub>, or SE<sub>1</sub> 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 ST<sub>8</sub> 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 ST<sub>8</sub> 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 ST<sub>8</sub> 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 ST<sub>8</sub> 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 ST<sub>8</sub> 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.

#### ~~18.15.7 Toxicity test~~

~~Under consideration.~~

~~NOTE—A test method is under development within IEC.~~

#### 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 ~~Clause 11 of IEC 60811-4-1~~ IEC 60811-605.