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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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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 Electro-technical Commission (IEC) is a worldwide organization for standardization comprising all national electro-technical 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: Cables and cable installations, of IEC technical committee 18: Electrical installations of ships and of mobile and fixed offshore units.

This third edition cancels and replaces the second edition published in 2001 and constitutes a technical revision.

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

a) the new insulating compounds contained in IEC 60092-351;
b) the new sheathing compounds contained in IEC 60092-359;
c) the publication of IEC 60092-376;
d) the inclusion of cables up to 30 kV in the revision of IEC 60092-354;

e) for use in a limited number of closely defined applications, the provision to allow the design of a single core cable with a single extrusion covering, having a thickness equal to that of both an insulation and sheath;

f) new tests for the determination of enhanced cold properties, oil resistance, and resistance to drilling fluids.

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

FDIS	Report on voting
18A/285/FDIS	18A/286/RVD

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

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

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 publication will remain unchanged until the maintenance result date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

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- withdrawn,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

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 specifications, for example IEC 60227 and IEC 60245, 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 referenced documents are indispensable for the application 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 Electro-technical Vocabulary (IEV) – Chapter 461: Electric cables*

IEC 60092-351:2004, *Electrical installations in ships – Part 351: Insulating materials for shipboard and offshore units, power, control, instrumentation, telecommunication and data cables*

IEC 60092-359, *Electrical installations in ships – Part 359: Sheathing materials for shipboard power and telecommunication cables*

IEC 60228, *Conductors of insulated cables*

IEC 60331-11:1999, *Tests for electric cables under fire conditions – Circuit integrity – Part 11: Apparatus – Fire alone at a flame temperature of at least 750 °C*

IEC 60331-12:2002, *Tests for electric cables under fire conditions – Circuit integrity – Part 12: Apparatus – Fire with shock at a temperature of at least 830° C*

IEC 60331-21:1999, *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 60331-31:2002, *Tests for electric cables under fire conditions – Circuit integrity – Part 31: Procedures and requirements for fire with shock – Cables of rated voltage up to and including 0,6/1 kV*

IEC 60332-1-2:2004, *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 60332-3-22:2000, *Tests on electric cables under fire conditions – Part 3-22: Test for vertical flame spread of vertically-mounted bunched wires or cables – Category A*

IEC 60684-2:1997, *Flexible insulating sleeving – Part 2: Methods of test*
Amendment 1 (2003)[1)]

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

IEC 60754-2:1991, *Test on gases evolved during combustion of materials from cables – Part 2: Determination of degree of acidity of gases by measuring pH and conductivity*

IEC 60811-1-1:1993, *Common test methods for insulating and sheathing materials of electric cables and optical cables – Part 1-1: Methods for general application – Measurement of thickness and overall dimensions – Tests for determining the mechanical properties*
Amendment 1 (2001)[2)]

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

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

IEC 60811-2-1:1998, *Common test methods for insulating and sheathing materials of electric and optical cables – Part 2-1: Methods specific to elastomeric compounds – Ozone resistance, hot set and mineral oil immersion tests*
Amendment 1 (2001)[3)]

IEC 60811-3-1:1985, *Common test methods for insulating and sheathing materials of electric cables – Part 3: Methods specific to PVC compounds – Section One: Pressure test at high temperature – Tests for resistance to cracking*

IEC 60811-3-2:1985, *Common test methods of insulating and sheathing materials of electric and optical cables – Part 3: Methods specific to PVC compounds – Section Two: Loss of mass test – Thermal stability test*

IEC 61034-1:2005, *Measurement of smoke density of cables burning under defined conditions – Part 1: Test apparatus*

IEC 61034-2:2005, *Measurement of smoke density of cables burning under defined conditions – Part 2: Test procedure and requirements*

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1) There exists a consolidated edition 2.1 (2003), including IEC 60684-2:1997 and its Amendment 1.

2) There exists a consolidated edition 2.1 (2001), including IEC 60811-1-1:1993 and its Amendment 1.

3) There exists a consolidated edition 2.1 (2001), including IEC 60811-2-1:1998 and its Amendment 1.

ISO 1817:2005, *Rubber vulcanized – Determination of the effect of liquids*

ISO 7989-2:2007, *Steel wire and wire products – Non-ferrous metalic 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 as well as the following terms and definitions apply.

3.1
approximate value
value which is neither guaranteed nor checked

NOTE It is used, for example, for the calculation of other dimensional values.

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

[IEV 461-05-10]

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

NOTE 1 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 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

[IEV 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 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 (North America)
assembly comprising a conductor and its own insulation (and screens, if any)

NOTE 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 a screen or a shield which has the specific function of earthing an electrostatic screen by ensuring a low resistive path throughout the length of the cable

[IEV 461-03-07, modified]

3.9
electrostatic screen
electrostatic shield (North America)
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 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

[IEC 60502-2, definition 3.1.4]

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

[IEV 461-04-05]

3.12
fire resistance (circuit integrity)
ability to continue to operate in the designated manner whilst subject to a specified flame source for a specified period of time

[IEC 60331-11, definition 3.1, modified]

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

[IEV 461-06-14]

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

[IEV 461-06-12]

3.15
inner covering
non-metallic covering which surrounds the assembly of the cores (and fillers, if any) of a multi-conductor cable and over which further layers are applied

NOTE 1 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 Taped inner coverings are also sometimes called lapped beddings.

[IEV 461-05-02, modified]

3.16
inner sheath
inner jacket (North America)
non-metallic sheath generally applied under a metallic sheath, reinforcement or armour It should be extruded. The inner sheath must have the following properties:

-It must be extruded.

-It can be used to fill the interstices.

-It must be of a material listed in IEC 60092-359.

-It must have a defined nominal thickness (value).

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 Additional un-insulated conductor(s) may be included in the cable.

NOTE 2 The assembly protection may consist of fillers, binders or inner coverings.

NOTE 3 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.

[IEV 461-06-01, modified]

3.18
insulation screen
core screen
electrical screen of non-metallic and/or metallic material covering the insulation

[IEV 461-03-03]

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

[IEV 461-04-01, modified]

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 (from IEC 60502-2)

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 Usually, in this standard, 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 (North America)
non metallic sheath applied over a covering, generally metallic, ensuring the protection of the cable from the outside. The outer sheath must have the following properties:

-It must be extruded.

-It can be used to fill the interstices.

-It must be of a material listed in IEC 60092-359.

-It must have a defined nominal thickness (value).

NOTE In North America, the term sheath is generally used for metallic coverings, whereas the term jacket is used only for non-metallic coverings.

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

[IEV 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 The cross section of a stranded conductor may be circular or otherwise shaped.

NOTE 2 The term “strand” is also used to designate a single wire.

[IEV 461-01-07, modified]

3.29
S/Z cabling
method of cabling in which the direction of lay of the cable components is periodically reversed

[IEV 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

[IEC 60502-2, definition 3.2.1]

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

[IEC 60502-2, definition 3.2.2]

3.31.3
type test
test made before supplying, on a general commercial basis, a type of cable covered by this standard, in order to demonstrate satisfactory performance characteristics to meet the intended application

NOTE 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.

[IEC 60502-2, definition 3.2.3)

4 Construction requirements

4.1 General requirements

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

4.1.1 Voltage designation

The standard method of designating the rated voltages of cables covered by this standard shall take the form U_o/U (U_m) where

U_o 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 r.m.s. values.

4.1.2 Cable marking

4.1.2.1 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 8.19.

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

4.1.2.2 Rated voltage and cable construction

When specified in the applicable product standard, the rated voltage (U_0/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 8.19

4.1.2.3 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 outersheath.

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 8.19.

4.1.3 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 8.19.

4.1.4 Halogen-free cables

For halogen-free cables, the non-metallic components shall meet the requirements given in Table 4.

4.2 Conductors

4.2.1 Material

The conductors shall consist of plain or metal-coated annealed copper (IEC 60228).

4.2.2 Metal coating and separator

The component copper wires shall be metal-coated when used for conductors having a thermosetting 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. For conductors having thermoplastic insulation, the metal coating may be omitted. 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 8.5.

4.2.3 Class and form

The conductors considered in this standard 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	**Minimum cross-sectional area** 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.

NOTE When a class 5 conductor is used, special consideration should be given to the current-carrying capacity and the voltage drop. Class 5 conductors have, in most cases, a lower conductivity than the equivalent class 2 conductor of the same nominal cross-sectional area.

4.2.4 Resistance

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

The d.c. 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 d.c. 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 compounds listed in IEC 60092-351;
b) a combination of two or more layer(s) of the compounds listed in IEC 60092-351;
c) a combination of one or more layers of inorganic tape(s) and one or more layer(s) of the compounds listed in IEC 60092-351;
d) a combination of S95 or HF S95 compound together with a varnished glass braid;
e) one of the compounds listed in IEC 60092-351 applied with enhanced thickness equivalent to the total thickness of insulation and sheath of a construction consisting of a single layer of insulation and a single layer of sheath.

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 0,1mm + 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 0,1mm + 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.

The thickness of the organic tape(s) shall be adequate to meet the performance requirements of the applicable product standard.

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.

NOTE 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 overlapping.

   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.

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,

b) 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

c) a combination of a) and b) above. In case of a combination of a metal/polyester tape and a braid, the drain wire may be omitted; or

d) a concentric layer of wires or a combination of wires and copper tape(s).

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.

NOTE 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 S/Z formations is permitted. When necessary, filler(s) or extruded layers as detailed in 4.6 may be used to obtain a circular cable.

NOTE 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.

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 60092-359. The 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 8.11 and ISO 7989-2, or copper, metal-coated copper or copper-alloy wires.

NOTE For high voltage cables described in IEC 60092-354, the use of double steel tape armour and round or flat steel wire armour are permitted. For further guidance on construction, see IEC 60502-2.

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:

$$F = \frac{NPd}{\sin \alpha} \quad \text{or} \quad (mnd/2\pi D)\ (1 + \pi^2 D^2/L^2)^{1/2}$$

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:

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

To obtain the minimum value of G (90 %), the minimum value of F should be 0,573.

4.9 Outer sheath

4.9.1 Material

The sheath shall be selected from one of those listed in IEC 60092-359. The 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.

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 standard are r.m.s. values.

5.2 Routine tests

5.2.1 General

The routine tests required by this standard are:

a) measurement of the electrical resistance of conductors (see 5.2.2);
b) voltage test (see 5.2.3);
c) insulation resistance test (volume resistivity determination 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 1 km in length in accordance with the formulae and factors given in IEC 60228.

Unless otherwise stated in the applicable product standard, the d.c. 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 1h.

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 are given in Table 2.

Table 2 – Routine test voltage

Rated voltage of cable	**Test voltage for 5 min**	
U_o/U kV	**alternating current (a.c.)** kV	**direct current (d.c.)** 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.

– 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 1s.

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:

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

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

– a.c. (50 Hz) 3,0 kV
– d.c. V a.c. × 1,5

NOTE The adoption of IEC 62230 is under consideration (see Annex B).

5.2.4 Insulation resistance test (volume resistivity determination)

The insulation resistance shall be measured at ambient temperature using a d.c. voltage of 80 V to 500 V, after any a.c. high-voltage test has been carried out, but before any d.c. 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 60092-351.

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 megohm kilometres) which is equivalent to $0{,}367.10^{-11}\ \rho$

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.

6 Sample tests

6.1 General

The sample tests required by this standard 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).

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
etc	etc	etc	etc	etc

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 standard. 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 Clause 8 of IEC 60811-1-1.

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 Clause 8 of IEC 60811-1-1.

6.6.3 Requirements

For each piece of sheath, the smallest value, rounded off to the nearest 0,01mm (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 Clause 8 of IEC 60811-1-1.

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 Clause 9 of IEC 60811-2-1 employing the conditions given in IEC 60092-351 for the insulation, and in IEC 60092-359 for the sheath.

6.8.2 Requirements

The test results shall comply with the requirements given in IEC 60092-351 for the insulation or IEC 60092-359 for the sheath.

7 Type tests, electrical

7.1 General

The type tests required by this standard, 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 maximum rated temperature (see 7.2.2).
c) Increase of the a.c. capacitance after immersion in water when required (see 7.3).
d) High-voltage test for 4h (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 water at ambient temperature at least 1 h before the test. The measurement shall be made between the conductor and water (see 7.4).

NOTE If requested, the measurement may be confirmed at (20 ± 1) °C.

The d.c. test voltage shall be 80 V to 500 V and shall be applied for not less than 1 min and not more than 5 min.

7.2.1.2 Calculations

Volume resistivity (ρ) shall be calculated by the method given in 5.2.4.

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 megohm kilometres) which is equivalent to $0,367 \cdot 10^{-11}\ \rho$

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 60092-351.

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 d.c. test voltage shall be 80V to 500V 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 5.2.4.

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 megohm kilometres) which is equivalent to $0{,}367 \cdot 10^{-11}\ \rho$

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 60092-351.

7.3 Increase in a.c. capacitance after immersion in water

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

7.3.1 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.

7.3.2 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.

7.3.3 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 a.c. 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 must be taken to ensure that the temperature and the water level are the same for all measurements.

The increase in a.c. 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.

7.3.4 Requirements

The values calculated from the measurements shall be not more than those specified in IEC 60092-351.

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

The cores of the cable sample with all outer coverings removed shall be immersed in 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.

7.4.1 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 d.c. resistance measured at 20 °C. The values obtained shall be recorded in the cable type-test report.

8 Type tests, non-electrical

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

8.1 Measurement of thickness of insulation

See sample test of 6.5.

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

See sample test of 6.6.

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

8.3.1 Sampling

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

8.3.2 Ageing treatments

The ageing treatments shall be carried out as described in 8.1 of IEC 60811-1-2 under the conditions specified in IEC 60092-351.

The 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 .

8.3.3 Conditioning and mechanical tests

Conditioning and the measurement of mechanical properties shall be carried out as described in Clause 9 of IEC 60811-1-1.

8.3.4 Requirements

The test results for unaged and aged pieces shall comply with the requirements given in IEC 60092-351.

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

8.4.1 Sampling

Sampling and the preparation of the test pieces shall be carried out as described in Clause 9 of IEC 60811-1-1.

8.4.2 Ageing treatments

The ageing treatments shall be carried out as described in Clause 8 of IEC 60811-1-2 under the conditions specified in IEC 60092-359.

8.4.3 Conditioning and mechanical tests

The conditioning and measurement of mechanical properties shall be carried out as described in Clause 9 of IEC 60811-1-1.

8.4.4 Requirements

The test results for unaged and aged test pieces shall comply with the requirements given in IEC 60092-359.

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

8.5.1 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.

8.5.2 Sampling

Samples shall be taken from the completed cable as described in 8 1.4 of IEC 60811-1-2.

8.5.3 Ageing treatment

The ageing treatment of the pieces of cable shall be carried out in an air oven, as described in Clause 8 of IEC 60811-1-2 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 1 of IEC 60092-351).
– Duration: 7 × 24h.

8.5.4 Mechanical tests

Test pieces of insulation and sheath from the aged pieces of cables shall be prepared as described in Clause 8 of IEC 60811-1-2 and subjected to mechanical tests.

8.5.5 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 60092-351 for the insulation and IEC 60092-359 for the sheath.

8.6 Loss of mass test on PVC insulation and PVC (ST1 and ST2) sheaths

8.6.1 Procedure

The sampling and test procedure shall be in accordance with Clause 8 of IEC 60811-3-2.

8.6.2 Requirements

The test results shall comply with the requirements given in IEC 60092-351 for insulation and IEC 60092-359 for sheaths.

8.7 Test for the behaviour of PVC insulation and PVC (ST1 and ST2) and SHF1 sheaths at high temperatures (hot pressure test)

8.7.1 Procedure

The sampling and test procedure shall be in accordance with Clause 8 of IEC 60811-3-1 employing the test conditions given in the test method and in IEC 60092-351 for the insulation, and IEC 60092-359 for the sheath.

8.7.2 Requirements

The test results shall comply with the requirements given in IEC 60092-351 for the insulation and IEC 60092-359 for the sheath.

8.8 Test for the behaviour of PVC insulation and PVC sheath (ST1 and ST2) and SHF1 and SHF2 sheaths at low temperature

8.8.1 Procedure

The sampling and test procedure shall be in accordance with Clause 8 of IEC 60811-1-4, employing the test temperature specified in IEC 60092-351 for the insulation or in IEC 60092-359 for the sheath.

8.8.2 Requirements

The test results shall comply with the requirements given in Clause 8 of IEC 60811-1-4.

8.9 Special test for low temperature behaviour (when required)

8.9.1 Procedure

The tests shall be carried out according to Annex E at a test temperature of (–40 ± 2) °C for the cold bend test and at (–35 ± 2) °C for the cold impact test.

8.9.2 Requirements

Requirements are given in Annex E.

8.10 Test of the metal coating of copper wires

The metal coating should 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.

8.11 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 should be carried out on wire specimens taken from the cable sample.

8.12 Test for resistance of PVC insulation and PVC (ST1 and ST2) and SHF1 sheaths to cracking (heat shock test)

8.12.1 Procedure

The sampling and test procedure shall be in accordance with Clause 9 of IEC 60811-3-1, the test temperature and period of heating being in accordance with IEC 60092-351 for the insulation and IEC 60092-359 for the sheath.

8.12.2 Requirements

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

8.13 Ozone resistance test for insulation and for sheaths

8.13.1 Procedure

The sampling and test procedure shall be carried out in accordance with Clause 8 of IEC 60811-2-1, the ozone concentration and test period being in accordance with IEC 60092-351 and IEC 60092-359.

8.13.2 Requirements

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

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

8.14.1 Hot oil immersion test

8.14.1.1 Procedure

The sampling and test procedure shall be carried out in accordance with Clause 10 of IEC 60811-2-1, employing the conditions given in IEC 60092-359.

8.14.1.2 Requirements

The test results shall comply with the requirements given in IEC 60092-359.

8.14.2 Enhanced hot oil immersion test (when required)

Test procedures and requirements are defined in Annex F.

8.15 Mud drilling fluid test (when required)

Drilling fluid resistance test procedures and requirements are defined in Annex G.

8.16 Fire tests

8.16.1 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.

8.16.2 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.

8.16.3 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 61034-1and IEC 61034-2.

8.16.4 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 4.

8.16.5 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 4.

8.16.6 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 4.

Table 4 – Test methods and requirements for halogen free compounds

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

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

The method of test and requirements shall be those specified in IEC 60331-12 and IEC 60331-31 or IEC 60331-11 and IEC 60331-21 as required in the relevant cable specification.

8.17 Determination of hardness for HEPR and HF HEPR

The sampling and test procedure shall be carried out in accordance with Annex A of IEC 60092-351.

The results of the test shall comply with the requirements given in IEC 60092-351.

8.18 Determination of elastic modulus for HEPR and HF HEPR

The sampling and test procedure shall be carried out in accordance with Annex B of IEC 60092-351.

The results of the test shall comply with the requirements given in IEC 60092-351.

8.19 Durability of print

The compliance with the durability requirement shall be checked by trying to remove the marking or the print by rubbing them lightly 10 times with a piece of cotton wool or cloth soaked in water.

Annex A
(normative)

Fictitious calculation method for determination of dimensions of protective coverings

A.1 Introduction

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.

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

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 the table above, 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 the table above shall be calculated in the following manner:

a) tape screen

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

where

n_t is the number of tapes;

t_t is the nominal thickness of an individual tape, in 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.

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

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

where

n_w is the number of wires;

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

n_h is the number of a counter-helix;

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

w_h is the width of a counter-helix, 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:

$D_f = k\, D_c$, 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	5,41
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*	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:

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

where

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

D_{c2} is the fictitious diameter of the insulated conductor with reduced cross-section – if required.

c) for control and instrumentation cables, the formulae are as follows:

a) diameter over laid-up cores:
   use the method given in Table A.3

b) diameter over a pair (D_p) a triple (D_t) or a quad (D_q):
   $d_p = D_c \times 2$, in mm
   or
   $d_t = D_c \times 2{,}16$, in mm
   or
   $d_q = D_c \times 2{,}42$, in mm
   Where D_c is the diameter of a single core.

c) diameter over laid-up pairs (D_p), triples (D_t) or quads (D_q):
   $D_p = d_p \times k \times c_f$, in mm
   or
   $D_t = d_t \times k \times c_f$, in mm
   or
   $D_q = d_q \times k \times c_f$, in mm
   Where the coefficient k is as given in Table A.3.
   The coefficient c_f is as given in Table A.4.

Table A.4 –Coefficient c_f

Cable type	Coefficient c_f
Individual screened pairs	0,89
Collectively screened pairs	0,82
Individually screened triples	0,94
Collectively screened triples	0,87
Individually screened quads	1,0
Collectively screened quads	1,0

A.3.4 Inner coverings

The fictitious diameter over the inner covering D_B is given by

$$D_B = D_f + 2t_B$$

where

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

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

These fictitious values for t_B apply to cables whether the inner covering is extruded or lapped. For control and instrumentation cables use D_p, D_t or D_q as D_f value in the formula for D_B.

A.3.5 Sheath

The fictitious diameter over the sheath D_s is given by

$$D_s = D_u + 2t_s, \text{ in mm}$$

where

D_u is the fictitious diameter under the sheath;

t_s is the thickness specified in the standard of the applicable cable.

A.3.6 Braid armour

For braid armour, the fictitious diameter over the armour D_x is given by

$$D_x = D_A + 5d_w\text{, in mm}$$

where

D_A is the fictitious diameter under the armour;

d_w is the nominal diameter of the braid wire.

Annex B
(informative)

Recommended minimum spark test voltage levels (according to IEC 62230)

B.1 General

The levels of test voltages given below are from IEC 62230 and are those for use where no alternative voltages are specified in the product standard. Details of the test method are given in IEC 62230.

B.2 Test voltages

B.2.1 General

The voltages given in this annex are recommended as the minimum levels to be used to locate defects in the layer under test. The applicability of these levels should be confirmed by the manufacturer and will depend upon the type of material being tested.

NOTE Some countries have established higher test levels in their national standards.

B.2.2 Contact electrodes

The high-voltage supply to the test electrode may be a.c., d.c., HF or pulsed voltage, as specified in Table B.1.

Table B.1 gives test voltages which are recommended for cables having a rated voltage (U_0) between 300 V and 3 000 V.

Table B.1 – Recommended minimum spark-test voltages for cables having rated voltage (U_0) between 300 V and 3 000 V

Tabulated radial thickness of layer under test mm		Test voltage kV			
From	**Up to**	**a.c.**	**d.c.**	**HF**	**Pulse**
0	0,25	3	5	4	5
0,26	0,50	5	7	6	7
0,51	0,75	6	9	7	9
0,76	1,00	7	11	8	11
1,01	1,25	9	13	10 [a]	13
1,26	1,50	10	15	11 [a]	15
1,51	1,75	12	17	13 [a]	17
1,76	2,00	13	20	14 [a]	20
2,01	2,25	14	22	15 [a]	
2,26	2,50	16	24	17 [a]	
2,51	2,75	17	26	18 [a]	
2,76	3,00	19	28	20 [a]	

[a] HF voltage testing for layer thicknesses greater than 1,0mm should be limited to frequencies between 500 Hz and 4 kHz.

Pulsed voltage testing is not recommended for layer thicknesses greater than 2,0mm.

As a test to replace the traditional voltage test in water for single-core cables without any outer metallic layer, the recommendations in Table B.1 only apply for thicknesses up to 2,0 mm and for a.c. or d.c. waveforms.

When testing laid-up core assemblies, i.e. cables without sheath, the test voltage level shall be that for the lowest individual insulation thickness in the assembly.

NOTE Particular cable standards may, in exceptional circumstances (for example, for sheathing materials known to exhibit low insulation resistance characteristics, i.e. K_i less than 100 MΩ·km), recommend or require a reduction in the test voltage to ensure that excessive leakage current does not flow and give rise to spurious faults. In no instance will the reduction be in excess of a factor of two and the fault detection system will be verified under the alternative test conditions.

B.2.3 Non-contact electrodes

The high-voltage supply to the test electrode shall be d.c. only. The conductor of the core or the metallic layer under the sheath shall be continuously earthed and the potential difference between the electrode and the conductor or the metallic layer shall be 18 kV.

Annex C
(normative)

Rounding of numbers

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

C.1.1 Rules

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

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

C.1.2 Illustrations

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

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

Examples:
2,12 ≈ 2,1
2,449 ≈ 2,4
25,0478 ≈ 25,0

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

Examples:
2,17 ≈ 2,2
2,453 ≈ 2,5
30,050 ≈ 30,1

C.2 Rounding of numbers for other purposes

C.2.1 Guidance

For purposes other than those considered under C.1.1., it may be required that values be rounded to more than one decimal place. This may occur, for instance, in calculating the value of several measurement results or the minimum value by applying a percentage tolerance to a given nominal value. In these cases, rounding shall be carried out to the number of decimal places specified in the applicable clauses.

C.2.2 The method of rounding shall then be

- if the last figure to be retained is followed, before rounding, by 0, 1, 2, 3 or 4, it shall remain unchanged (rounding down);
- if the last figure to be retained is followed, before rounding, by 9, 8, 7, 6 or 5, it shall be increased by one (rounding up).

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

Annex D
(normative)

Calculation of the lower and upper limits for the outer dimensions of cables with circular copper conductors

D.1 General

This annex specifies a method for the calculation of the lower and upper limits for the outer diameter of cables with circular copper conductors.

D.2 Lower limit for the outer diameter

D.2.1 Obtain the lower limit of the conductor diameter from Table D.1

D.2.2 Calculate the nominal diameter over the core by adding to the appropriate value of the conductor diameter, obtained as in D.2.1, twice the specified mean value of the thickness of the insulation and of any other mandatory coverings of the individual core.

D.2.3 Calculate the nominal diameter over the core assembly by multiplying the value obtained in D.2.2 by the appropriate value of the assembly coefficient, k, given in Table A.3.

D.2.4 Calculate the nominal outer diameter D_o of the finished cable by adding to the value obtained in D.2.3 twice the specified mean value of the thickness of the sheath (or sheaths) and of the other mandatory covering, if any, over the core assembly (see Clause D.4).

D.2.5 The lower limit D_{min} of the outer diameter is obtained by multiplying D_o by 0,97 and rounding off the value obtained:

– to the nearest lower decimal, if 0,97 $D_o \leq$ 5 mm;

– to the nearest lower even decimal, if 5 mm < 0,97 $D_o \leq$ 10 mm;

– to the nearest lower half-unit, if 0,97 D_o > 10 mm.

Examples:

If	0,97 D_o = 4,33	D_{min} =	4,3
	0,97 D_o = 7,33	D_{min} =	7,2
	0,97 D_o = 11,33	D_{min} =	11,0
	0,97 D_o = 11,83	D_{min} =	11,5

D.3 Upper limit for the outer diameter

D.3.1 Obtain the upper limit of the conductor diameter from Table D.1.

D.3.2 Calculate the nominal diameter over the core by adding to the appropriate value of the conductor diameter obtained as in D.3.1 twice the specified mean value of the thickness of the insulation and of all (both mandatory and optional) coverings over the conductor, specified for the cable in question.

D.3.3 Calculate the nominal diameter over the core assembly by multiplying the value obtained in D.3.2 by the appropriate assembly coefficient, k, given in Table A.3.

D.3.4 Calculate the nominal outer diameter D_1 of the finished cable by adding to the value obtained in D.3.3 twice the specified mean value of the thickness of the sheath (or sheaths) and of all (both mandatory and optional) other coverings over the core assembly, specified for the cable or cord in question (see Clause D.4).

D.3.5 The upper limit D_{max} of the outer diameter is calculated to two decimal places as follows:

$$D_{max} = 1{,}05D_1 + X$$

where

X = 0,3 mm for single-core cables if $D_1 \leq 5$ mm;

X = 0,4 mm for single-core cables if $D_1 > 5$ mm, and for multi-core cables if $D_1 \leq 5$ mm;

X = 0,5 mm for multi-core cables if $D_1 > 5$ mm.

D_{max} is rounded off in a similar way as D_{min} (see D.2.5) but to the next highest value instead of to the nearest lower value.

Examples:

If	$1{,}05\,D_1 + X =$ 4,84	$D_{max} =$ 4,9
	$1{,}05\,D_1 + X =$ 9,23	$D_{max} =$ 9,4
	$1{,}05\,D_1 + X =$ 12,11	$D_{max} =$ 12,5
	$1{,}05\,D_1 + X$ 12,62	$D_{max} =$ 13,0

D.4 Thickness of the mandatory or optional coverings other than the insulation and the sheath(s)

Separator between conductor and insulation .... 0,08 mm

Proofed textile tape, textile braid round each core .... 0,15 mm

Separator between two layers of a sheath.. 0,15 mm

Outer textile braid .... 0,30 mm

Metal braid...2,5 × diameter of the component wire in mm

Table D.1 – Lower and upper limits of circular copper conductors for cables for fixed installations

Nominal cross-sectional area mm²	Class 2 Diameter of conductor		Class 5 Diameter of conductor	
	Lower limit mm	Upper limit mm	Lower limit mm	Upper limit mm
0,5	0,85	0,95	0,85	0,95
0,75	1,1	1,25	1,0	1,10
1	1,15	1,35	1,15	1,35
1,5	1,45	1,65	1,45	1,65
2,5	1,86	2,10	1,86	2,10
4	2,35	2,63	2,35	2,63
6	2,89	3,22	2,95	3,25
10	3,75	4,18	4,00	4,50
16	4,72	5,26	5,00	5,60
25	5,95	6,62	6,20	6,90
35	7,00	7,80	7,60	8,5
50	8,15	9,08	9,20	10,2
70	9,79	10,9	10,6	12,1
95	11,5	12,9	12,5	14,0
120	13,0	14,4	13,9	15,5
150	14,4	15,9	15,5	17,3
185	16,1	17,9	17,2	19,2
240	18,5	20,3	19,8	22,0
300	20,7	22,7	22,0	24,5
400	23,8	26,1	27,8	31,0
500	26,7	29,2	31,4	35,0
630	31,0	34,0	35,0	39,0

Annex E
(normative)

Cold bend test and impact test for low temperature behaviour

E.1 Cold bend test at any specified low temperature

E.1.1 Method No. 1

E.1.1.1 Apparatus

The apparatus shall include a chamber capable of maintaining the required test temperature and large enough that the bending operation may be carried out in it on the necessary mandrel onto which the specimen is to be wound.

E.1.1.2 Procedure

The straight specimen and the appropriate mandrel shall be placed in the conditioning chamber and allowed to remain for a period of 4 h. The specimen, while still in the chamber, shall be bent around the mandrel at such a rate that the time taken to complete the specified number of turns is between 15 s and 30 s. If the tension on the specimen is not specified, it shall be just sufficient to cause the specimen to conform to the periphery of the mandrel. Unless rotation of the mandrel is performed remotely, the specimen and mandrel shall be handled using thermally insulated gloves. If it is necessary (due to handling difficulties) to remove a specimen from the chamber, then bending must commence as quickly as possible and be completed within 30 s from the time of removal.

E.1.2 Method No. 2

E.1.2.1 Apparatus

See E.1.1.1.

E.1.2.2 Procedure

The straight specimen and a mandrel 10 times the overall diameter of the finished cable shall be placed in the conditioning chamber and allowed to remain for the specified period. The specimen, while still in the chamber, shall be wrapped one turn around the mandrel, straightened, wrapped one turn around the mandrel in the opposite direction, straightened, wrapped one turn around the mandrel in the reverse direction, and straightened. The wrapping around the mandrel shall be done slowly and at a uniform rate of speed, the applied tension being just sufficient to cause the specimen to conform to the periphery of the mandrel.

E.1.3 Examination and Requirements

The sheath and underlying components shall not show cracks or breaks.

Following the bending operation, the specimen, shall be cut and opened where necessary to study underlying components and examined for no cracks, breaks in braids or tapes, amount of space between convolutions of a wrap, etc. Cracking or flaking of lacquers, paints, asphaltic compounds, and the like shall be ignored unless specifically required to be examined.

E.2 Impact test at any specified low temperature

E.2.1 Apparatus

The apparatus shall include a device for impacting the wire or cable specimens; a refrigerator capable of maintaining the specified temperature; and sample supports of short lengths of wood (clear spruce) approximately 50 mm x 100 mm in dimension.

a) The impact apparatus shall consist of two vertically mounted uprights provided with grooves that serve as a track for the impact component. The impact component shall have a mass of 1,36 kg and be provided with a steel head for striking the test specimen. The head shall be 28,5 mm in diameter and have a flat striking surface 25 mm in diameter with slightly rounded edges. The impact component shall be provided with a locking mechanism that permits it to be released from the specified height.
b) The refrigerator shall be equipped with a rigid post having a solid base. The top of the post shall be provided with means for securely holding the 50 mm × 100 mm wood (clear spruce) sample support on which the test specimen is impacted.

   NOTE Clear spruce has been found to be an effective material to support the sample and is acceptable in testing to date. However, in cases of dispute clear spruce shall be used as the reference material.

E.2.2 Procedures

Ten straight 0,13 m specimens of the wire or cable to be tested shall be placed in the refrigerator chamber, which has been cooled to the specified temperature. The chamber shall then be maintained at this temperature for a period of 4 h. Immediately following the temperature conditioning, each of the specimens, in turn, shall be placed in the direction of the grain on the wooden piece fastened to the top of the post within the refrigerator chamber, the major cross-sectional axis of a flat cable being parallel with the surface supporting it. The specimen shall be subjected to the impact of the hammer head falling freely from a height of 915 mm measured between the hammer face and the top of the specimen. Care shall be taken to ensure that the specimen is hit squarely.

NOTE If necessary, a sample may be removed from the chamber, provided it is impacted within 15 s at room temperature. Where there is a conflict, the impact inside the chamber should be the referee method.

E.2.3 Examination and Requirements

The sheath and insulation of each specimen shall be examined and shall show no cracks and breaks.

Annex F
(normative)

Procedure and requirements for enhanced hot oil immersion test for sheaths

F.1 Sampling and preparation of the test pieces

Five tests pieces shall be prepared in accordance with procedures described in 9.2.2 and 9.2.3 of IEC 60811-1-1.

The test of determination of linear swell shall be carried out on dumb-bell samples of thickness (1,25 ± 0,25) mm.

F.2 Determination of the cross-sectional area of the test piece

See the test method in 9.2.4 of IEC 60811-1-1.

F.3 Oil to be used

Mineral oil type IRM 902 (in accordance with ISO 1817).

F.4 Procedure

Before immersion of each test piece, the weight to within 0,1 mg and linear dimension in mm along the axis of the dumb-bell (to one decimal place) shall be measured at room temperature.

Then, the test pieces shall be immersed in an oil bath previously heated to (100 ± 2) °C and shall be maintained in oil at that temperature for 7 days. At the end of the specific duration, the test pieces shall be removed from the oil, blotted lightly to remove oil excess and suspended in air at ambient temperature for at least 16 h but not more than 24 h, unless otherwise specified in the relevant cable standard. At the end of this period, any further excess oil shall be removed by lightly blotting the tests pieces, and then the linear swell, weight and mechanical properties of each test piece shall be measured.

F.5 Expression of results

The calculation of tensile strength shall be based on the area of the test piece measured before immersion.

The difference between the median value obtained of the five test pieces immersed in oil and the median value of the values obtained for the unaged test pieces, expressed as a percentage of the latter, shall not exceed the percentage specified in the requirements given in F.6-a, and F.6-b.

The change in linear swell and weight are calculated as follows:

((linear dimension after immersion/linear dimension before immersion) x 100) - 100%

((weight after immersion/weight before immersion) x 100) - 100%

F.6 Requirements

a) Tensile strength: Maximum variation from unaged samples of 40 %

b) Elongation at break: Maximum variation from unaged samples of 40 %

c) Linear swell: Maximum variation from unaged samples of 15 %

d) Change in weight: Maximum variation from unaged samples of 15 %

NOTE The requirement for linear swell will in due time be transferred to IEC 60092-359.

Annex G
(normative)

Drilling fluid test procedure and requirements

G.1 Drilling fluid resistance test

Drilling fluids are used in almost every oilfield drilling operation. The fluids used in the so-called drilling fluid systems may come into contact with cables and may affect the functioning of the cables. The suitability of electric cable sheathing materials (as given in IEC 60092-359) to exposure to these drilling fluids is heavily dependent on the type of drilling fluid present.

G.2 Drilling fluid to be used

The various drilling fluids can be grouped in three categories and for the water-based and oil-based mud, specific test drilling fluids are defined here

A material for which drilling fluid resistance is needed in one or more of the categories below shall also fulfil the normal oil test as given in IEC 60092-359 for SHF2 materials, as well as a test in IRM 903 oil (in accordance with ISO 1817) following the procedure described in Annex F for enhanced oil resistance. For this test in IRM 903 oil the following requirements are applicable:

a) tensile strength: maximum variations from unaged samples of 30 %;
b) elongation at break: maximum variations from unaged samples of 30 %;
c) linear swell: maximum variation from unaged samples of 30 %;
d) change in weight: maximum variation from unaged samples of 30 %.

In order to qualify a material in one or more of the drilling fluid categories, the material shall be tested separately for each category in the representative test drilling fluid.

	Drilling fluid type	Representative type
1	Water-based mud	Calcium Bromide Brine
2	Oil-based mud	Carbo Sea
3	Ester-based mud	Under consideration

NOTE The specific test drilling fluids and test method for ester-based mud is under consideration.

G.3 Procedure

Five tests pieces shall be prepared in accordance with procedures described in 9.2.2 and 9.2.3 of IEC 60811-1-1.

The test for determination of linear swell is carried out on dumb-bell samples of thickness (1, 25 ± 0, 25) mm.

The method of the determination of the cross-sectional area of test piece is given in 9.2.4 of IEC 60811-1-1.

Before immersion of each test piece, the weight to within 0,1 mg and linear dimension in mm along the axis of the dumb-bell (to one decimal place) shall be measured at room temperature.

Then, the test pieces shall be immersed in the particular fluid previously heated to (70 ± 2) °C and shall be maintained at that temperature for 56 days. At the end of the specific duration, the test pieces shall be removed from the fluid, blotted lightly to remove excess fluid and suspended in air at ambient temperature for at least for 16 h but not more than 24 h, unless otherwise specified in the relevant cable standard. At this end of this period, any further excess fluid shall be removed by lightly blotting the test pieces, and then the linear swell, weight and mechanical properties of each test piece shall be measured.

G.4 Expression of results

The calculation of tensile strength shall be based on the cross-sectional area of the test piece measured before immersion.

The difference between the median value obtained of the five test pieces immersed in fluid and the median value of the values obtained for the unaged test pieces, expressed as a percentage of the latter, shall not exceed the percentage specified in the requirements given in G.5-a, and G.5-b.

The change in linear swell and weight are calculated as follows:

– ((linear dimension after immersion/linear dimension before immersion) x 100) - 100%
  – ((weight after immersion/weight before immersion) x 100) - 100%

G.5 Requirements

a) Tensile strength: Maximum variation from unaged samples of 25 %

b) Elongation at break: Maximum variation from unaged samples of 25 %

c) Linear swell: Maximum variation from unaged samples of 20 %

d) Change in weight: Maximum variation from unaged samples of 15 %

NOTE Materials meeting this drilling fluid resistance qualification test are not automatically approved for use in a specific drilling fluid or in particular operating conditions, specific agreement with the cable manufacturer and/or additional testing in the specific oil and particular conditions being needed. The requirements in due time will be transferred to IEC 60092-359.

Bibliography

IEC 60092-354: *Electrical installations in ships – Part 354: Single and three-core power cables with extruded solid insulation for rated voltages 6 kV (U_m = 7,2 kV) up to 30 kV (U_m = 36 kV)*

IEC 60227(all parts): *Polyvinyl chloride insulated cables of rated voltages up to and including 450/750 V*

IEC 60245(all parts): *Rubber insulated cables – Rated voltages up to and including 450/750 V*

IEC 60502-2, *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 62230: *Electric cables – spark-test method*

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