INTERNATIONAL STANDARD

IEC 60092-350

Second edition
2001-06

Electrical installations in ships –

Part 350:
Shipboard power cables –
General construction and test requirements

Installations électriques à bord des navires –

Partie 350:
Câbles d'énergie pour utilisation à bord des navires –
Construction générale et prescriptions d'essai

Reference number
IEC 60092-350:2001(E)

Publication numbering

As from 1 January 1997 all IEC publications are issued with a designation in the 60000 series. For example, IEC 34-1 is now referred to as IEC 60034-1.

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Commission Electrotechnique Internationale
International Electrotechnical Commission
Международная Электротехническая Комиссия

PRICE CODE S

For price, see current catalogue

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

ELECTRICAL INSTALLATIONS IN SHIPS –

Part 350: Shipboard power cables – General construction and test requirements

FOREWORD

1) The IEC (International Electrotechnical Commission) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of the 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, the IEC publishes International Standards. 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. The IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
2) The formal decisions or agreements of the IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested National Committees.
3) The documents produced have the form of recommendations for international use and are published in the form of standards, technical specifications, technical reports or guides and they are accepted by the National Committees in that sense.
4) In order to promote international unification, IEC National Committees undertake to apply IEC International Standards transparently to the maximum extent possible in their national and regional standards. Any divergence between the IEC Standard and the corresponding national or regional standard shall be clearly indicated in the latter.
5) The IEC provides no marking procedure to indicate its approval and cannot be rendered responsible for any equipment declared to be in conformity with one of its standards.
6) Attention is drawn to the possibility that some of the elements of this International Standard may be the subject of patent rights. The IEC shall not be held responsible for identifying any or all such patent rights.

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 second edition cancels and replaces the first edition published in 1988, Amendment 1 (1994) and Amendment 2 (1999), and constitutes a technical revision.

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

FDIS	Report on voting
18A/206/FDIS	18A/213/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 3.

Annexes A, B, D, E and F form an integral part of this standard.

Annex C is for information only.

This standard forms a part of IEC 60092 *Electrical installations in ships.*

The committee has decided that the contents of this publication will remain unchanged until 2004. At this date, the publication will be:

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

ELECTRICAL INSTALLATIONS IN SHIPS –

Part 350: Shipboard power cables – General construction and test requirements

1 Scope

This part of IEC 60092 specifies the general constructional requirements and general test recommendations for shipboard cables with copper conductors intended for power systems at voltages up to and including 8,7/15 kV.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of IEC 60092. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of IEC 60092 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of IEC and ISO maintain registers of currently valid International Standards.

IEC 60092-351, *Electrical installations in ships – Part 351: Insulating materials for shipboard and mobile and fixed offshore units power, telecommunication and control 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 (all parts), *Tests for electric cables under fire conditions – Circuit integrity*

IEC 60332-3, *Tests on electric cables under fire conditions – Part 3: Tests on bunched wires or cables*

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

IEC 60811-1-2, *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, *Common test methods for insulating and sheathing materials of electric cables – Part 1: Methods for general application – Section Four: Tests at low temperature*

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

IEC 60811-3-1, *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, *Common test methods for insulating and sheathing materials of electric cables – Part 3: Methods specific to PVC compounds – Section Two: Loss of mass test – Thermal stability test*

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

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

3 Definitions

For the purpose of this standard, the following definitions apply.

3.1 Definitions concerning cables

3.1.1
insulated cable
assembly consisting of

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

Additional uninsulated conductor(s) may be included in the cable

3.1.2
radial field cable
cable in which each core is covered with an individual screen

3.1.3
screen
conducting layer(s) having the function of control of the electric field within the insulation. It may also provide smooth surfaces at the boundaries of the insulation and assist in the elimination of spaces at these boundaries

3.1.4
conductor
part of the cable which has the specific function of carrying current

3.1.5
stranded conductor
conductor consisting of a number of individual wires, all or the major part of which should have a helical form

NOTE The stranded conductor may be circular or shaped.

3.1.6
core
assembly comprising a conductor and its own insulation

3.1.7
core screen
electric screen of non-metallic and/or metallic materials covering the insulation

3.1.8
shield
surrounding earthed metallic layer to confine the electric field within the cable and/or to protect the cable from external electric influence

3.1.9
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

3.1.10
cord
flexible cable with a limited number of conductors of small cross-sectional area

3.1.11
length of lay
axial length of one complete turn of the helix formed by one of the cable components

3.1.12
separator
thin layer, used as a barrier to prevent mutually detrimental effects between different components of a cable, for example between conductor and insulation or between insulation and sheath

3.1.13
filler
material used to fill the interstices between the cores of a multiconductor cable

3.1.14
inner covering
non-metallic covering which surrounds the assembly of the cores (and fillers, if any) of a multicore cable and over which the protective covering is applied

3.1.15
sheath
uniform and continuous tubular covering consisting of non-metallic material, generally extruded

3.1.16
oversheath
non-metallic sheath applied over a metallic covering, constituting the outermost sheath of the cable

3.1.17
armour
covering consisting of metal tape(s) or wires, generally used to protect the cable from external mechanical effects

3.1.18
braid
covering made of plaited metallic or non-metallic material

3.2 Definitions of dimensional values

3.2.1
nominal value
value by which a quantity is designated and which is often used in tables. Usually, nominal values give rise to values to be checked by measurements, taking into account specified tolerances

3.2.2
approximate value
value which is neither guaranteed nor checked; it is used, for example, for the calculation of other dimensional values

3.2.3
median value
when several results have been obtained and ordered in increasing (or decreasing) succession, the median value is the middle value if the number of available values is odd, and the mean of the two middle values if the number is even

3.2.4
fictitious value
value calculated according to the "fictitious method" described in annex A

3.3 Definitions concerning the tests

3.3.1
routine tests
routine tests are tests made on all finished cable lengths to demonstrate the integrity of the cable

NOTE By agreement between purchaser, manufacturer and, when involved, approval organization (making reference, for example, to results of quality control procedures), the number of lengths of finished cable on which these tests should be carried out may be reduced.

3.3.2
special tests
tests made by the manufacturer on samples of completed cable or components taken from a completed cable, at a specified frequency, so as to verify that the finished product meets the design specifications

3.3.3
type tests
tests required to be made by a manufacturer 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. 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 which might change the performance characteristics

4 Conductors

4.1 Material

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

4.2 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. For conductors having thermoplastic insulation, the metal coating may be omitted. The same applies to thermosetting insulation provided suitable type tests demonstrate that no harmful effects occur.

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 chemical test is required it shall be carried out with the methods and requirements specified in annex E.

4.3 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.

NOTE 1 In these applications the class 5 conductors are used only to facilitate easier installation and termination under certain circumstances. Cables with such class 5 conductors should not be regarded as flexible cables.

NOTE 2 When using cables with class 5 conductors, users should carefully check the applicable current rating, which may be lower than for cables with the same cross-sectional area of class 2 conductors.

Stranded circular non-compacted or compacted and sector-shaped conductors are permitted for class 2.

The nominal cross-sectional area of the conductors shall have one of the values specified in table II or table III of IEC 60228, with the following limitations:

- for all types of conductors, the nominal cross-sectional area shall not exceed, in general, 630 mm^2.

NOTE 3 For any cable requiring larger conductors, these should comply with the requirement for class 2 or class 5 of IEC 60228.

Circular non-compacted class 2 and flexible class 5 conductors should be not less than 1 mm^2 nominal cross-sectional area.

Circular compacted class 2 conductors should be not less than 10 mm^2 nominal cross-sectional area. (Cross-sectional areas less than 10 mm^2 are under consideration.)

NOTE 4 Sector-shaped conductors should be not less than 25 mm^2 nominal cross-sectional area.

NOTE 5 Conductors for cables suitable for portable use in ships are under consideration.

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

Compliance with these requirements is checked by the appropriate test requirements specified in clauses 8 to 12 of this standard.

5 Insulation

5.1 Material

The insulation shall consist of one of the insulating compounds considered in IEC 60092-351.

5.2 Application of the insulation

The insulation shall be extruded closely to the conductor or to the separator, if any.

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

5.3 Insulation thickness

The insulation thicknesses are specified for each type of cable in the relevant standard.

The average thickness of the insulation shall be not less than the value specified for each type of insulation and conductor cross-section.

The thickness at any point may be less than the specified value provided that the difference does not exceed 0,1 mm + 10 % of the specified value.

6 Cabling

The cores of a multicore cable shall be laid up. The use of fillers is permitted in the assembly of multicore cables.

7 Inner covering, fillers and binders

7.1 Material

The inner covering, if any, may be extruded or lapped, as specified in the relevant standard of the cable.

The inner covering, fillers and binders, if any, shall be of non-hygroscopic suitable material, capable of withstanding the temperature arising when the conductors are operating at their maximum rated temperature, and compatible with the insulating material.

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

When rubberlike or plastic inner coverings or fillers are specified, they should consist of rubber (including regenerated and/or non-vulcanized rubber) or plastic compounds, and shall be resistant to moisture. When a non-metallic sheath is applied directly over the inner covering or the fillers, it may (at manufacturer's option) substitute partially or totally for the inner covering or fillers.

When a "watertight cable" is specified, the spaces among cores and sheath and the interstices in the conductor strands shall be filled so as to obtain a continuous sealing all along the cable, which shall comply with the watertightness test specified in 11.10.

7.2 Inner covering thickness

The approximate thickness of the extruded or lapped inner coverings, if any, is specified in the relevant standard for the cable.

8 Protective covering

8.1 Constituent elements of protective coverings

The protective covering of any cable consists of one or more "constituent elements" which shall be specified by the relevant standard for the cable. The following types of "constituent elements" are considered in this standard:

a) Metallic elements:
   1) metal braid armour;
   2) metal wire armour;
   3) metal tape armour.

b) Non-metallic elements:
   1) thermosetting or thermoplastic sheath;
   2) impregnated fibrous braid;
   3) bedding for metal armour;
   4) paint for metal armour.

8.2 Metal braid armour

The standard type of braid armour shall be made of zinc-coated (galvanized) steel wires complying with the galvanizing test specified in 11.12 and annex F, or copper, tinned copper or copper-alloy wires. On special request, the braid may be formed of aluminium-alloy wires with protection against corrosion.

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 annexes A and B. (For test method, see item b) of 11.6.)

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

$$F = \frac{NPd}{\sin \alpha}$$

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.

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.

8.3 Metal wire armour

The standard type of metal wire armour shall consist of zinc-coated mild steel wires having an elongation at break of at least 12 % and complying with the galvanized test specified in 11.12 and annex F.

On special request, wires may be of a non-magnetic material instead of steel.

Also on special request, and where the diameter under armour is greater than 15 mm, a flat wire armour may be used.

The wires should be applied over the bedding so as to form a uniform and substantially uninterrupted cylindrical layer and so as to ensure sufficient flexibility for the finished cable.

8.4 Metal tape armour

The standard type of metal tape armour shall be made of annealed steel tapes which, on special request, may be galvanized. Tapes of non-magnetic metals (for instance copper- or aluminium-alloys) may be used, on special request, in place of steel tapes.

NOTE The risk of corrosion shall be considered when using aluminium alloys.

The armour shall, in general, be formed of two tapes wound over the bedding in the same direction so that the gap in the first layer is not more than one-half of the tape width, and the second layer covers this gap with an overlap.

Particular types of metal tape armour (for instance consisting of one tape) may be permitted, provided their mechanical characteristics are specified.

For cables whose diameter under the bedding is less than 10 mm, the use of a metal type armour is not recommended.

8.5 Dimensions of the metal armours

For the purposes of this standard, when wire diameters, tape thicknesses and other similar armouring dimensions are specified, they shall be understood as nominal values, complying with 11.6.

8.6 Non-metallic sheath

8.6.1 Material

The sheath shall consist of one of the sheathing compounds considered in IEC 60092-359. The quality of the sheathing material shall be suitable for the operating temperature of the cable.

8.6.2 Thickness of sheath

The thicknesses of the sheaths are specified in the relevant standard for each type of cable. The average value of the sheath thickness shall be not less than the specified value.

The thickness at any point may be less than the specified value but shall not fall below 85 % of the specified nominal thickness by more than 0,1 mm for sheaths applied on a smooth cylindrical surface, or below 80 % of the specified nominal thickness by more than 0,2 mm for sheaths applied on an irregular cylindrical surface.

8.7 Impregnated textile braid

The textile braid, if permitted, shall be of cotton, hemp, glass, or synthetic or other equivalent textile fibre.

It shall be effectively impregnated with a compound which is resistant to moisture and free from deleterious action upon the various materials constituting the cable.

8.8 Bedding of armour

When tapes are used as a bedding, they shall be wound in such a manner that each tape covers the gap (if any) between the adjacent edges. Woven tapes (for instance cotton or glass tapes) should be saturated or coated with a moisture-resistant compound.

Synthetic tapes (for instance PVC tapes) do not need coating.

When fibrous rovings are used (for instance jute or glass rovings), they shall be wound in close spirals and be saturated and filled with a moisture-resistant compound.

When a fibrous braid is used as a bedding, it shall comply with 8.7.

When a non-metallic sheath is used as a bedding, it shall comply with 8.6.

The relevant thickness shall be considered as an approximate value.

8.9 Removal of the protective coverings

It shall be possible to remove easily:

– the outer sheath from the metallic covering

and

– the metallic covering from the inner covering or the inner sheath.

9 Test conditions

9.1 Ambient temperature

Unless otherwise specified in the details for a particular test, voltage tests shall be made at an ambient temperature of (20 ± 15) °C and other tests at an ambient temperature of (20 ± 5) °C.

9.2 Frequency and waveform of power frequency test voltages

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

10 Routine tests

10.1 General

The routine tests required by this standard are:

a) measurement of the electrical resistance of conductors (see 10.2);
b) high-voltage test (see 10.3);
c) insulation resistance test (see 10.4).

The routine tests shall normally be carried out in all finished cable lengths, but the number of lengths may be reduced by agreement between the purchaser, the manufacturer and, when involved, the approval organization (making reference, for instance, to the results of quality control procedures).

The routine test may be carried out, at the manufacturer's option, either on delivery lengths or on manufacturing lengths before they are cut into delivery lengths.

10.2 Electrical resistance of conductors

a) For multicore cables, measurements shall be made on all conductors of each cable length selected for the routine test.

b) The completed cable length, or a sample therefrom, shall be in the test room, which shall be maintained at a reasonably constant temperature for at least 12 h before the test. If it is doubtful whether the conductor temperature is the same as the room temperature, the resistance shall be measured after the cable has been in the test room for 24 h. Alternatively, the resistance shall be measured on a sample of conductor conditioned for at least 1 h in a temperature-controlled bath.

   The measured value of resistance shall be corrected to a temperature of 20 °C and 1 km length in accordance with the formulae and factors given in clause 6 of IEC 60228.

c) The d.c. resistance of each conductor at 20 °C shall not exceed the appropriate maximum value specified in table II for class 2 and table III for class 5 of IEC 60228.

10.3 High-voltage test

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

b) Single-core cables without metallic covering shall be immersed in water at room temperature for 1 h and the test voltage then applied for 5 min between the conductor and the water.

   Alternatively for single-core cycles without sheath, at manufacturer's option, a spark test *shall be carried out on the cable. The spark test equipment shall detect a puncture in the* insulation having a diameter equal to or greater than half of the specified insulation thickness. The recovery time of the spark shall be not greater than 1 s. The magnitude and the presence of the voltage shall be such that with the electrode system employed and at the speed employed for the passage of the cable through the spark tester, the test requirements are effectively met. The reference method to be used to establish the efficacy of the spark testing equipment is given in annex D.

c) For multicore cables and single-core cycles with metallic covering, the test voltage shall be applied for 5 min in succession between each insulated conductor and all the other ones connected to earth and to the metallic covering, 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 the other conductors and between each conductor and the metallic covering, if any.

d) Unless otherwise stated in the relevant standard for the cable, the values of the test voltage for the standard rated voltages are given in the following table 1:

Table 1 – Test voltage

Rated voltage of cable U_o/U kV	Test voltage for 5 min	
	Alternating current (a.c.) kV	Direct current (d.c.) kV
Up to and including 0,15 / 0,25	1,5	3,6
Up to and including 0,6 / 1,0	3,5	8,4
Up to and including 1,8 / 3	6,5	15,6
Up to and including 3,6 / 6	11	26,4
Up to and including 6 / 10	15	36
Up to and including 8,7 / 15	22	52,8

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

10.4 Measurement of insulation resistance

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

b) 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.

c) The connection procedure in carrying out the test on different types of cables shall be as follows:
   - for single-core cables with metallic covering, the insulation resistance measurement shall be performed between the conductor and the metallic covering;
   - for single-core cables without metallic covering, 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 covering, 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.

d) 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.

e) The insulation resistance constant K_i shall be calculated using the formula:

$$K_i = \frac{\ell R \times 10^{-9}}{\log_{10} \frac{D}{d}} \text{ M}\Omega\cdot\text{km}$$

where

R is the measured insulation resistance, in ohms, corrected to 20 °C;

ℓ is the length of the cable, in metres;

D is the outer diameter of the insulation, in millimetres;

d is the inner diameter of the insulation, in millimetres.

The calculated value of K_i shall be not less than the value specified for the relevant insulating material in table 2 of IEC 60092-351.

NOTE 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.

11 Special tests

11.1 General

The special tests required by this standard are:

a) conductor examination (see 11.3);

b) check of dimensions (see 11.4 and 11.7);

c) Hot-set test for insulation and for sheaths: see tables 2 and 3 for applicability of compounds in the test method (see 11.8);

d) test at low temperature for PVC (see 11.9);

e) watertightness test (see 11.10);

f) test of the metal coating of copper wires (see 11.11);

g) galvanizing test (see 11.12).

11.2 Frequency of special 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 manufacturing 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) Electrical and 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 multicore cables or 4 km of single-core cables, on the following basis:

Table 2 – Number of samples according to cable length

Cable length				Number of samples
Multicore cables		Single-core cables		
Above km	Up to and including km	Above km	Up to and including km	
2	10	4	20	1
10	20	20	40	2
20	30	40	60	3
etc.		etc.		etc.

11.3 Conductor examination

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

11.4 Measurement of thickness of insulation

a) Sampling

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 made shall be limited to either three cores or 10 % of the cores, whichever figure is the larger.

If the average thickness measured or the lowest value on either of the two pieces, fails to meet the requirements specified in item c) of 11.4, 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.

b) Procedure

The test procedure shall be in accordance with clause 8 of IEC 60811-1-1.

c) Requirements

For each piece of core, the average values, which shall be rounded off to the nearest 0,1 mm (see annex B), shall be not less than the specified nominal thickness and the smallest value shall not fall below 90 % of the specified thickness by more than 0,1 mm.

11.5 Measurements of thickness of non-metallic sheaths (excluding inner coverings)

a) Sampling

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.

If the average thickness measured or the lowest value measured on either of the two pieces fails to meet the requirements specified in item c) of 11.5, 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.

b) Procedure

The test procedure shall be in accordance with clause 8 of IEC 60811-1-1.

c) Requirements

Each piece of sheath shall comply with the following:

- For a sheath applied on a smooth cylindrical surface (e.g. on an inner covering or the insulation of a single core):
  - the average, which shall be rounded off to the nearest 0,1 mm (see annex B), of the measured values shall be not less than the specified nominal thickness;
  - the smallest value shall not fall below 85 % of the specified nominal thickness by more than 0,1 mm.
- For a sheath applied on an irregular cylindrical surface (e.g. a penetrating sheath embodying an inner covering or a sheath applied directly over a tape or wire armour), the smallest measured value shall not fall below 80 % of the specified nominal thickness by more than 0,2 mm.

11.6 Dimensions of armourings

a) A number of micrometer measurements should be made on some specimens selected at random, in order to check that metal wire diameters and metal tape thicknesses comply with the nominal values. Compliance should be understood as follows: All individual measured values to be not smaller than 90 % of the nominal value minus 0,03 mm, and not greater than 110 % of the average value plus 0,03 mm.

b) Checking of the coverage density of a metal braid armour should be carried out by weighing a braid specimen at least 25 cm long; the weight should not be less than 90 % of the calculated weight of an equivalent tube as specified under 8.2. Alternatively, the filling factor shall be not less than 0,573 (see note to 8.2).

11.7 Measurement of external diameter

If the measurement of the external diameter of the cable is required as a special test, it shall be carried out in accordance with clause 8 of IEC 60811-1-1.

11.8 Hot-set test for insulation and for sheaths (see tables 2 and 3 for applicability of compounds in the test method)

a) 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 table 4 of IEC 60092-351 for insulation, and in table II of IEC 60092-359 for sheaths.

b) Requirements

The test results shall comply with the requirements given in table 4 of IEC 60092-351 for insulations and table II of IEC 60092-359 for sheaths.

11.9 Test for the behaviour at low temperature of PVC insulation and PVC, SHF 1 and SHF 2 sheaths

a) Procedure

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

b) Requirements

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

11.10 Watertightness test

When a cable is required to be "watertight" this test should be carried out with the method and requirements given in the following items.

a) General

If a cable is required to be "watertight", the volume of water lost by the cable specimen, when tested in the conditions specified in items b), c) and d) below, should be not greater than the value V calculated from the formula:

$$V = 10\ N\ (A + 2), \text{ in cm}^3$$

where

N is the number of conductors in the cable, and

A is the cross-section of each conductor, in mm^2.

In any case, the lost volume should be not more than 2 000 cm^3.

b) Specimens

The specimen should be a piece of finished cable, 1,5 m long, which has not been subjected to prior flexing, heating or any other test. The metal armour may be removed from the ends, without disturbing the cable, to facilitate the making of a watertight gland.

c) Apparatus

A small water tank fitted with a watertight stuffing tubes should be connected with a device permitting the application of a controlled pressure, which is measured by a gauge, and with a device permitting the detection of leakages, if any. The fitting used for securing specimens to the tank should neither constrict nor widen the ends of the said specimens and should not give rise to leakage.

d) Procedure

One end of each specimen should be secured to the tank, then the water pressure raised in about 1 min to 0,1 MPa and maintained at this value for 3 h. Any water from the other end or from the surface of the specimen should be collected and measured.

11.11 Test of the metal coating of copper wires

The metal coating should be considered satisfactory, if, on visual inspection (see 11.3), the wire surface appears smooth and uniform and the insulation is not adherent to the conductor.

If a chemical test is required, it should be carried out with the method and requirements specified in annex E (colorimetric method).

11.12 Galvanizing test

When a galvanizing test is required for checking the resistance of steel wires against rusting, the immersion test specified in annex F should be carried out on wire specimens taken from the cable sample. If paint (see item b) 4) of 8.1) is applied on the armour, this test should be made on specimens taken from wires prior to their application of the cable.

12 Type tests, electrical

12.1 General

The type tests required by this standard, and to be applied on samples of completed cable, 10 m to 15 m long, are the following:

a) insulation resistance measurement at room temperature (see 12.2.1);

b) insulation resistance measurement at operating temperature (see 12.2.2);

c) increase of the a.c. capacity after immersion in water (see 12.3);

d) high-voltage test for 4 h (see 12.4).

12.2 Insulation resistance measurement

12.2.1 Measurement at room temperature

a) 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 room temperature at least 1 h before the test. The measurement shall be made between conductor and water.

If requested, 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.

b) Calculations

The "insulation resistance constant K_i" shall be calculated from the formula:

$$K_i = \frac{\ell \cdot R \times 10^{-9}}{\log_{10} \frac{D}{d}} = 10^{-9} \times 0{,}367\rho \cdot \text{M}\Omega \cdot \text{km}$$

Volume resistivity may also be calculated from the measured insulation resistance by the following formula:

$$\rho = \frac{2\pi \, \ell R}{\ell_n \frac{D}{d}}$$

where

R is the measured insulation resistance in ohms;

ℓ is the length of the cable in metres;

D is the outer diameter of the insulation in millimetres;

d is the inner diameter of the insulation in millimetres.

c) Requirements

The values calculated from the measurement shall be not less than those specified in table 2 of IEC 60092-351.

NOTE 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.

12.2.2 Measurement at maximum rated temperature

a) 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 80 V to 500 V and shall be applied for not less than 1 min and not more than 5 min.

b) Calculations

The insulation resistance constant and/or the volume resistivity shall be calculated from the insulation resistance by the formulae given in item b) of 12.2.1.

c) Requirements

The values calculated from the measurements shall be not less than those specified in table 2 of IEC 60092-351.

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

When required by the purchaser and agreed by the manufacturer, the water absorption test for insulating materials described in IEC 60092-351 shall be carried out in accordance with the following method:

a) Preparation of test specimens

Every test specimen shall consist of a core sample 4,50 m long in which any covering of the insulation (including vulcanization tape if any) has been removed.

b) Apparatus

A water-tank shall be used such that the central portion of the test specimen is immersed over a length of 3 m whilst a length of 0,75 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.

c) 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.

d) Electrical measurements

The capacitance between conductor and water shall be measured with low-voltage a.c. at a frequency of 800 Hz to 1 000 Hz.

These measurements shall be carried out:

- at the end of the first day;
- at the end of the seventh day;
- at the end of the fourteenth day;

precautions being taken to ensure that the temperature and water level are the same for all measurements.

e) Results to be obtained

The capacitance C1, C7 and C14 so found should comply with the following conditions:

$$C_{14} - C_1 \leq 0{,}15\ C_1$$

$$C_{14} - C_7 \leq 0{,}05\ C_7$$

12.4 High-voltage test for 4 h

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. No breakdown of the insulation shall occur.

13 Type tests, non-electrical

The non-electrical type tests required by this standard are summarized in table 3 for insulation and in table 4 for non-metallic sheaths.

13.1 Measurement of thickness of insulation

a) Sampling

One sample of each insulated cable core shall be taken from each of three places separated from each other by at least 1 m.

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

b) Procedure

The measurement shall be made as described in clause 8 of IEC 60811-1-1.

c) Requirements

The average, which shall be rounded off to the nearest 0,1 mm (see annex B), of all the measured values on each core, shall be not less than the specified nominal thickness, and the smallest measured value shall not fall below 90 % of the specified nominal thickness by more than 0,1 mm.

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

a) Sampling

One sample of cable shall be taken from each of three places separated from each other by at least 1 m.

b) Procedure

The measurements shall be made as described in clause 8 of IEC 60811-1-1.

c) Requirements

Each piece of sheath shall comply with the following:

– For a sheath applied on a smooth cylindrical surface (e.g. on an inner covering or the insulation of a single core):
  - The average, which shall be rounded off to the nearest 0,1 mm (see annex B) of the measured values, shall be not less than the specified nominal thickness;
  - the smallest value shall not fall below 85 % of the specified nominal thickness by more than 0,1 mm.

– For a sheath applied on an irregular cylindrical surface (e.g. a penetrating sheath on an unarmoured multicore cable without inner covering, or a sheath applied directly over a tape or wire armour):
  - the smallest value shall not fall below 80 % of the specified nominal value by more than 0,2 mm.

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

a) Sampling

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

b) Ageing treatments

The ageing treatments shall be carried out as described in clause 8 of IEC 60811-1-2 under the conditions specified in table 3 of IEC 60092-351.

c) 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.

d) Requirements

The test results for unaged and aged pieces shall comply with the requirements given in table 3 of IEC 60092-351.

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

a) Sampling

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

b) Ageing treatments

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

c) 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.

d) Requirements

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

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

a) General

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

The test is applicable to cables of all types.

b) Sampling

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

c) Ageing treatment

The ageing treatment of the pieces of cable should 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 × 24 h

d) 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.

e) Requirements

The variations between the median values of tensile strength and elongation at break before and after ageing (see 13.3 and 13.4) shall not exceed the corresponding values applying to the test for ageing in an air oven specified in table 3 of IEC 60092-351 for insulation and table II of IEC 60092-359 for sheath.

13.6 Loss of mass test on PVC insulation and sheaths

a) Procedure

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

b) Requirements

The test results shall comply with the requirements given in table 4 of IEC 60092-351 for insulation and table III of IEC 60092-359 for sheaths.

13.7 Test for the behaviour at high temperature of PVC insulation and PVC and SHF 1 sheaths (pressure test)

a) 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 table 4 of IEC 60092-351 for insulation, and table III of IEC 60092-359 for sheaths.

b) Requirements

The test results shall comply with the requirements given in table 4 of IEC 60092-351 for insulation and table III of IEC 60092-359 for sheaths.

13.8 Test for the behaviour at low temperature of PVC insulation and PVC, SHF 1 and SHF 2 sheaths

a) Procedure

The sampling and test procedures shall be in accordance with clause 8 of IEC 60811-1-4 employing the test temperatures specified in table 4 of IEC 60092-351 for insulation and table III of IEC 60092-359 for sheaths.

b) Requirements

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

13.9 Test for resistance to cracking of PVC insulation and PVC and SHF 1 sheaths (heat shock test)

a) 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 table 4 of IEC 60092-351 for insulation and table III of IEC 60092-359 for sheaths.

b) Requirements

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

13.10 Ozone resistance test for insulation and for sheaths (see tables 1 and 2 for applicability of compounds in the test method)

a) Procedure

The sampling and test procedure shall be carried out in accordance with clause 8 of IEC 60811-2-1, the test parameters being in accordance with table 4 of IEC 60092-351 for insulation and table III of IEC 60092-359 for sheaths.

b) Requirements

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

13.11 Hot-set test for insulations and for sheaths (see tables 2 and 3 for applicability of compounds in the test method)

a) 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 table 4 of IEC 60092-351 for insulation and table II of IEC 60092-359 for sheaths.

b) Requirements

The test results shall comply with the requirements given in table 4 of IEC 60092-351.

13.12 Oil immersion test for elastomeric sheaths

a) 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 table II of IEC 60092-359.

b) Requirements

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

13.13 Flame retardance test

This test shall be carried out on pieces of completed cable. The methods of test and requirements shall be those specified in IEC 60332-3 for category A.

13.14 Test for fire-proof or fire-resisting cables

This test shall be carried out on pieces of completed cable only when specially required.

The method of test and requirements shall be those specified in IEC 60331.

13.15 Determination of hardness for HEPR and HF HEPR insulations

a) Procedure

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

b) Requirements

The test results of the test shall comply with the requirements given in table 4 of IEC 60092-351.

13.16 Determination of elastic modulus for HEPR and HF HEPR insulation

a) Procedure

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

b) Requirements

The results of the test shall comply with the requirements given in table 4 of IEC 60092-351.

13.17 Determination of degree of acidity of gases evolved during the combustion of insulating materials by measuring pH and conductivity

a) Procedure

The sampling and test procedure shall be carried out in accordance with IEC 60754-2.

b) Requirements

The results of the test shall comply with the requirements given in table 4 of IEC 60092-351.

13.18 Determination of the amount of halogen acid gas for sheathing materials

a) Procedure

The sampling and test procedure shall be carried out in accordance with IEC 60754-1.

b) Requirements

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

Table 3 – Non-electrical type tests for insulation

0		1	2	3	4	5	6	7	8	9	10
Designation of compounds		Insulation									
		Thermo-plastic	Elastomeric								
		PVC/A	S 95	HFS 95	EPR	HF EPR	HEPR	HF HEPR	XLPE	HF XLPE	HF 85
1	Dimensions										
1a	Measurement of thickness	x	x	x	x	x	x	x	x	x	x
2	Mechanical properties (tensile strength and elongation)										
2a	Before ageing	x	x	x	x	x	x	x	x	x	x
2b	After ageing in air bomb	–	–	–	x	x	x	x	–	–	–
2c	After ageing in air oven	x	x	x	x	x	x	x	x	x	x
2d	After additional ageing in air oven (compatibility)	x	x	x	x	x	x	x	x	x	x
3	Thermoplastic properties										
3a	Hot pressure test (indentation)	x	–	–	–	–	–	–	–	–	–
3b	Behaviour at low temperature	x	–	–	–	–	–	–	–	–	–
4	Miscellaneous										
4a	Loss of mass test in air oven	x	–	–	–	–	–	–	–	–	–
4b	Heat shock test (cracking)	x	–	–	–	–	–	–	–	–	–
4c	Ozone resistance test	–	–	–	x	x	x	x	–	–	x
4d	Hot set test	–	x	x	x	x	x	x	x	x	x
4f	Hardness	–	–	–	–	–	x	x	–	–	–
4g	Elastic modulus	–	–	–	–	–	x	x	–	–	–
4h	pH	–	–	x	–	x	–	x	–	x	x
4j	Conductivity	–	–	x	–	x	–	x	–	x	x
x	Indicates that the type test is to be applied										

Table 4 – Non-electrical type tests for non-metallic sheaths

0		11	12	13	14	15	16
Designation of compounds		Non-metallic sheaths					
		Thermoplastic			Elastomeric		
		ST 1	ST 2	SHF1	SE 1	SH	SHF2
1	Dimensions						
1a	Measurement of thickness	x	x	x	x	x	x
2	Mechanical properties (tensile strength and elongation)						
2a	Before ageing	x	x	x	x	x	x
2b	After ageing in air bomb	–	–	–	–	–	–
2c	After ageing in air oven	x	x	x	x	x	x
2d	After additional ageing in air oven (compatibility)	x	x	x	x	x	x
2e	After immersion in hot oil	–	–	–	x	x	x
3	Thermoplastic properties						
3a	Hot pressure test (indentation)	x	x	x	–	–	–
3b	Behaviour at low temperature	x	x	x	–	–	x
4	Miscellaneous						
4a	Loss of mass test in air oven	–	x		–	–	
4b	Heat shock test (cracking)	x	x	x	–	–	–
4c	Ozone resistance test	–	–	–	x	x	x
4d	Hot set test	–	–	–	x	x	x
4e	Flame retardance test	x	x	x	x	x	x
4f	Hardness	–	–	–	–	–	–
4g	Elastic modulus	–	–	–	–	–	–
4h	Determination of the amount of halogen acid gas	–	–	x	–	–	x
x	Indicates that the type test is to be applied						

Annex A
(normative)

The fictitious calculation method for determination of dimensions of protective coverings

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

This sometimes causes problems. The calculated nominal diameters are not necessarily the same as the actual values achieved in production. In borderline cases, queries can arise if the thickness of a covering does not correspond to the actual diameter because the calculated diameter is slightly different. Variations in shaped conductor dimensions between manufacturers and different methods of calculation cause differences in nominal diameters and may therefore lead to variations in the 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. Thicknesses of 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.1 General

A.1.1 The following fictitious method of calculating thicknesses of various coverings in a cable has been adopted to ensure that any differences which can arise in independent calculations, for example due to the assumption of conductor dimensions and the unavoidable differences between nominal and actually achieved diameters, are eliminated.

A.1.2 All thickness values and diameters shall be rounded, according to the rules given in annex B to the first decimal figure.

A.1.3 Holding strips, for example counter-helix over armour, if not thicker than 0,3 mm, are neglected in this calculation method.

A.2 Method

A.2.1 Conductors

The fictitious diameter (d_l) of a conductor, irrespective of shape or compactness, is given for each nominal cross-section in the following table:

Table A.1 – Fictitious diameter d_l

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

A.2.2 Cores

The fictitious diameter D_c of any core is given by:

$$D_c = d_l + 2\,t_i\text{, in millimetres}$$

where t_i is the nominal thickness of insulation.

A.2.3 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:

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

where the coefficient k is as given in the following table:

Table A.2 – Assembly coefficient *k*

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*	3,35	31	6,70
8	3,45	32	6,70
8*	3,66	33	6,70
9	3,80	34	7,00
9*	4,00	35	7,00
10	4,00	36	7,00
10*	4,40	37	7,00
11	4,00	38	7,33
12	4,16	39	7,33
12*	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*	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		
* Cores assembled in one layer.			

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

$$D_f = \frac{2{,}41(3D_{c1}+D_{c2})}{4}\text{, in millimetres}$$

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.

A.2.4 Inner coverings

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

$$D_B = D_f + 2\ t_B$$

where t_B is the appropriate value of the inner covering, if any, specified in the standard of the relevant cable.

A.2.5 Sheath

The fictitious diameter over the sheath D_s is given by:

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

where

D_u is the fictitious diameter under the sheath;

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

A.2.6 Additional bedding for tape-armoured cables (provided over the inner covering)

Table A.3 – Diameter

Fictitious diameter under the additional bedding		Increase in diameter for additional bedding mm
Above mm	**Up to and including** mm	
–	30	1,0
30	–	1,6

A.2.7 Armour

The fictitious diameter over the armour D_x is given by:

- for flat or round wire armour:

$$D_x = D_A + 2\ t_A\text{, in millimetres}$$

  where

  D_A is the fictitious diameter under the armour;

  t_A is the thickness or diameter of the armour wire.

- for tape armour:

$$D_x = D_A + 4\ t_A\text{, in millimetres}$$

  where

  D_A is the fictitious diameter under the armour;

  t_A is the thickness of the armour tape.

– for braid armour:

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

where

D_A is the fictitious diameter under the armour;

D_w is the nominal diameter of the braid wire.

Annex B
(normative)

Rounding of numbers

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

B.1.1 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.

B.1.2 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

B.2 Rounding of numbers for other purposes

B.2.1 For purposes other than those considered under B.1.1, it may be required that values be rounded to more than one decimal place. This may occur, for instance, in calculating the average value of several measurement results, or the minimum value by applying a percentage tolerance to a given nominal value. In these cases, rounding shall be carried out to the number of decimal places specified in the relevant clauses.

B.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 C
(Informative)

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

C.1 General

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

C.2 Lower limit for the average outer diameter

C.2.1 Take as diameter D of the conductor the value given in table C.2 for cables for fixed wiring.

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

C.2.3 Calculate the nominal diameter over the core assembly by multiplying the value obtained in C.2.2 by the appropriate value of the assembly coefficient, *k*, given in the following table C1.

Table C.1 – Assembly coefficient *k* values

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*	3,35	31	6,70
8	3,45	32	6,70
8*	3,66	33	6,70
9	3,80	34	7,00
9*	4,00	35	7,00
10	4,00	36	7,00
10*	4,40	37	7,00
11	4,00	38	7,33
12	4,16	39	7,33
12*	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*	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		
* Cores assembled in one layer			

C.2.4 Calculate the nominal outer diameter D_o of the finished cable by adding to the value obtained in C.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 C.4).

C.2.5 The lower limit D_{min} of the average 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

C.3 Upper limit for the average outer diameter

C.3.1 Take as diameter *D* of the conductor the value given in table C.2.

C.3.2 Calculate the nominal diameter over the core by adding to the appropriate value of the conductor diameter, obtained as in C.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.

C.3.3 Calculate the nominal diameter over the core assembly by multiplying the value obtained in C.3.2 by the appropriate assembly coefficient, *k*, given in C.2.3.

C.3.4 Calculate the nominal outer diameter D_1 of the finished cable by adding to the value obtained in C.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 C.4).

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

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

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 multicore cables if $D_1 \leq 5$ mm;

X = 0,5 mm for multicore cables if $D_1 > 5$ mm.

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

Examples:

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

C.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 millimetres)

Table C.2 – Lower and upper limits of diameter of circular copper conductors for cables for fixed installation

Nominal cross-sectional area mm^2	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
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	[a]	31[b]
500	26,7	29,2	[a]	35[b]
630	31,0	34,0	[a]	39[b]

NOTE 1 It is stressed that the conductor diameters are intended for the purpose of this method only.

NOTE 2 The conductor diameters have been calculated so that they fulfil the maximum diameters given in the tables of IEC 60228.

NOTE 3 Any change in the said tables may change the values of the diameters in this annex.

NOTE 4 Cross-sectional areas larger than 630 mm^2 are under consideration.

NOTE 5 The values 0,5 mm^2 and 1 mm^2 are not intended for fixed power installations.

[a] Under consideration

[b] IEC 60228A (1982), table 1

Annex D
(normative)

Procedure for checking the efficacy of the spark testing method

D.1 Object

The object of this procedure is to standardize the method by which manufacturers may demonstrate that their spark testing method is effective in detecting faults in the insulation as specified in item b) of 10.3.

The manufacturer's instructions for production and control procedures shall provide that cables for which spark testing is required shall be effectively tested in practice.

D.2 Procedure

D.2.1 Manufacturers shall have available two lengths of insulated core which have been specially prepared for testing. One of the cores shall have the smallest insulation thickness for the relevant types of cable, the other core should have the largest insulation thickness for the relevant type of cable.

D.2.2 The preparation of the punctures in the insulation shall be effected as follows:

a) The insulation shall be removed from the core for a length of about five times the nominal insulation thickness.

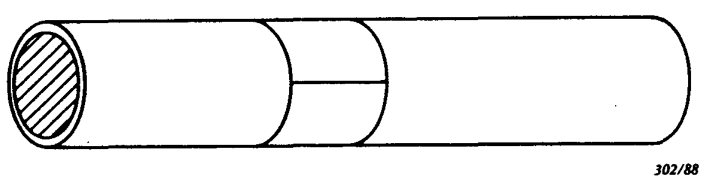

Figure D.1 – Test sample

b) From the piece of insulation which has been removed, a segment of about 30° shall be removed; the remaining piece of the insulation shall then be replaced on the conductor.

c) Over the replaced piece of the insulation, one layer of adhering tape (e.g. PE terephthalate) shall be placed in a longitudinal direction, with an overlap. This overlap shall be situated on the opposite side of the core from the position where the insulation was removed.

   The layer shall have a length of at least ten times the nominal insulation thickness.

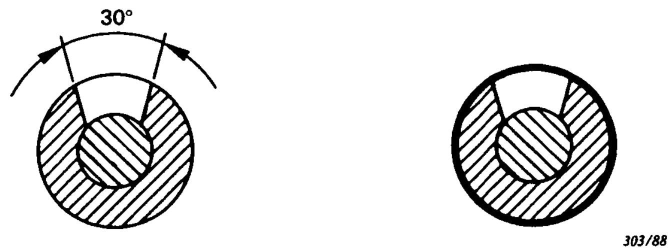

Figure D.2 – Test sample

d) In this layer, and in the middle of the area from which the insulation has been removed, a hole shall be punched in the tape with a hot needle. The diameter of this hole shall be equal to half of the allowed minimum insulation thickness.

The other test piece shall be prepared in the same way.

D.2.3 The prepared test pieces shall then be passed through the spark test equipment at the highest speed for which the equipment is intended, the voltage applied between the electrode and the conductor being that normally used.

The equipment shall register one fault when each test piece is spark tested.

D.2.4 Method to check the recovery time

At least two faults shall be passed through the spark test equipment at its actual operating speed v (in metres per second), the distance in metres between two faults being not greater than the value of v.

All the faults shall be registered by the equipment.

Annex E
(normative)

Test of the metal coating of copper wires

E.1 Preparation of specimens

A cable sampling 0,30 m long is dismantled to expose the copper conductors, avoiding damage to the metal coating over the wires. Several wire pieces are taken from the outer layer of each conductor and cut into shorter sections which will permit complete immersion in the persulphate solution.

The wires are thoroughly cleaned with a suitable solvent and wiped dry with a clean soft cloth. The ends of each wire portion are completely coated with wax to protect the exposed copper.

Two specimens from the cable sample in this manner are prepared. The total length of each specimen is calculated with the formula $L = 300/d$, where d is the nominal wire diameter, both L and d being expressed in millimetres (or $L = 0,465/d$, both L and d being expressed in inches). The wax-coated ends are not included in determining the length L.

E.2 Special solutions

a) Test solution (ammonium persulphate)

Dissolve 10 g of ammonium persulphate $(NH_4)_2S_2O_8$ (crystals containing not less than 95 % of ammonium persulphate) in 500 ml of distilled water. Add 75 ml of chemically pure solution of ammonia (density 0,90) and dilute to 1 l with distilled water.

The ammonium persulphate solution shall be freshly prepared each day that tests are to be conducted and shall not be subjected to temperatures above 35 °C.

b) Reference colour standard (copper sulphate – ammonium dioxide)

Dissolve 0,200 g of anhydrous copper sulphate ($CuSO_4$) in distilled water. Add 75 ml of a chemically pure solution of ammonia (density 0,90) and dilute to 1 l.

E.3 Test procedure

Each specimen of the required length L is immersed in 100 ml of the test solution, using as a container a test tube of appropriate dimensions. The specimen is left immersed in the test solution at a temperature of (20 ± 3) °C for a period of 15 min. The specimen is then removed and the test solution compared with an equal depth of the reference colour standard contained in a similar test tube. The colour comparison is be made by viewing the solutions lengthwise through the test tubes.

The colour of the test solution after immersion of the test specimen shall not be darker than that of the reference colour standard solution. Both specimens shall comply with this requirement.

Annex F
(normative)

Galvanizing test for steel wires

Five specimens, 200 mm long, are cleaned with a piece of wadding soaked in benzine and dried.

The specimens are immersed one by one in a glass vessel with a height of 160 mm and a diameter of 35 mm about four-fifths full of a solution of copper sulphate. The liquid shall not be stirred. After 1 min the specimens are removed from the liquid and immediately cleaned in running water with the aid of a piece of wadding to remove spongy precipitation of copper.

This operation is repeated with the same liquid until a coherent precipitation of copper occurs which cannot be removed with the wadding. The part of the specimen within 30 mm from the submerged end is not considered.

For each specimen a fresh solution shall be used. This solution contains one part of copper sulphate ($CuSO_4 \cdot 5H_2O$) in five parts of water (187 g/l). After complete dissolution, 1 g to 2 g per litre of copper hydroxide or powdered copper carbonate or copper oxide is added in order to neutralize the free sulphuric acid generally contained in the copper sulphate used for the solution. The solution is kept at a temperature of (20 ± 0,5) °C.

The average number of immersions for the five specimens shall be not less than the number indicated in the following table before non-removable red copper appears on the specimen, as stated above.

Table F.1 – Number of immersions for the galvanizing test

Nominal diameter of round wires or thickness of shaped wires		Minimum number of immersions (of 1 min)
Exceeding mm	Not exceeding mm	
0,8	1,3	1
1,3	2,0	2
2,0	2,5	3
2,5	5,1	4

NOTE 1 Wires having a diameter not exceeding 0,8 mm should withstand at least one dip of 0,5 min.

NOTE 2 It sometimes happens that copper is deposited on the zinc coating itself, giving a false appearance of failure. Such a deposit may be tested for adherence after the completion of the final dip, either by peeling, light rubbing or immersion in a solution of hydrochloric acid (1/10) for 15 s, followed by immediate rinsing in clean running water with vigorous scrubbing. If the copper has been removed and zinc appears underneath, the sample should not be deemed to have failed.

Bibliography

IEC 60228A:1982, *First supplement to Publication 60228 (1978): Conductors of insulated cables – Guide to the dimensional limits of circular conductors*

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Typeset and printed by the IEC Central Office
GENEVA, SWITZERLAND