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INTERNATIONAL STANDARD

Electrical installations in ships –
Part 350: General construction and test methods of power, control and instrumentation cables for shipboard and offshore applications

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CONTENTS

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ELECTRICAL INSTALLATIONS IN SHIPS –

Part 350: General construction and test methods of power, control and instrumentation cables for shipboard and offshore applications

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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International Standard IEC 60092-350 has been prepared by subcommittee 18A: Electric cables for ships and mobile and fixed offshore units, of IEC technical committee 18: Electrical installations of ships and of mobile and fixed offshore units.

This fifth edition cancels and replaces the fourth edition published in 2014 and constitutes a technical revision.

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

a) more detailed description of the test procedures in 7.7.6 and 7.7.7;
b) description of the relationship between Annex A and Annex D.

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

CDV	Report on voting
18A/420/FDIS	18A/423/RVC

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

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

The list of all the parts of the IEC 60092 series, under the general title *Electrical installations in ships*, 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.

A bilingual version of this publication may be issued at a later date.

ELECTRICAL INSTALLATIONS IN SHIPS –

Part 350: General construction and test methods of power, control and instrumentation cables for shipboard and offshore applications

1 Scope

This part of IEC 60092 provides the general constructional requirements and test methods for use in the manufacture of electric power, control and instrumentation cables with copper conductors intended for fixed electrical systems at voltages up to and including 18/30(36) kV on board ships and offshore (mobile and fixed) units.

The reference to fixed systems includes those that are subjected to vibration (due to the movement of the ship or installation) or movement (due to motion of the ship or installation) and not to those that are intended for frequent flexing. Cables suitable for frequent or continual flexing use are detailed in other IEC standards, for example IEC 60227 (all parts) and IEC 60245 (all parts), and their uses are restricted to those situations which do not directly involve exposure to a marine environment, for example, portable tools and domestic appliances.

The following types of cables are not included:

– optical fibre;
– sub-sea and umbilical cables;
– data and communication cables;
– coaxial cables.

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 60050-461, *International Electrotechnical Vocabulary – Part 461: Electric cables* (available at www.electropedia.org)

IEC 60092-360:2014, *Electrical installations in ships – Part 360: Insulating and sheathing materials for shipboard and offshore units, power, control, instrumentation and telecommunication cables*

IEC 60228, *Conductors of insulated cables*

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

IEC 60331-1, *Tests for electric cables under fire conditions – Circuit integrity – Part 1: Test method for fire with shock at a temperature of at least 830 °C for cables of rated voltage up to and including 0,6/1,0 kV and with an overall diameter exceeding 20 mm*

IEC 60331-2, *Tests for electric cables under fire conditions – Circuit integrity – Part 2: Test method for fire with shock at a temperature of at least 830 °C for cables of rated voltage up to and including 0,6/1,0 kV and with an overall diameter not exceeding 20 mm*

IEC 60331-11, *Tests for electric cables under fire conditions – Circuit integrity – Part 11: Apparatus – Fire alone at a flame temperature of at least 750 °C*

IEC 60331-21, *Tests for electric cables under fire conditions – Circuit integrity – Part 21: Procedures and requirements – Cables of rated voltage up to and including 0,6/1,0 kV*

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 60332-3-22, *Tests on electric and optical fibre cables under fire conditions – Part 3-22: Test for vertical flame spread of vertically-mounted bunched wires or cables – Category A*

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

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 60811-403, *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 60811-504, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 505: 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 505: 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 60885-3, *Electrical test methods for electric cables – Part 3: Test methods for partial discharge measurements on lengths of extruded power cables*

IEC 61034-1, *Measurement of smoke density of cables burning under defined conditions – Part 1: Test apparatus*

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

ISO 7989-2:2007, *Steel wire and wire products – Non-ferrous metallic coatings on steel wire – Part 2: Zinc or zinc-alloy coating*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-461 and the following 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
approximate value
value which is neither guaranteed nor checked

Note 1 to entry: It is used, for example, for the calculation of other dimensional values.

3.2
braid
covering formed from braided metallic or non-metallic material

[SOURCE: IEC 60050-461:2008, 461-05-10]

3.3
braid armour
covering formed from braided metal wires used to protect a cable from external mechanical effects

Note 1 to entry: Where the rules of the applicable national, regulatory or approval body permit the practice, it is also possible to use the braid armour as an earth conductor.

Note 2 to entry: Copper-wire braid armour may also provide a limited function of an electrostatic collective screen, provided it is effectively earthed.

3.4
compatibility test
test intended to check that the insulation and sheath are not liable to deteriorate in operation due to contact either with each other or with other components in the cable

3.5
conductor
<of a cable> part of a cable which has the specific function of carrying current

[SOURCE: IEC 60050-461:2008, 461-01-01]

3.6
conductor screen
non-metallic conducting layer applied between the conductor and insulation to equalise the electrical stress between these components

Note 1 to entry: It may also provide smooth surfaces at the boundaries of the insulation and assist in the elimination of spaces at these boundaries

3.7
core-insulated conductor, US
assembly comprising a conductor and its own insulation (and screens, if any)

Note 1 to entry: In North American usage, the core of a cable has been defined as the assembly of components of a cable lying under a common covering such as the sheath (jacket).

3.8
drain wire
un-insulated wire laid in contact with an electrical screen or an electrical shield which has the specific function of earthing an electrostatic screen by ensuring a low resistive path throughout the length of the cable

3.9
electrostatic screen
electrostatic shield, US
earthed metallic layer surrounding a cable which confines the electric field generated by the cable within the cable cores, pair(s), triples(s) or quad(s), and/or protects the core(s), pair(s), triple(s) or quad(s) from external influence

Note 1 to entry: Metallic sheaths, foils, braids, armours and earthed concentric conductors may also serve as an electrostatic screen, provided they are effectively grounded or earthed.

3.10
fictitious value
value calculated according to the "fictitious method" described in Annex A

3.11
filler
material used to fill the interstices between the cores of a multi-conductor cable

[SOURCE: IEC 60050-461:2008, 461-04-05]

3.12
fire resistance
circuit integrity
ability of an electric cable to continue to operate in a designated manner whilst subjected to a specified flame source for a specified period of time under specified conditions

3.13
flexible cable
cable which is required to be capable of being flexed while in service and of which the structure and materials are such as to fulfil this requirement

[SOURCE: IEC 60050-461:2008, 461-06-14]

3.14
individually screened cable
radial field cable
cable in which each core is covered with an individual screen

[SOURCE: IEC 60050-461:2008, 461-06-12]

3.15
inner covering
non-metallic covering which surrounds the core or the assembly of the cores or the cabling elements (and fillers, if any) of a multi-conductor cable and over which further layers are applied and which has no mechanical or electrical functions

Note 1 to entry: The inner covering can be either extruded or taped, and in either case forms a continuous layer, which has only an approximate value of thickness and no defined mechanical requirements.

Note 2 to entry: Taped inner coverings are also sometimes called "lapped beddings".

3.16
inner sheath
inner jacket, US
non-metallic sheath generally applied under a metallic sheath, reinforcement or armour

Note 1 to entry: The inner sheath shall have the following properties:

– it shall be extruded;
– it may be used to fill the interstices;
– it shall be of a material listed in IEC 60092-360;
– it shall have a defined nominal thickness (value).

[SOURCE: IEC 60050-461:2008, 461-05-13, modified – The note to entry has been added.]

3.17
insulated cable
assembly consisting of

– one or more cores;
– their individual covering(s) (if any);
– assembly protection (if any);
– protective covering(s) (if any).

Note 1 to entry: Additional un-insulated conductor(s) may be included in the cable.

Note 2 to entry: The assembly protection may consist of fillers, binders or inner coverings.

Note 3 to entry: The protective covering(s) consists of one or more "constituent elements" such as a metallic braid, wire or a metallic screen, thermosetting or thermoplastic sheaths, (impregnated) fibrous braid or woven tape, bedding for metal armour or paint for metal armour.

[SOURCE: IEC 60050-461:2008, 461-06-01, modified – Notes 2 and 3 to entry have been added.]

3.18
insulation screen
core screen
electrical screen of non-metallic semi-conducting layer in combination with a metallic layer

3.19
length of lay
axial length of one complete turn of the helix formed by one cable component in a twisted construction

[SOURCE: IEC 60050-461:2008, 461-04-01, modified – The words "in a twisted construction" have been added.]

3.20
median value
middle value, when several results have been obtained and ordered in increasing (or decreasing) succession, if the number of available values is odd, and the mean of the two middle values if the number is even

3.21
multi-unit cable
cable consisting of more than one pair, triple or quad unit either unscreened or with an individual electrostatic screen around each unit or having an electrostatic screen applied around the assembly of units (a collective screen) in a twisted construction

3.22
nominal value
value by which quantity is designated, and which is often used in tables

Note 1 to entry: Usually, in this document, nominal values refer to values which are to be checked by measurements, taking into account specified tolerances.

3.23
oversheath
outer sheath
protective overall jacket, US
protective jacket
non metallic sheath applied over a covering, generally metallic, ensuring the protection of the cable from the outside

Note 1 to entry: The outer sheath shall have the following properties:

– it shall be extruded;
– it may be used to fill the interstices;
– it shall be of a material listed in IEC 60092-360;
– it shall have a defined nominal thickness (value).

Note 2 to entry: In North-America, the term sheath is generally used for metallic coverings, whereas the term jacket is used only for non-metallic coverings.

[SOURCE: IEC 60050-461:2008, 461-05-04, modified – Note 2 to entry has been replaced by a new note.]

3.24
pair unit
two cores laid up with or without interstitial fillers or binder tape(s)

3.25
quad unit
four cores laid up with or without interstitial fillers or binder tape(s)

3.26
separator
thin layer used as a barrier to prevent mutually detrimental effects between different components of a cable, such as between the conductor and insulation or between insulation and sheath

[SOURCE: IEC 60050-461:2008, 461-05-01]

3.27
single unit cable
cable consisting of either one pair, triple or quad unit, either unscreened or with an individual electrostatic screen

3.28
stranded conductor
conductor consisting of a number of individual wires all or some of which generally have a helical form

Note 1 to entry: The cross section of a stranded conductor may be circular or otherwise shaped.

Note 2 to entry: The term "strand" is also used to designate a single wire.

[SOURCE: IEC 60050-461:2008, 461-01-07, modified – The words "or strands" have been deleted from the definition.]

3.29
SZ cabling
method of cabling in which the direction of lay of the cable components is periodically reversed

[SOURCE: IEC 60050-461:2008, 461-04-07]

3.30
triple unit
three cores laid up with or without interstitial fillers or binder(s)

3.31 tests

3.31.1
routine test
test made by the manufacturer on each manufactured length of cable to check that each length meets the specified requirements

3.31.2
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

3.31.3
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 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.

4 Constructional requirements

4.1 General requirements

4.1.1 General

The construction of the cable is given in the applicable product standard.

4.1.2 Voltage designation

The standard method of designating the rated voltages of cables covered by this document shall take the form

$$U_0/U\ (U_m)$$

where

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

U is the rated power-frequency voltage between phase 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.

All voltages are given as RMS values.

4.1.3 Cable marking

4.1.3.1 Indication of origin

Cables shall be provided with a continuous indication of origin (manufacturer's name and/or trade mark) by one or more of the following methods:

a) printing, indenting or embossing on the outer sheath;

b) a printed tape within the cable;

c) the inclusion of identification threads within the cable;

d) printing on the insulation of at least one core.

The marking shall be legible.

Spacing and dimensions of the indication of origin shall be as given in the applicable product standard.

Conformity shall be checked by visual examination, and the durability of the print, where applicable, shall be in accordance with the test given in 8.20.

NOTE National or regulatory authorities or approval bodies might request the method of marking according to their applicable rules.

4.1.3.2 Rated voltage and cable construction

When specified in the applicable product standard, the rated voltage (U_o/U) and the construction (number of cores and cross-sectional area of the conductors) shall be printed, indented or embossed on the outer sheath.

The marking shall be legible.

Spacing and dimensions shall be as given in the applicable product standard.

Conformity shall be checked by visual examination, and the durability of the print where applicable shall be in accordance with the test as given in 8.20.

4.1.3.3 Optional cable designation/external markings

When agreed between the manufacturer and purchaser, cables may, in addition, be marked with a code designation that signifies the type of insulation/screening/armouring and sheathing materials used in their construction.

The marking shall be by embossing, indenting or printing on the outer sheath.

The marking shall be legible.

Spacing and dimensions shall be as given in the applicable product standard.

Conformity shall be checked by visual examination, and the durability of the print where applicable shall be in accordance with the test as given in 8.20.

4.1.4 Core identification

All cores shall be clearly identified.

The cores of multi-core cables or cores within pair, triple or quad unit(s) shall be identified by colour or numbering as given in the applicable product standard.

The colour or numbering shall be clearly identifiable and durable.

Spacing and dimensions of any numbering shall be as given in the applicable product standard.

Conformity shall be checked by visual examination, and the durability of the print where applicable shall be in accordance with the test as given in 8.20.

4.1.5 Halogen-free cables

For halogen-free cables, the non-metallic components shall meet the requirements given in Table 7.

4.2 Conductors

4.2.1 Material

The conductors shall consist of plain or metal-coated annealed copper.

4.2.2 Metal coating and separator

The component copper wires shall be metal-coated when used for conductors having a cross-linked insulation, unless a separator between the conductor and the insulation is provided, or suitable compatibility type tests are carried out to demonstrate that no harmful effects occur with uncoated copper wires. The metal coating shall be considered as satisfactory if, on visual inspection, the wire surface appears smooth, uniform and bright, and the insulation does not adhere to the conductor.

If a compatibility test is required, it shall be carried out using the method and requirements specified in 8.6.

4.2.3 Class and form

The conductors considered in this document are intended only for fixed installations and shall comply with class 2 or class 5 of IEC 60228. The minimum nominal conductor size depends on the voltage rating of the cable and shall be in accordance with Table 1.

Stranded copper class 2 conductors are recommended for general fixed-installation systems.

To aid installation, a conductor of class 5 may be used. Cables using class 5 conductors should not be regarded as suitable for repeated flexing in service.

Stranded circular non-compacted or compacted conductors are permitted for all cross-sections. Sector-shaped conductors are permitted for cross-sections of 10 mm^2 and above.

Table 1 – Minimum size of conductors

U	**Nominal cross-sectional area (minimum)** mm^2
250 V	0,5
1 000 V	1,0
3 kV	10
6 kV	10
10 kV	16
15 kV	25
20 kV	35
30 kV	50

The nominal size of the conductors shall be limited to 630 mm^2 in accordance with the values specified in IEC 60228.

All conductors shall have a regular shape and shall be free from sharp projections and other defects liable to damage the insulation.

4.2.4 Resistance

Unless specified in the applicable standard, the DC resistance of the conductors shall not exceed the applicable maximum value given in IEC 60228.

The DC resistance of conductors used in multi-unit (pairs, triples or quads) cables shall not exceed the maximum value given in the applicable product standard.

The DC resistance of drain wires shall not exceed the maximum value given in the applicable product standard.

Braids, including an optional earth lead underneath and in continuous contact with the braid, and armours, when used as earthing conductors, should have a value of conductance at least equal to that of the value for phase conductors for cross-sections up to and including 16 mm^2 and 50 % of the value for phase conductors with cross-sections greater than 16 mm^2.

The use of braids or armours as earthing conductors may not be permitted in some countries or by some approval authorities.

4.3 Insulation system

4.3.1 Material

The insulation system shall consist of at least one of the following:

a) one of the insulation compounds listed in IEC 60092-360;

b) a combination of two or more layer(s) of the insulation compounds listed in IEC 60092-360 that complies with the full requirements of one type;

c) a combination of one or more layers of inorganic tape(s), and one or more layer(s) of the insulation compounds listed in IEC 60092-360 that complies with the full requirements of one type.

4.3.2 Application

The insulation shall be extruded in one or more closely adherent layers. The insulation system shall form a compact and homogeneous body and shall be so applied that it fits closely onto the conductor or tape(s), if any.

It shall be possible to remove the insulation without damaging the conductor or the metal coating, if any.

Compliance shall be checked by visual inspection.

4.3.3 Insulation thickness

The thickness of insulation is specified for each size and type of cable in the applicable product standard.

For single core or multi-core cables, the thickness at any point may be less than the specified value, provided the difference does not exceed 0,1 mm + 10 % of the specified value.

For single-unit or multi-unit cables, the thickness at any point may be less than the specified value, provided the difference does not exceed 0,1 mm + 20 % of the specified value.

The thickness of any separator, screen or inorganic tape(s) applied over the conductor or over the insulation shall not be included in the thickness of insulation.

4.4 Screens

4.4.1 Conductor and insulation screens for high-voltage cables

4.4.1.1 Conductor screen

The conductor screen shall consist of an extruded semi-conducting compound which may be applied over a semi-conducting tape.

The extruded semi-conducting compound shall be firmly bonded to the insulation.

4.4.1.2 Insulation screen

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

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

The metallic layer shall be applied over the individual cores.

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

The dimensional, physical and electrical requirements of the metallic layer shall be determined taking into account any other requirements (for example, national or approval authority regulations and standards), including the value of current to be carried in the case of fault.

4.4.2 Screens (shields) for low voltage cables

4.4.2.1 Construction

The screen shall consist of one of the following:

a) a metal/polyester laminated electrostatic screening tape applied with the metallic side in contact with a drain wire or a metallic screening tape with an appropriate overlap;

   The metal/polyester tape shall be either aluminium-bonded to polyester or copper-bonded to polyester. The thickness of the tape is specified in the applicable product standard. The metal/polyester tape shall be in contact with a drain wire which shall be composed of metal-coated annealed copper wires in the case of aluminium laminate tape and either plain or tinned annealed copper wires in the case of copper laminate tape. The maximum resistance of the drain wire is specified in the applicable product standard.

b) the metallic screening tape shall be a plain or metal-coated tape (the thickness of the tape is specified in the applicable product standard); or

c) a plain copper or metal-coated copper braid with a drain wire if necessary applied in accordance with the formula given in 4.8.2; or

d) a combination of a) and c) or b) and c) above. Using this option, the drain wire may be omitted.

4.4.2.2 Application

The screen may be applied either over a single unit as an individual screen or over a formation of multi-cores or multi-units as a collective screen.

The electrostatic screens may also serve as an electromagnetic screen, in which case the requirements need to be verified with the customer.

In multi-unit cables, the individual electrostatic screens shall be electrically isolated both from each other and the collective screen, if any.

4.5 Cabling

4.5.1 Multi-core cables

The individual cores shall be twisted together in concentric layers with either a right- or left-hand lay. The use of reversed lay (SZ formations) is permitted. When necessary, filler(s) or extruded layers as detailed in 4.6 may be used to obtain a circular cable.

A non-hygroscopic binder tape or tapes may be applied over each layer.

4.5.2 Multi-unit cables

The formation of the individual units and then the assembly of the units shall be in accordance with the applicable product standard.

4.6 Inner coverings, fillers and binders

The inner covering, if any, may be extruded or lapped, as specified in the relevant standard of the cable. The inner covering shall be extruded in case of a braid armour of galvanized steel wires.

It shall be possible to remove the inner covering without damaging the underlying components.

Taped inner coverings shall be applied in one or more overlapping layers.

An open helix of suitable tape is permitted as a binder before application of an extruded inner covering. The thickness of the binder tape is optional.

The inner covering, fillers and binders, if any, shall be of non-hygroscopic material. The material selected shall be compatible with cable components with which it is in contact and compatible with the operating temperature of the cable.

NOTE In hazardous locations, inner coverings used instead of an inner sheath will not prevent the migration of combustible gas or dust particles through the cable. This is normally prevented by hazardous location rated cable glands dependent upon an impervious inner sheath on which to effect a seal.

4.7 Inner sheath

4.7.1 Material

The inner sheath material shall be selected from one of those listed in IEC 60092-360. The sheathing compound selected shall be compatible with the cable components with which it is in contact and compatible with the operating temperature of the cable.

4.7.2 Application

The inner sheath shall be extruded in one or more closely adherent layers. The inner sheath shall form a compact and homogeneous body and shall be so applied that it fits closely onto the underlying components.

It shall be possible to remove the inner sheath without damaging the underlying insulation and/or screen(s).

4.7.3 Thickness of inner sheath

The thickness of the inner sheath for each size and type of cable shall be as specified in the applicable product standard.

Unless specified in the applicable product standard, the thickness at any point may be less than the specified value, providing the difference does not exceed 0,1 mm + 15 % of the specified value for sheaths applied on a smooth cylindrical surface, or 0,2 mm + 20 % of the specified value for sheaths applied on an irregular cylindrical surface.

The thickness of any tape(s) under or over the inner sheath shall not be included in the measurement of the thickness of the inner sheath.

4.8 Metal braid armour

4.8.1 Material

The metal braid armour shall be made of zinc-coated (galvanized) steel wires complying with the galvanizing test specified in 8.12 and ISO 7989-2, or copper, metal-coated copper or copper-alloy wires.

4.8.2 Application

The "coverage density" of the braid shall be such that the weight of the braid is at least 90 % of the weight of a tube of the same metal, having an internal diameter equal to the calculated internal diameter under the braid and a thickness equal to the nominal diameter of the wires forming the braid.

The diameter under the braid is calculated with the fictitious method given in Annex A.

NOTE An alternative method for evaluating the "coverage density" of symmetrical braids is given by the following formula giving the "filling factor", F:

$$F = \frac{NPd}{\sin\alpha}\text{, or}$$

$$(mnd/2\pi D)\ (1 + \pi^2 D^2/L^2)^{1/2}$$

where

α	is the slope angle between the cable axis and the braid wires;
d	is the diameter of braid wire;
N	is the number of wires per carrier;
P	is the number of picks per millimetre;
m	is the total number of spindles;
n	is the total number of ends per spindle;
D	is the mean diameter of the braid;
L	is the lay length of the braiding wire.

The corresponding "coverage density", expressed as a percentage, is given by the formula:

$$G = \frac{\pi}{2} \times F \times 100$$

The coverage density G of 90 % is reached for a value of filling factor F of 0,573.

4.9 Outer sheath

4.9.1 Material

The sheath shall be selected from one of those listed in IEC 60092-360. The sheathing compound selected shall be compatible with the cable components with which it is in contact and compatible with the operating temperature of the cable.

4.9.2 Application

The outer sheath shall be extruded in one or more closely adherent layers. The outer sheath shall form a compact and homogeneous body and shall be so applied that it fits closely onto the underlying components.

It shall be possible to remove the outer sheath without damaging the underlying insulation and/or screen(s).

4.9.3 Thickness of outer sheath

The thickness of sheath for each size and type of cable shall be as specified in the applicable product standard.

Unless specified in the applicable product standard, the thickness at any point may be less than the specified value, if any, providing the difference does not exceed 0,1 mm + 15 % of the specified value for sheaths applied on a smooth cylindrical surface, or 0,2 mm + 20 % of the specified value for sheaths applied on an irregular cylindrical surface.

4.9.4 Calculation of lower and upper limits for the outer dimensions of cables

The calculation of lower and upper limits for the outer dimensions of cables with circular copper conductors are given in Annex D.

5 Test methods

5.1 Test conditions

5.1.1 Ambient temperature

Unless otherwise specified in the details for the particular test, tests shall be made at an ambient temperature of (20 ± 15) °C.

5.1.2 Frequency, waveform and magnitude of power-frequency test voltages

The frequency of the alternating test voltages shall be in the range 49 Hz to 61 Hz. The waveform shall be substantially sinusoidal. The power-frequency test voltages given in this document are RMS values.

5.2 Routine tests

5.2.1 General

The routine tests required by this document are:

a) measurement of the electrical resistance of conductors (see 5.2.2);

b) voltage test (see 5.2.3);

c) partial discharge test for rated voltages 6 kV up to 30 kV (see 5.2.4).

The routine tests are normally carried out on each manufactured cable length and may be carried out, at the manufacturer's option, either on delivery lengths or on manufactured lengths before they are cut into delivery lengths.

5.2.2 Measurement of the electrical resistance of the conductors

Resistance measurements shall be made on all conductors of each cable length submitted to the routine test.

The completed 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 the 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. As an alternative, the resistance shall 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 a length of 1 km in accordance with the formulae and factors given in IEC 60228.

Unless otherwise stated in the applicable product standard, the DC resistance of each conductor at 20 °C shall not exceed the appropriate maximum value specified for the applicable class of conductor in IEC 60228.

5.2.3 Voltage test

5.2.3.1 General

The voltage test shall be made at ambient temperature using, at the manufacturer's option, alternating voltage at power frequency, direct voltage or, where applicable, spark testing (high-frequency or other forms of voltage).

5.2.3.2 Single-core cable without metallic layer

If the single-core cable has no metallic layer, the cable as delivered shall be immersed in water at ambient temperature for a minimum period of 1 h.

A voltage shall be applied between the conductor and the water.

The voltage and the duration of its application shall be as given in Table 2.

Alternatively, the whole length of the completed cable as delivered shall be spark-tested (see 5.2.3.7).

5.2.3.3 Multi-core cable and cables with one or more metallic layers

A voltage shall be applied in turn between each conductor and each of the other conductors and the metallic layer, 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 layer, if any.

In radial field cables, the voltage shall be applied between the conductor and the core screen.

The voltage and the duration of its application shall be as given in Table 2.

5.2.3.4 Voltage test on sheath

The test shall be made on sheathed cable where there is a metallic layer under the sheath.

The whole length of the completed cable as delivered shall be spark-tested (see 5.2.3.7).

5.2.3.5 Test voltage

Unless otherwise stated in the applicable product standard for the cable, the values of the test voltage for the standard rated voltages shall be those given in Table 2.

Table 2 – Routine test voltage

Rated voltage of cable U_0/U kV	Test voltage for 5 min	
	Alternating current (AC) kV	Direct current (DC) [a] kV
0,15/0,25	1,5	3,6
0,6/1	3,5	8,4
1,8/3	6,5	15,6
3,6/6	12,5	–
6/10	21	–
8,7/15	30,5	–
12/20	42	–
18/30	63	–

NOTE The values for enhanced insulation thickness are given in the product standard.

[a] DC testing is not recommended for cables with rated voltages > 1,8/3 kV.

5.2.3.6 Requirement

The test voltage shall be increased gradually to the specified value and no breakdown of the insulation shall occur.

5.2.3.7 Spark test

When specified, this test shall be carried out in the final stage of manufacture.

The cable shall withstand the test voltage specified without failure of the insulation or sheath as appropriate. The spark test equipment used shall detect a puncture in the insulation or sheath having a diameter equal to, or greater than, half the specified insulation or sheath thickness. The recovery time of the spark tester shall be not greater than 1 s.

The magnitude and presence of the voltage shall be such that, with the electrode system used and at the speed used for the passage of the cable through the spark tester, the test requirements are met.

Unless otherwise stated in the applicable product standard for the cable, the values of the test voltage for insulation shall be:

– AC (50 Hz) 3,0 kV + (5× tabulated insulation thickness in mm) kV
– DC V AC × 1,5
– H.F. V AC + 1,0 kV

Unless otherwise stated in the applicable product standard for the cable, the values of the test voltage for sheath shall be:

– AC (50 Hz) 3,0 kV
– DC V AC × 1,5

NOTE For recommended minimum spark test voltage levels, see Annex B.

5.2.4 Partial discharge test

The partial discharge test shall be carried out in accordance with IEC 60885-3.

The magnitude of the discharge at 1,73 U_0 shall not exceed 5 pC.

6 Sample tests

6.1 General

The sample tests required by this document are:

a) conductor examination (see 6.4);

b) check of dimensions (see 6.5 to 6.7);

c) hot-set test for insulations and sheaths (see 6.8);

d) insulation resistance test (volume resistivity determination, see 6.9).

6.2 Frequency of sample tests

a) Conductor examination and check of dimensions

Conductor examination, measurement of the thickness of insulation and sheath and measurement of the overall diameter, if required by the purchaser, shall be made on one length from each manufactured series of the same type and size of cable, but shall be limited to not more than 10 % of the number of lengths in any one contract.

b) Physical tests

By agreement between the purchaser and manufacturer, the test specified shall be made on samples taken from cables manufactured for the contract, provided that the total length in the contract exceeds 2 km of multi-core cables or 4 km of single-core cables. The number of samples to be tested is given in Table 3.

Table 3 – Number of samples according to cable length

Cable length				Number of samples
Multi-core 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
> 30	–	> 60	–	a b

a For multicore cable lengths > 30 km, add one sample for each additional 10 km.

b For single core cable lengths > 60 km, add one sample for each additional 20 km.

6.3 Repetition of tests

If any sample fails any of the tests of 6.2, 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.

6.4 Conductor examination

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

6.5 Measurement of thickness of insulation

6.5.1 General

Each cable length selected for the test shall be represented by two pieces of cable, one taken from each end, any portion which may have suffered damage being discarded.

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

6.5.2 Procedure

The test procedure shall be in accordance with the IEC 60811-201.

6.5.3 Requirements

For each piece of core, the smallest value, rounded off to the nearest 0,01 mm (see Annex C) shall not be less than specified in the applicable product standard.

If the measured value on either of the two pieces fails to meet the requirements specified in 4.3.3, two further pieces shall be checked. If both of these further pieces meet the specified requirements, the cable is deemed to comply, but if one of them does not meet the requirements, the cable is deemed not to comply.

6.6 Measurements of thickness of non-metallic sheaths

6.6.1 General

Each cable length selected for the test shall be represented by two pieces of cable, one taken from each end, any portion which may have suffered damage having been discarded.

6.6.2 Procedure

The test procedure shall be in accordance with IEC 60811-202.

6.6.3 Requirements

For each piece of sheath, the smallest value, rounded off to the nearest 0,01 mm (see Annex C) shall not be less than specified in the applicable product standard.

If the measured value on either of the two pieces fails to meet the requirements specified in 4.7.3 or 4.9.3, two further pieces shall be checked. If both of these further pieces meet the specified requirements, the cable is deemed to comply, but if one of them does not meet the requirements, the cable is deemed not to comply.

6.7 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.

6.8 Hot-set test for insulations and sheaths

6.8.1 General procedure

The sampling and test procedure shall be carried out in accordance with IEC 60811-507 employing the conditions given in IEC 60092-360 for the insulation and for the sheath.

6.8.2 Requirements

The test results shall comply with the requirements given in IEC 60092-360 for the insulation and for the sheath.

6.9 Insulation resistance test (volume resistivity determination)

The insulation resistance shall be measured at ambient temperature using a DC voltage of 80 V to 500 V, after any AC high-voltage test has been carried out, but before any DC high-voltage test is carried out.

The measurement shall in general be effected 1 min after application of the voltage. In certain cases, however, in order to reach a substantial steady-state condition, the time of application may be prolonged up to a maximum of 5 min.

The connection procedure in carrying out the test on different types of cables shall be as follows.

– For single-core cables with a metallic layer, the insulation resistance measurement shall be performed between the conductor and the metallic covering.
– For single-core cables without a metallic layer, the insulation resistance measurement shall be performed between the conductor and the water in which the cable shall be immersed at least 1 h before the test.
– For cables having two to five conductors, with or without metallic layer, the insulation resistance measurement shall be performed in turn between each conductor and all other conductors connected together and to the metallic covering, if any.
– For cables having more than five conductors, the insulation resistance measurement test shall be performed: first, between all conductors of uneven number in all layers and all conductors of even number in all layers; second, between all conductors of even layers and all conductors of uneven layers; third, if necessary, between the first and the last conductor of each layer having an uneven number of conductors.
– For cables with individually screened units, an additional insulation resistance test shall be performed in turn between each screen and all other screens connected together and to the metallic armour, if any.

The measurement values of the insulation resistance shall be corrected to the reference temperature of 20 °C by using an appropriate temperature correction factor based on experimental results obtained on the insulation material concerned.

Volume resistivity (ρ) shall be calculated from the measured insulation resistance by the formula:

$$\rho = 2\,\pi\,LR\,/\,\ln(D/d)$$

where

ρ is the volume resistivity in ohms centimetre;

R is the measured insulation resistance, corrected to 20 °C, 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 calculated value of volume resistivity (ρ) shall be not less than the value specified for the applicable insulating material in IEC 60092-360.

NOTE 1 In some instances, the value for the volume resistivity is given in the form of the "insulation resistance constant K_i" value (expressed in MΩ·km) which is equivalent to 0,367 × $10^{-11}\,\rho$ (ρ expressed in Ω·cm).

NOTE 2 For the core of shaped conductors, the ratio D/d is the ratio of the perimeter over the insulation to the perimeter over the conductors.

7 Type tests, electrical

7.1 General

The type tests defined by this document, and to be applied on samples of completed cable, 10 m to 15 m long unless otherwise specified, are the following:

a) insulation resistance measurement at ambient temperature (see 7.2.1);

b) insulation resistance measurement at the maximum rated temperature (see 7.2.2);

c) increase of the AC capacitance after immersion in water when required (see 7.3);

d) high-voltage test for 4 h (see 7.4);

e) mutual capacitance (see 7.5);

f) inductance (see 7.6).

7.2 Insulation resistance measurement

7.2.1 Measurement at ambient temperature

7.2.1.1 General

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 deionised water at ambient temperature at least 1 h before the test. The measurement shall be made between the conductor and the water (see 7.4).

The DC test voltage shall be in the range 80 V to 500 V and shall be applied for not less than 1 min and not more than 5 min. If requested, the measurement may be confirmed at (20 ± 2) °C.

7.2.1.2 Calculations

Volume resistivity (ρ) shall be calculated by the method given in 6.9.

NOTE In some instances, the value for the volume resistivity is given in the form of the "insulation resistance constant K_i" value (expressed in MΩ·km) which is equivalent to $0,367 \cdot 10^{-11}$ ρ (ρ expressed in Ω·cm).

7.2.1.3 Requirements

The calculated value of volume resistivity (ρ) shall be not less than the value specified for the applicable insulating material in IEC 60092-360.

7.2.2 Measurement at maximum rated temperature

7.2.2.1 General

The cores of the cable sample with all outer coverings removed shall be immersed in water, which shall be heated at the specified temperature for at least 1 h before test.

The DC test voltage shall be in the range 80 V to 500 V and shall be applied for not less than 1 min and not more than 5 min.

7.2.2.2 Calculations

Volume resistivity (ρ) shall be calculated by the method given in 6.9.

NOTE In some instances, the value for the volume resistivity is given in the form of the "insulation resistance constant K_i" value (expressed in MΩ·km) which is equivalent to $0,367 \cdot 10^{-11}$ ρ (ρ expressed in Ω cm).

7.2.2.3 Requirements

The calculated value of volume resistivity (ρ) shall be not less than the value specified for the applicable insulating material in IEC 60092-360.

7.3 Increase in AC capacitance after immersion in water

7.3.1 General

The increase in AC capacitance test shall be carried out in accordance with the following method.

7.3.2 Preparation of test specimens

Every test specimen shall consist of a core sample 4,5 m long in which any covering of the insulation (including vulcanization tape, if any) has been removed.

7.3.3 Apparatus

A water tank shall be used so that the central portion of the test specimen is immersed over a length of 3 m whilst a length of 0,7 m is maintained above the water level at each end.

The water shall be thermostatically maintained at a temperature of (50 ± 2) °C.

The water level shall be maintained constant.

7.3.4 Procedure

The test specimen shall first be dried for 24 h in an oven, the air of which is maintained between 70 °C and 75 °C.

As soon as the test specimen is removed from the oven, the specimen shall be immersed, as indicated above, in tap water which has been previously heated to 50 °C.

The immersion shall be maintained at this temperature for 14 days.

The capacitance between the conductor and the water shall be measured with low-voltage AC at a frequency of 900 Hz ± 100 Hz. Three measurements shall be carried out:

– at the end of the first day: C1;
– at the end of the seventh day: C7;
– at the end of the fourteenth day: C14.

Precaution shall be taken to ensure that the temperature and the water level are the same for all measurements.

The increase in AC capacitance shall be calculated and expressed in a percentage:

a) between the end of the first day and the end of the fourteenth day: (C14 – C1)/C1;
b) between the end of the seventh day and the end of the fourteenth day: (C14 – C7)/C7.

7.3.5 Requirements

The values calculated from the measurements shall be not more than those specified in IEC 60092-360.

7.4 High-voltage test for 4 h for cables rated up to 1,8/3 kV

7.4.1 General

The cores of the cable sample with all outer coverings removed shall be immersed in deionised water at room temperature for at least 1 h.

A power-frequency voltage equal to three times the rated voltage U_0 shall be gradually applied and maintained continuously for 4 h between the conductor and the water.

7.4.2 Requirement

No breakdown of the insulation shall occur.

7.5 Mutual capacitance (control and instrumentation cables only)

The mutual capacitance shall be measured at 1 kHz on a total of at least two pairs, triples or quads that have been selected at random from the inner and outer layers. The values obtained shall be recorded in the cable type-test report.

7.6 Inductance to resistance ratio (control and instrumentation cables only)

The inductance-to-resistance ratio (L/R ratio) shall be calculated from measurements of inductance (L) made at 1 kHz on a total of at least two pairs, triples or quads that have been selected at random from the inner and outer layers and the DC resistance measured at 20 °C. The values obtained shall be recorded in the cable type-test report.

7.7 High voltage sequence test (cables having a voltage rating higher than 3,6/6 (7,2) kV)

7.7.1 General

The electrical type tests listed in 7.7 shall be performed on a sample of completed cable 10 m to 15 m in length between the test accessories.

With the exception of the provisions in 7.7.2, all the tests listed in 7.7.1 shall be applied successively to the same sample.

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

The normal sequence of tests shall be:

a) partial discharge test (see 7.7.3);
b) bending test, plus partial discharge test the magnitude of the discharge at 1,73 U_0 shall be recorded (see 7.7.4);
c) tan δ measurement as a function of the voltage (see 7.7.5);
d) tan δ measurement as a function of the temperature (see 7.7.6);
e) heating cycle test plus partial discharge test; the magnitude of the discharge at 1,73 U_0 shall be recorded (see 7.7.7);
f) impulse withstand test, followed by a power-frequency voltage test (see 7.7.8);
g) voltage test for 4 h (see 7.7.9).

7.7.2 Special provisions

Tests c) and d) in 7.7.1 may be carried out on a different sample from the sample used for the normal sequence of tests listed.

7.7.3 Partial discharge test

The partial discharge test shall be carried out as described in IEC 60885-3.

The test voltage shall be raised gradually to and held at 2,00 U_0 and then slowly reduced to 1,73 U_0.The magnitude of discharge at 1,73 U_0 shall be measured and recorded. This value shall not be higher than 5 pC.

7.7.4 Bending test

a) The sample shall be bent around a test cylinder (for example the hub of a drum) at room temperature for at least one complete turn. It shall then be unwound, and the process repeated, except that the bending of the sample shall be in the reverse direction.

This cycle of operations shall be carried out three times.

b) The diameter of the cylinder shall be:

– for single-core cables: 20 (d + D) ± 5 %;

– for three-core cables: 15 (d + D) ± 5 %;

where

D is the actual external diameter of the cable sample, in millimetres;

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

c) On completion of this test, the sample shall be subjected to a partial discharge measurement and shall comply with the requirements given in 7.7.3 above.

7.7.5 Tan δ measurement as a function of the voltage

a) The power factor of the sample mechanically conditioned, as described in a) and b) of 7.7.4, shall be measured at ambient temperature with a power-frequency voltage of 0,5 U_0, U_0 and 2 U_0.

b) The measurement value shall not exceed those given in Table 4.

Table 4 – Tan δ versus voltage

	EPR, HEPR	XLPE
Maximum tan δ at U_0	200 × 10^{-4}	40 × 10^{-4}
Maximum increment of tan δ between 0,5 U_0 and 2 U_0	25 × 10^{-4}	20 × 10^{-4}

7.7.6 Tan δ measurement as a function of the temperature

a) The sample of completed cables shall be heated by one of the two following methods; in each method, the temperature of the conductor shall be determined either by measuring the conductor resistance, or by a thermometer in the bath or oven or on the surface of the screen.

1) The sample shall be placed either in a tank of liquid or in an oven, or heating current shall be passed through the metallic insulation screen.

2) The temperature shall be raised gradually, until the conductor has reached the highest rated temperature for the relevant insulating compound given in IEC 60092-360.

b) The power factor shall be measured with a power-frequency voltage of 2 kV at the temperature specified in 1) and 2) of a) above.

c) The measured values shall comply with the requirements given in Table 5.

Table 5 – Tan δ versus temperature

	EPR, HEPR	XLPE
Maximum tan δ at ambient temperature	200×10^{-4}	40×10^{-4}
Maximum tan δ at rated temperature (90 °C)	400×10^{-4}	80×10^{-4}

7.7.7 Heating cycle test plus partial discharge test

a) The sample, which has been subjected to the tests 7.7.5 and 7.7.6, shall be laid out on the floor of the test room, and heated by passing alternating current through the conductor, until the conductor reaches a steady temperature 10 °C above the maximum rated temperature of the insulation in normal operation.

For multicore cables, the heating current shall be passed through all conductors.

This heating current shall be applied for at least 2 h, followed by at least 4 h of natural cooling in air.

This cycle shall be repeated twice more.

b) After the third cycle, the sample shall be subjected to the partial discharge measurement described in 7.7.3 and shall comply with the requirements of that subclause.

7.7.8 Impulse withstand test, followed by a power-frequency voltage test

a) This test shall be performed on the sample at a conductor temperature 5 °C above the maximum rated operating temperature of the insulation.

The impulse voltage shall be applied according to the procedure given in IEC 60230.

b) The cable shall withstand without failure 10 positive and 10 negative voltage impulses, of the appropriate value given in Table 6.

Table 6 – Impulse withstand voltages

Rated voltage U_0	kV	3,6	6,0	8,7	12	18
Test voltage	kVp	60	75	95	125	170

c) After the test given in items a) and b), the cable sample shall be subjected, at room temperature, to a power-frequency voltage test for 15 min (on each core).

The values of the test voltage shall be those specified in Table 2.

No breakdown of the insulation shall occur.

7.7.9 High-voltage test for 4 h

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

A power-frequency voltage of 4 U_0 shall be applied for 4 h at room temperature between each conductor and metallic screen(s).

The test voltage shall be increased gradually to the specified value, and maintained for 4 h. No breakdown of the insulation shall occur.

8 Type tests (non-electrical)

8.1 General

The non-electrical type tests required by this document are the following.

8.2 Measurement of thickness of insulation

See sample test of 6.5.

8.3 Measurement of thickness of non-metallic sheaths (excluding inner coverings)

See sample test of 6.6.

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

8.4.1 Sampling

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

8.4.2 Ageing treatments

Ageing treatments shall be carried out as described in IEC 60811-401 under the conditions specified in IEC 60092-360.

Tensile tests before and after ageing with copper conductor are not applicable for cables with a voltage rating above 0,6/1,0 (1,2) kV.

8.4.3 Conditioning and mechanical tests

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

8.4.4 Requirements

The test results for unaged and aged pieces shall comply with the requirements given in IEC 60092-360.

8.5 Tests for determining the mechanical properties of sheaths before and after ageing

8.5.1 Sampling

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

8.5.2 Ageing treatments

Ageing treatments shall be carried out as described in IEC 60811-401 under the conditions specified in IEC 60092-360.

8.5.3 Conditioning and mechanical tests

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

8.5.4 Requirements

The test results for unaged and aged test pieces shall comply with the requirements given in IEC 60092-360.

8.6 Additional ageing test on pieces of completed cables (compatibility test)

8.6.1 General

This test is intended to check that the insulation and sheath are not liable to deteriorate in operation due to contact with each other or with other components in the cable.

The test is applicable to cables of all types.

8.6.2 Sampling

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

8.6.3 Ageing treatment

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) °C above the rated operating conductor temperature of the cable or, if the operating temperature of the cable is not known, (10 ± 2) °C above the highest rated temperature for the insulating material (see Table 2 of IEC 60092-360:2014).
– Duration: 7 × 24 h.

8.6.4 Mechanical tests

Test pieces of insulation and sheath from the aged pieces of cables shall be prepared as described in IEC 60811-501 and subjected to mechanical tests.

8.6.5 Requirements

The variations between the median values of tensile strength and elongation at break before and after ageing shall not exceed the corresponding values applying to the test for ageing in an air oven specified in IEC 60092-360 for the insulation and for the sheath.

8.7 Loss of mass test on PVC ST 2 sheath

8.7.1 Procedure

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

8.7.2 Requirements

The test results shall comply with the requirements given in IEC 60092-360 for ST 2 sheaths.

8.8 Test for the behaviour of PVC ST 2 and halogen-free SHF 1 sheaths at high temperature (hot pressure test)

8.8.1 Procedure

The sampling and test procedure shall be in accordance with IEC 60811-508 employing the test conditions given in the test method and in IEC 60092-360.

8.8.2 Requirements

The test results shall comply with the requirements given in IEC 60092-360 for ST 2 and SHF 1 sheaths.

8.9 Test for the behaviour of PVC sheath ST 2 and halogen-free SHF 1 and SHF 2 sheaths at low temperature

8.9.1 Procedure

The sampling and test procedure shall be in accordance with IEC 60811-506 for cold impact and IEC 60811-504 for cold bending or IEC 60811-505 for elongation at break when the cable is not subjected to bending test.

The tests shall be carried out at a test temperature of (−15 ± 2) °C.

8.9.2 Requirements

The test results shall comply with the requirements given in IEC 60092-360.

8.10 Special test for low temperature behaviour (when required)

The test procedures and requirements for low temperature behaviour are defined in Annex E.

The tests shall be carried out at a test temperature of (−40 ± 2) °C for the cold bending and at (−35 ± 2) °C for the cold impact test.

8.11 Test of the metal coating of copper wires

The metal coating shall be considered satisfactory if, on visual inspection (see 6.4), the wire surface appears smooth, uniform and bright, and the insulation is not adherent to the conductor.

8.12 Galvanizing test

When a galvanizing test is required for checking the resistance of steel wires against rusting, the immersion test specified in 5.3 of ISO 7989-2:2007 shall be carried out on wire specimens taken from the cable sample.

8.13 Test for resistance of PVC ST 2 and halogen-free SHF 1 sheaths to cracking (heat shock test)

8.13.1 Procedure

The sampling and test procedure shall be in accordance with IEC 60811-509.

The test temperature and period of heating shall be in accordance with IEC 60092-360.

8.13.2 Requirements

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

8.14 Ozone resistance test for insulation and for sheaths

8.14.1 Procedure

The sampling and test procedure shall be carried out in accordance with IEC 60811-403.

The ozone concentration and test period shall be in accordance with IEC 60092-360.

8.14.2 Requirements

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

8.15 Hot oil immersion test and enhanced hot oil immersion test for sheaths

8.15.1 Hot oil immersion test

8.15.1.1 Procedure

The sampling and test procedure shall be carried out in accordance with IEC 60811-404, employing the conditions given in IEC 60092-360.

8.15.1.2 Requirements

The test results shall comply with the requirements given in IEC 60092-360.

8.15.2 Enhanced hot oil immersion test (when required)

The test procedures and requirements shall be in accordance with IEC 60092-360.

8.16 Mud drilling fluid test (when required)

Drilling fluid resistance test procedures and requirements shall be in accordance with IEC 60092-360.

8.17 Fire tests

8.17.1 Flame-spread test on single cables

This test shall be carried out on samples of completed cables.

The test method and requirements shall be in accordance with IEC 60332-1-2.

8.17.2 Flame-spread test on bunched cables

The cables shall be tested according to IEC 60332-3-22. However, the touching configuration (in one or more layers) and the standard 300 mm wide ladder shall be used for all conductor sizes.

8.17.3 Smoke emission test

This test shall be carried out on samples of completed cables claimed to have low smoke emission.

The test method and requirements shall be those specified in IEC 61034-1 and IEC 61034-2.

8.17.4 Acid gas emission test

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

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

The results of the test shall comply with the requirements of Table 7.

8.17.5 pH and conductivity test

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

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

The results of the test shall comply with the requirements of Table 7.

8.17.6 Fluorine content test

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

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

The results of the test shall comply with the requirements of Table 7.

Table 7 – Test methods and requirements for halogen-free components

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

8.17.7 Fire-resistance test (test for circuit integrity cables)

The test shall be carried out in accordance with IEC 60331-11 and IEC 60331-21 or IEC 60331-1 or IEC 60331-2 as required in the relevant cable specification. The minimum time to failure shall be 90 min.

NOTE: The quoted test methods are for cables up to and including 0,6/1,0 kV. A test method for higher voltages is under development.

8.18 Determination of hardness for HEPR

The sampling and test procedure shall be carried out in accordance with Annex A of IEC 60092-360:2014.

The results of the test shall comply with the requirements given in IEC 60092-360.

8.19 Determination of elastic modulus for HEPR

The sampling and test procedure shall be carried out in accordance with Annex B of IEC 60092-360:2014.

The results of the test shall comply with the requirements given in IEC 60092-360.

8.20 Durability of print

A portion of the marking shall be rubbed lightly 10 times with a piece of cotton wool or cloth soaked in water. The marking shall remain legible.

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 are the cause of differences in nominal diameters and may therefore lead to variations in the thickness of coverings used on the same basic design of cable.

To avoid these difficulties, the fictitious calculation method was invented. 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, insulation thickness and number of cores. The thickness of the sheaths 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, thickness being pre-calculated and specified for each size of cable.

The fictitious calculation is used only to determine dimensions of sheaths and cable coverings. It is not a replacement for the calculation of normal 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 diameter, are eliminated.

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

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

A.3 Method

A.3.1 Conductors

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

Table A.1 – Fictitious diameter of conductor

Nominal cross-section of conductors mm^2	d_L mm	Nominal cross-section of conductors mm^2	d_L mm
0,5	0,8	50	8,0
0,75	0,95	70	9,4
1	1,1	95	11,0
1,5	1,4	120	12,4
2,5	1,8	150	13,8
4	2,3	185	15,3
6	2,8	240	17,5
10	3,6	300	19,5
16	4,5	400	22,6
25	5,6	500	25,2
35	6,7	630	28,3

A.3.2 Cores

The fictitious diameter D_c of any core is given by

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

$$D_c = d_L + 2\ t_i \text{ in mm}$$

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

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

where

t_i is the nominal thickness of insulation.

If a metallic screen or a concentric conductor is applied, a further addition shall be made according to Table A.2 or A.3.2 e) (braid screen).

Table A.2 – Increase of diameter for concentric conductors and metallic screens made of tape or wire

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

If the cross-section of the concentric conductor or metallic screen lies between two of the values given in Table A.2, then the increase in diameter is that given for the larger of the two cross-sections.

If a metallic screen is applied, the cross-sectional area of the screen to be used in Table A.2 shall be calculated in the following manner:

c) tape screen

$$A = n_t \times t_t \times w_t$$

where

A is the cross-sectional area

n_t is the number of tapes;

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

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

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

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

d) wire screen (with a counter-helix, if any)

$$A = \frac{n_w \times d_w^2 \times \pi}{4} + n_h \times t_h \times w_h$$

where

A is the cross-sectional area;

n_w is the number of wires;

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

n_h is the number of a counter-helix;

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

w_h is the width of a counter-helix, in mm.

e) braid screen

If a metallic braid screen is applied, the fictitious diameter over the screen is given by:

$$D_c + 5\ d_w \text{ in mm}$$

where

D_c is the fictitious diameter of the core, in mm;

d_w is the nominal diameter of the braid wire, in mm.

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:

$$D_f = k\, D_c \text{, in mm}$$

where the coefficient k is given in Table A.3.

Table A.3 – Assembly coefficient k for laid-up

Number of cores	Assembly coefficient k	Number of cores	Assembly coefficient k
2	2,00	25	6,00
3	2,16	26	6,00
4	2,42	27	6,15
5	2,70	28	6,41
6	3,00	29	6,41
7	3,00	30	6,41
7 [a]	3,35	31	6,70
8	3,45	32	6,70
8 [a]	3,66	33	6,70
9	3,80	34	7,00
9 [a]	4,00	35	7,00
10	4,00	36	7,00
10 [a]	4,40	37	7,00
11	4,00	38	7,33
12	4,16	39	7,33
12 [a]	5,00	40	7,33
13	4,41	41	7,67
14	4,41	42	7,67
15	4,70	43	7,67
16	4,70	44	8,00
17	5,00	45	8,00
18	5,00	46	8,00
18 [a]	7,00	47	8,00
19	5,00	48	8,15
20	5,33	52	8,41
21	5,33	61	9,00
22	5,67		
23	5,67		
24	6,00		

[a] Cores assembled in one layer.

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

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

where

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