IEC 63026

Edition 1.0 2019-12

INTERNATIONAL STANDARD

colour inside

Submarine power cables with extruded insulation and their accessories for rated voltages from 6 kV (U_m = 7,2 kV) up to 60 kV (U_m = 72,5 kV) – Test methods and requirements

IEC 63026:2019-12(en)

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INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 29.060.20 ISBN 978-2-8322-7642-6

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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SUBMARINE POWER CABLES WITH EXTRUDED INSULATION AND THEIR ACCESSORIES FOR RATED VOLTAGES FROM 6 kV (U_m = 7,2 kV) UP TO 60 kV (U_m = 72,5 kV) – TEST METHODS AND REQUIREMENTS

FOREWORD

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International Standard IEC 63026 has been prepared by IEC technical committee 20: Electric cables.

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

FDIS	Report on voting
20/1888/FDIS	20/1895/RVD

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

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

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific document. At this date, the document will be

- reconfirmed,
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INTRODUCTION

As a result of the growing demand for inter-array cables for offshore windfarms, IEC TC 20 decided to develop an International Standard for medium voltage submarine cable systems.

The worldwide mandate to reduce carbon emissions has stimulated major developments of power production systems where the principal contribution comes from offshore wind farms.

Due to the location of these wind power generation systems, large amounts of submarine cables are required to inter-connect individual power generating units (inter-array cable) and to connect to the mainland (power export cable).

Many offshore wind farms have been built or are today under construction and there are plans for even more farms to be built in future. Although the focus is on wind farms, the need for cable connections to other types of offshore generation will increase. At this stage most of the information and expertise already available on cables for the connection to the mainland grid can be found in CIGRE documents.

Requirements of this document are mainly based on IEC 60502-2, IEC 60840 and CIGRE TB 490, *Recommendations for testing of long AC submarine cables with extruded insulation for system voltage above 30 (36) kV to 500 (550) kV*. References to the relevant applicable mechanical tests are taken from CIGRE TB 623, *Recommendations for mechanical testing of submarine cables.*

A list of relevant additional references is given in the bibliography.

SUBMARINE POWER CABLES WITH EXTRUDED INSULATION AND THEIR ACCESSORIES FOR RATED VOLTAGES FROM 6 kV (U_m = 7,2 kV) UP TO 60 kV (U_m = 72,5 kV) – TEST METHODS AND REQUIREMENTS

1 Scope

This document specifies test methods and requirements for power cable systems, cables with extruded insulation and their accessories for fixed submarine installations, for rated voltages from 6 kV (U_m = 7,2 kV) up to 60 kV (U_m = 72,5 kV).

This document includes the electrical tests and the physical tests on materials and components as well as the specific mechanical tests that are applicable to submarine cable systems.

The requirements apply to armoured single-core cables and three-core cables in combination with their accessories, terminations and joints for usual conditions of installation and operation, but not to special cables and their accessories, such as submarine cables for dynamic applications (i.e. for direct connection to a floating structure), for which modifications to the standard tests can be necessary or special test conditions be devised.

This document is applicable to submarine cables installed in permanently submerged conditions with water depths up to 250 m.

NOTE This document does not include accessories having a mechanical function only, such as hang-offs or armour clamps.

2 Normative references

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

IEC 60228, *Conductors of insulated cables*

IEC 60229:2007, *Electric cables – Tests on extruded oversheaths with a special protective function*

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

IEC 60287-1-1:2006, *Electric cables – Calculation of the current rating – Part 1-1: Current rating equations (100 % load factor) and calculation of losses – General*

IEC 60502-2:2014, *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 60502-4, *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 4: Test requirements on accessories for cables with rated voltages from 6 kV (U_m = 7,2 kV) up to 30 kV (U_m = 36 kV)*

IEC 60811-201, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 201: General tests – Measurement of insulation thickness*

IEC 60811-202, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 202: General tests – Measurement of thickness of non-metallic sheath*

IEC 60811-203, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 203: General tests – Measurement of overall dimensions*

IEC 60811-401, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 401: Miscellaneous tests – Thermal ageing methods – Ageing in an air oven*

IEC 60811-402, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 402: Miscellaneous tests – Water absorption tests*

IEC 60811-403, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 403: Miscellaneous tests – Ozone resistance test on cross-linked* compounds

IEC 60811-501, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 501: Mechanical tests – Tests for determining the mechanical properties of insulating and sheathing compounds*

IEC 60811-502, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 502: Mechanical tests – Shrinkage test for insulations*

IEC 60811-503, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 503: Mechanical tests – Shrinkage test for sheaths*

IEC 60811-507, *Electric and optical fibre cables – Test methods for non-metallic materials–- Part 507: Mechanical tests – Hot set test for cross-linked materials*

IEC 60811-508, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 508: Mechanical tests – Pressure test at high temperature for insulation and sheaths*

IEC 60811-605, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 605: Physical tests – Measurement of carbon black and/or mineral filler in polyethylene compounds*

IEC 60840, *Power cables with extruded insulation and their accessories for rated voltages above 30 kV (U_m = 36 kV) up to 150 kV (U_m = 170 kV) – Test methods and requirements*

IEC 60885-3, *Electrical test methods for electric cables – Part 3: Test methods for partial discharge measurements on lengths of extruded power cables*

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

3 Terms and definitions

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

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

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

3.1 Definitions of dimensional values (thicknesses, cross-sections, etc.)

3.1.1
nominal value
value by which a quantity is designated and which is often used in tables

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

3.1.2
median value
when several test results have been obtained and ordered in an increasing (or decreasing) succession, middle value if the number of available values is odd, and mean of the two middle values if the number is even

3.2 Definitions concerning tests

3.2.1
routine test
test made by the manufacturer on each manufactured component (length of cable or accessory) to check that the component meets the specified requirements

3.2.2
sample test
test made by the manufacturer on samples of completed cable or components taken from a completed cable or accessory, at a specified frequency so as to verify that the finished product meets the specified requirements

3.2.3
type test
test made before supplying on a general commercial basis a type of cable system covered by IEC 63026, in order to demonstrate satisfactory performance characteristics to meet the intended application

Note 1 to entry: Once successfully completed, these tests need not be repeated, unless changes are made in the cable or accessory with respect to materials, manufacturing process, design or design electrical stress levels, which might adversely change the performance characteristics.

3.2.4
electrical test after installation
test made to demonstrate the integrity of the cable system as installed

Note 1 to entry: Integrated optical elements, if present, will be tested upon customer request. Tests to be defined on agreement between customer and manufacturer.

3.3 Other definitions

3.3.1
cable system
cable with installed accessories including components used for thermo-mechanical restraint of systems limited to those used for terminations and joints only

3.3.2
nominal electrical stress
electrical stress calculated at U_0 using nominal dimensions

3.3.3
test object
object, which is a cable length or an accessory, to be subjected to testing

3.3.4
test assembly
assembly, which is a combination of series connected test objects, i.e. cable and accessories, simultaneously under test

3.4 Definitions concerning test objects

3.4.1
extrusion length
length of cable conductor with the insulation and semi-conducting layers continuously extruded in the same non-interrupted extrusion operation

3.4.2
manufacturing length
whole extrusion length (or parts thereof if cut), where construction elements (outside the outer semi-conducting layer) have been applied

3.4.3
delivery length
completed cable length, typically on a drum, in a coil or on a turntable

3.4.4
factory joint
joint between extrusion lengths/manufacturing lengths that is manufactured under controlled factory conditions

Note 1 to entry: Factory joints have the same mechanical and electrical performance as the original cable and are generally fully flexible.

3.4.5
field joint
joint between two delivery lengths of cable that is completed with all cable construction elements

Note 1 to entry: A field joint is generally used to connect two delivery lengths offshore or in the beach area. In this document the requirements for field joints are the same as for repair joints.

Note 2 to entry: The requirements in this document are different for rigid and flexible types of joint.

Note 3 to entry: Repair and field joints may be of identical design.

3.4.6
repair joint
joint used for repairing a damaged submarine cable

Note 1 to entry: The requirements in this document are different for rigid and flexible types of joint.

Note 2 to entry: Repair and field joints may be of identical design.

3.4.7
rigid joint
joint which cannot be subjected to the coiling or tensile bending tests

3.4.8
flexible repair joint
flexible field joint
repair (field) joint that is manufactured under controlled conditions and that is fully flexible

Note 1 to entry: Flexible repair (field) joints have the same mechanical and electrical performance as the original cable.

3.4.9
asymmetric joint
joint which connects two cables with the same insulation system, but of different design

Note 1 to entry: Examples of different design are different conductors, different insulation or screen dimensions, or land and submarine cables.

3.4.10
long length
cable length which cannot be moved into a shielded room for the partial discharge measurement

3.4.11
significant wave height
average wave height (trough to crest) of the highest third of the waves

4 Voltage designations, materials and rounding of numbers

4.1 Rated voltages

The rated voltages U_0/U (U_m) of the cables considered in this document are as follows:

U_0/U (U_m) = 3,6/6 (7,2) – 6/10 (12) – 8,7/15 (17,5) – 12/20 (24) – 18/30 (36) – 26/45 (52) – 36/60 (72,5) kV.

NOTE 1 The voltages given above are the standard designations although in some countries other designations are used, e.g. – 5,8/10 – 6,6/11 – 11,5/20 – 17,3/30 – 19/33 – 21/35 – 26/35 – 26/46 – 38/66 kV.

In the voltage designation of cables U_0/U (U_m):

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

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

U_m is "highest voltage for equipment" (see IEC 60038).

The rated voltage of the cable for a given application shall be suitable for the operating conditions in the system in which the cable is used. To facilitate the selection of the cable, systems are divided into three categories:

– category A: this category comprises those systems in which any phase conductor that comes into contact with earth, or an earth conductor, is disconnected from the system within 1 min;
– category B: this category comprises those systems which, under fault conditions, are operated for a short time with one phase earthed. This period, according to IEC 60183, should not exceed 1 h. For cables covered by this document, a longer period, not exceeding 8 h on any occasion, can be tolerated. The total duration of earth faults in any year should not exceed 125 h;
– category C: this category comprises all systems which do not fall into category A or B.

It should be realized that in a system where an earth fault is not automatically and promptly isolated, the extra stresses on the insulation of cables during the earth fault reduce the life of the cables to a certain degree. If the system is expected to be operated fairly often with a permanent earth fault, it may be advisable to classify the system in category C.

The values of U_0 recommended for cables to be used in three-phase systems are listed in Table 1.

Table 1 – Recommended rated voltages U_0

Highest voltage for equipment (U_m) kV	Rated voltage (U_0) kV	
	Categories A and B	Category C
7,2	3,6	6,0
12,0	6,0	8,7
17,5	8,7	12,0
24,0	12,0	18,0
36,0	18,0	26,0
52,0	26,0	36,0
72,5	36,0	–

4.2 Cable insulating compounds

This document applies to cables insulated with the materials listed in Table 2. The table specifies, for cables with each type of insulating compound, the maximum operating conductor temperatures on which the specified test conditions are based.

Table 2 – Insulating materials

Insulating material	Maximum conductor temperature °C	
	Normal operation	Short-circuit (5 s maximum duration)
Cross-linked polyethylene (XLPE)	90	250
Ethylene propylene rubber (EPR and HEPR)	90	250

The temperatures in Table 2 are based on the intrinsic properties of the insulating materials. It is important to take into account other factors when using these values for the calculation of current ratings.

For guidance on continuous current ratings calculation, reference should be made to IEC 60287 (all parts).

For guidance on emergency and cyclic load current rating calculation, reference should be made to IEC 60853 (all parts).

For guidance on short-circuit temperatures, reference should be made to IEC 60986 and IEC 61443.

For guidance on short-circuit current calculation, reference should be made to IEC 60949.

4.3 Rounding of numbers

The procedure given in Annex B shall be applied to all numbers and values employed or derived during the use of this document.

5 Cable construction

5.1 General

The cable construction requirements are given in 5.2 to 5.10.

5.2 Conductors

Conductors shall be either of class 1 or class 2 of plain or metal-coated annealed copper or of plain aluminium or aluminium alloy in accordance with IEC 60228. For all conductors, measures have to be taken to achieve longitudinal water-tightness. By agreement between customer and the manufacturer, the conductor may not need to be water blocked.

5.3 Insulation

Insulation shall be extruded solid dielectric of one of the types listed in Table 2.

For cables with a highest voltage for equipment U_m up to 36 kV, the nominal insulation thickness is that indicated in IEC 60502-2:2014, Clause 6; alternatively, by agreement between the customer and the manufacturer, the insulation thickness can be selected on the basis of the admissible electrical stress at U_m.

For cables above U_m = 36 kV and up to U_m = 72,5 kV the nominal insulation thickness is that declared by the manufacturer.

For all cables, the selected insulation thickness shall result in a nominal electric stress at the conductor screen not higher than 8,0 kV/mm and at the insulation screen not higher than 4,0 kV/mm.

Higher stress cables are under consideration.

The thickness of any separator or semi-conducting screen on the conductor or over the insulation shall not be included in the thickness of the insulation.

5.4 Screening

Screening of individual cores in single or three-core cables, shall consist of a conductor screen and an insulation screen.

The conductor screen shall be non-metal and shall consist of an extruded semi-conducting compound, which may be applied on top of a semi-conducting tape. The extruded semi-conducting compound shall be firmly bonded to the insulation.

The insulation screen shall consist of a non-metal semi-conducting layer in combination with a metal screen.

The non-metal layer shall be extruded directly upon the insulation of each core and consist of a firmly bonded semi-conducting compound.

For submarine cables, semi-conducting screens should be firmly bonded in order to better resist the mechanical stresses during the cable laying.

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

5.5 Metal screen

The metal screen shall be applied over the individual cores or the core assembly and shall consist of one or more tapes, or a braid, or a concentric layer of wires, or a combination of wires and tape(s), or a metal sheath.

Measures may be taken to achieve longitudinal water-tightness in the metal screen. When choosing the material of the screen, special consideration shall be given to the possibility of corrosion, to ensure satisfactory mechanical and electrical performance.

In particular cases, the steel wire armour of three-core cables can be considered a metal screen.

5.6 Core oversheathing materials

When requested, an oversheath is applied over the metal screen. An oversheath based on polyethylene (PE) type ST_7 is recommended, see tables 5 and 7.

Alternatively, a semi-conductive PE oversheath is allowed. It is recommended that this oversheath material should have the same non-electrical properties as for ST_7, except for the carbon black content.

Particular care should be taken to limit the transient overvoltages that may affect long submarine cables.

5.7 Assembly of three-core cables and fillers

The assembly of three-core cables shall maintain an approximately round shape.

The materials used for the fillers and the bedding shall be suitable for the operating temperature of the cable and compatible with the insulating material and/or sheath material and with the marine environment.

5.8 Cable armour

This document covers round or flat wire armour, the wires shall be of galvanized steel, stainless steel, copper or tinned copper or other corrosion-resistant metal alloys. In some circumstances in order to make the cable lighter the armour can be a mixture of metal wires and plastic wires.

An additional layer of metal tapes may be applied for extra protection in special applications if required.

The armour may be a single or a double layer of wires that may be applied in the same or opposite direction depending on the laying conditions and the mechanical performance requested for the cable. The armour shall be applied on a bedding layer to avoid damaging the core(s).

Non-magnetic armour shall be used for single-core cables.

When choosing the material of the armour, special consideration shall be given to the possibility of corrosion, not only for mechanical safety, but also for electrical safety.

5.9 Cable outer serving

The materials used for the serving are usually of textile origin (e.g. polypropylene yarns) of suitable thickness and shall be suitable for the operating temperature of the cable and compatible with any cable material the outer serving is in physical contact with (e.g. metal sheath, armour, oversheath, or other material) and with the marine environment.

An extruded layer can also be applied in place of the textile yarn serving.

5.10 Packaging

Depending on the length of the connection, submarine cables can be wound on drums, in coils or on turntables. When the cables are wound into fixed coils on every turn, the cable is subjected to a 360° twist; particular care shall be taken on the bending radius and on the coiling procedures to avoid cable damage.

6 Cable characteristics

For the purpose of carrying out the cable system tests described in this document and recording the results, the cable shall be identified. The following characteristics shall be known or declared:

a) name of manufacturer, type, designation and manufacturing date (date of last production phase) or date code;

b) rated voltage: values shall be given for U_0, U, U_m (see 4.1 and 8.4);

c) maximum laying depth in water;

d) type of conductor, its material and nominal cross-sectional area, in square millimetres; conductor construction; nature of measures taken to achieve longitudinal water tightness;

e) material and nominal thickness of insulation (t_n) (see 5.3);

f) type of manufacturing process for the insulation system;

g) nature of watertightness measures in the screening area;

h) material and construction of metal screen, for example number and diameter of wires; the DC resistance of the metal screen; material, construction and nominal thickness of metal sheath, or longitudinally applied metal tape or foil bonded to the oversheath, if any;

i) material and nominal thickness of the core oversheath if any;

j) material type, number of layers, direction of lay and diameter of the wire in each layer of the wire armour; material type and thickness of the additional layer of metal tapes, if any;

k) material type and thickness of the outer serving, if any;

l) nominal diameter of the conductor (d);

m) nominal overall diameter of the cable (D);

n) nominal inner diameter (d_{ii}) and calculated nominal outer diameter (D_{io}) of the insulation;

o) nominal capacitance, corrected to 1 km length, between conductor and metal screen;

p) calculated nominal electrical stress, in kV/mm, at conductor screen (E_i) and at insulation screen (E_o):

$$E_i = \frac{2U_0}{d_{ii} \times \ln(D_{io} / d_{ii})}$$

$$E_o = \frac{2U_0}{D_{io} \times \ln(D_{io} / d_{ii})}$$

where

$D_{io} = d_{ii} + 2t_n$;

D_{io} is the calculated nominal outer diameter of the insulation, in mm;

d_{ii} is the declared nominal inner diameter of the insulation, in mm;

t_n is the declared nominal insulation thickness, in mm.

7 Accessory characteristics

For the purpose of carrying out the cable system or accessory tests described in this document and recording the results, the accessory shall be identified.

The following characteristics shall be known or declared:

a) cables used for testing accessories shall be correctly identified as in Clause 6;
b) conductor connections used within the accessories shall be correctly identified, where applicable, with respect to
   – assembly technique,
   – tooling, dies and necessary setting,
   – preparation of contact surfaces,
   – type, reference number and any other identification of the connector,
   – details of the type test approval of the connector, if applicable;
c) accessories to be tested shall be correctly identified with respect to
   – name of manufacturer and drawings,
   – armour clamp details, where applicable,
   – type, designation and manufacturing date or date code,
   – rated voltage (see Clause 6, item b) above),
   – installation instructions (reference and date).

8 Test conditions

8.1 Ambient temperature

Unless otherwise specified in the details for the particular test, tests shall be carried out at an ambient temperature of (20 ± 15) °C. A deviation from this temperature range should be agreed upon by the manufacturer and the customer.

8.2 Frequency and waveform for AC voltage tests

Unless otherwise indicated in this document, the frequency of the alternating test voltages shall be in the range 10 Hz to 500 Hz. The waveform shall be substantially sinusoidal. The values quoted are RMS values.

8.3 Lightning impulse test

The test shall be performed in accordance with IEC 60230.

8.4 Relationship of test voltages to rated voltages

Where test voltages are specified in this document as multiples of the rated voltage U_0, the value of U_0 for the determination of the test voltages shall be as specified in Table 4.

For cables and accessories of rated voltages not shown in the table, the value of U_0 for determination of test voltages may be the same as for the nearest rated voltage which is given, provided that the value of U_m for the cable and accessory is not higher than the corresponding value in the table. Otherwise, and particularly if the rated voltage is not close to one of the values in the table, the value of U_0 on which the test voltages are based shall be the rated value, i.e. U divided by $\sqrt{3}$.

The test voltages in this document are based on the assumption that the cables and accessories are used on systems of category A or B, as defined in IEC 60183.

8.5 Determination of the cable conductor temperature

The conductor temperature of the cable under test shall be determined as described in Annex A.

9 Routine tests on cables and accessories

9.1 General

Submarine cables are characterized by long lengths and to carry out the AC voltage test may be difficult and could require specific apparatus.

The routine test shall be distinguished between tests on manufacturing lengths, tests on factory joints, tests on delivery lengths and tests on accessories.

The routine tests required by this document are described in 9.2 to 9.4.

9.2 Test on manufacturing lengths

9.2.1 Partial discharge test

When the cable length is not too long to perform a partial discharge (PD) test, then a test shall be carried out in accordance with IEC 60885-3, except that the sensitivity as defined in IEC 60885-3 shall be 10 pC or less. In particular, the attenuation of pulses shall be assessed as specified in IEC 60885-3 when determining the declared sensitivity level.

The procedure of PD measurements is as follows:

The test voltage shall be raised gradually to and held at 2 U_0 for 10 s and then slowly reduced to 1,73 U_0.

There shall be no detectable discharge exceeding the declared sensitivity level at 1,73 x U_0.

Since it is not feasible to move long cable lengths to a screened environment, it may not be possible to perform the measurement according to IEC 60885-3. In this case if PD measurements are carried out they will therefore be for information only.

If the cable length is defined as long (see 3.4.10) the PD measurement may be performed on short samples by agreement between supplier and customer. In this case the sensitivity as defined in IEC 60885-3 shall be 5 pC or less.

9.2.2 AC voltage test

An AC voltage test shall be carried out at ambient temperature.

The test voltage shall be raised gradually to the specified value, which then shall be held for the specified time between the conductor and the metal screen as per the Table 4, column 4.

No breakdown of the insulation shall occur during the test.

It is permissible to interrupt the test, for example due to overheating of the test equipment, provided that the overall test duration requirement is met.

9.3 Test on factory joints

Recommendations on tests on factory joints are given in Annex F.

9.4 Test on delivery lengths

9.4.1 General

These tests may be considered as a factory acceptance test (FAT) for the delivery length. If permanent mechanical equipment (e.g. hang-off heads) is delivered mounted on the cable before shipment, the FAT shall be performed after the assembly of such permanent mechanical equipment.

9.4.2 AC voltage test

Every delivery length of cable shall be submitted to an AC voltage test as described in 9.2.2. If the complete delivery length is too long to allow application of the test voltage given in Table 4, column 4, a reduced test voltage but with a longer duration, may be agreed between supplier and customer.

9.4.3 Partial discharge test

In certain cases, where the delivery lengths are relatively short, it may be possible to carry out a partial discharge test on each complete delivery length. The test shall be performed according to 9.2.1 and the test on the manufacturing length is replaced by the test on the delivery length.

If the cable length is long, see 3.4.10, then, if PD measurements are carried out, they will be for information only.

9.5 Test on accessories

The routine tests on joints (other than factory joints) and terminations, shall follow the requirements of IEC 60502-4 or IEC 60840 as applicable.

If the accessory is not built up by any pre-fabricated components, the manufacturer and customer shall agree on the most practical solution, if any, to check the quality of the accessory.

10 Sample tests on cables

10.1 General

The following tests a) to i) shall be carried out on each core of the samples and test j) on a completed cable:

a) conductor examination;

b) measurement of electrical resistance of conductor and of metal screen;

c) measurement of thickness of insulation;

d) measurement of thickness of oversheath, where present;

e) measurement of thickness of metal sheath, where present;

f) measurement of diameters, if required;

g) hot set test for XLPE and EPR insulations;

h) measurement of capacitance;

i) tests on components of cables with longitudinally applied metal tape or foil, bonded to the oversheath;

j) examination of cable.

This document does not cover tests on fibre optic cables which may be part of an AC MV submarine cable. It is recommended that the directives of IEC technical committee 86 are followed.

10.2 Frequency of tests

The frequency of the tests shall be in accordance with agreed quality control procedures. In the absence of such an agreement, the sample tests shall be made for contracts with a cable length up to 20 km and a repeat of sample tests shall be made for every additional 50 km of delivered cable length. If it is necessary to take two samples from one single delivery length, the samples shall be taken from both ends.

10.3 Repetition of tests

If the sample from any length selected for the tests fails in any of the tests in Clause 10, further samples shall be taken from two further lengths of the same batch and subjected to the same tests as those in which the original sample failed. If both additional samples pass the tests, the other cables in the batch from which they were taken shall be regarded as having complied with the requirements of this document. If either fails, this batch of cables shall be regarded as having failed to comply.

10.4 Conductor examination

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

10.5 Measurement of electrical resistance of conductor and of metal screen

The cable length, or a sample thereof, shall be placed in the test room, which shall be maintained at a reasonably constant temperature for at least 12 h before the test. If there is a doubt that the conductor or metal screen temperature is not 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 may be measured on a sample of conductor or metal screen, conditioned for at least 1 h in a temperature-controlled liquid bath.

The DC resistance of the conductor and metal screen shall be corrected to a temperature of 20 °C and a 1 km length in accordance with the formulae and factors given in IEC 60228. For screens other than copper or aluminium, temperature coefficients and correction formulae shall be taken respectively from Table 1 and IEC 60287-1-1:2006, 2.1.1.

The corrected DC resistance of the conductor at 20 °C shall not exceed either the appropriate maximum value specified in IEC 60228 or the declared value.

The corrected DC resistance of the metal screen at 20 °C shall not exceed the declared value.

10.6 Measurement of thickness of insulation

10.6.1 General

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

Each cable length selected for the test shall be represented by a piece taken from one end after having discarded, if necessary, any portion that may have suffered damage.

10.6.2 Requirements for the insulation

The minimum measured thickness shall not be less than 90 % of the nominal thickness:

$$t_{min} \geq 0{,}90\ t_n$$

and additionally:

$$\frac{t_{max} - t_{min}}{t_{max}} \leq 0{,}15$$

where

t_{max}	is the maximum measured thickness, in millimetres;
t_{min}	is the minimum measured thickness, in millimetres;
t_n	is the nominal thickness, in millimetres.
t_{max} and t_{min}	shall be measured at the same cross-section of the insulation.

The thickness of the semi-conducting screens on the conductor and over the insulation shall not be included in the thickness of the insulation.

10.7 Measurement of thickness of oversheath

10.7.1 General

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

Each cable length selected for the test shall be represented by a piece taken from one end after having discarded, if necessary, any portion that may have suffered damage.

10.7.2 Requirements for the oversheath

The minimum measured thickness shall not be less than 80 % of the nominal thickness minus 0,2 mm:

$$t_{min} \geq 0{,}8\ t_n - 0{,}2$$

where

t_{min} is the minimum measured thickness, in millimetres;

t_n is the nominal thickness, in millimetres.

10.8 Measurement of thickness of metal sheath

10.8.1 General

The tests in 10.8.2 to 10.8.4 apply if the cable has a metal sheath of lead or lead alloy.

10.8.2 General

If the cable has a lead or lead alloy sheath, the minimum thickness of the metal sheath shall not be less than 95 % of the nominal thickness minus 0,1 mm:

$$t_{min} \geq 0{,}95\ t_n - 0{,}1$$

where

t_{min} is the minimum measured thickness, in millimetres;

t_n is the nominal thickness, in millimetres.

The thickness of the sheath shall be measured by one of the following methods, at the discretion of the manufacturer.

10.8.3 Strip method

The measurement shall be made with a micrometer with plane faces of 4 mm to 8 mm diameter. The accuracy of the micrometer shall be ±0,01 mm.

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

10.8.4 Ring method

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

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

10.9 Measurement of diameters

If the purchaser requires that the diameter of the core and/or the overall diameter of the cable shall be measured, the measurements shall be carried out in accordance with IEC 60811-203.

10.10 Hot set test for XLPE, EPR and HEPR insulations

10.10.1 Procedure

The sampling and test procedure shall be carried out in accordance with IEC 60811-507, employing the test conditions given in Table 8.

The test pieces shall be taken from that part of the insulation where the degree of cross-linking is considered to be the lowest for the curing process employed.

10.10.2 Requirements

The test results shall comply with the requirements given in Table 8.

10.11 Measurement of capacitance

The capacitance shall be measured between conductor and metal screen/sheath at ambient temperature, and the ambient temperature shall be recorded with the test data.

The measured value of the capacitance shall be corrected to a 1 km length and shall not exceed the declared nominal value by more than 8 %.

10.12 Tests on components of cables with a longitudinally applied metal tape or foil, bonded to the oversheath

For cables with a longitudinally applied metal tape or foil, bonded to the oversheath, a 1 m sample shall be taken from the complete cable and subjected to the tests and requirements in Annex D.

10.13 Examination of completed cable

A sample of completed cable (length: more than one pitch of wire armour) shall be subjected to a visual inspection to ensure that the cable construction conforms to the declared design, and the manufacturing process has not caused any harmful defects.

11 Sample tests on accessories

11.1 Factory joints

11.1.1 General

For AC submarine cable systems, each manufactured length and each factory joint shall be tested under the routine tests described in 9.2, 9.3 and 9.4. Since routine tests check the quality of the whole submarine cable system itself, the sample tests listed in 11.1.2 to 11.1.6 shall be performed on one factory joint, on the core only, prior to the start of any cable joint manufacturing. The same procedure shall be used for constructing the sample test joint and the cable joints during production.

In case of contracts involving different conductor cross sectional areas, normally one joint for each size shall be tested. A reduced number of tests can be carried out by agreement between supplier and customer.

A sample of at least 10 m cable and a factory joint shall be prepared for the tests.

If the factory joint is type tested under the contract, the sample tests may be omitted.

11.1.2 PD measurement and AC voltage test

After restoring the semi-conductive insulation screen and the metal screen, and if applicable, the core oversheath, the PD measurement and the AC voltage test shall be performed in accordance with 9.2.1 and 9.2.2. The sensitivity as defined in IEC 60885-3 shall be 5 pC or less.

11.1.3 Lightning impulse voltage test

The lightning impulse voltage test shall be performed under the same conditions as in 12.5.6.

11.1.4 Hot set test for insulation

The hot set test shall be performed according to 10.10.

11.1.5 Tensile test

The tensile test of the conductor joint shall be performed according to the manufacturer's specification. The tensile force applied to the conductor shall not be lower than the declared value given by the cable manufacturer. The test may be performed using a separate conductor sample.

11.1.6 Joint inspection

Examination of the joint by dissection with normal or corrected vision without magnification, shall reveal no signs of deterioration (e.g. electrical degradation, or shrinkage) which could affect the joint in service operation.

11.1.7 Pass criteria

If a factory joint fails in any of the tests listed above, two additional joints shall be tested successfully.

11.2 Sample tests on repair (field) joints and terminations

11.2.1 Tests on components

The characteristics of each component shall be verified in accordance with the specifications of the accessory manufacturer, either through test reports from the supplier of a given component or through tests by the accessory manufacturer.

The manufacturer of a given accessory shall provide a list of the tests to be performed on each component, indicating the frequency of each test.

The components shall be inspected against their drawings. There shall be no deviation outside the declared tolerances.

NOTE As components differ from one supplier to another, it is not possible to define common sample tests on components in this document.

11.2.2 Tests on complete accessory

For accessories where the main insulation cannot be routine tested (see 9.1), the following electrical tests shall be carried out by the manufacturer on an accessory fully assembled up to and including the outer metal screen. External layers outside the metal screen, such as armour, may be omitted:

a) partial discharge test (see 9.2.1);
b) AC voltage test (see 9.2.2).

The sequence in which these tests are carried out is at the discretion of the manufacturer.

NOTE Examples of main insulations that cannot be routine tested are heat shrink insulations, cold shrink insulations and insulations taped and/or moulded on site.

These tests shall be performed on one accessory of each type per contract.

If the sample fails either of the above two tests, two further samples of the same accessory type shall be taken from the contract and subjected to the same tests. If both additional samples pass the tests, the other accessories of the same type from the contract shall be regarded as having complied with the requirements of this document. If either fails, this type of accessory of the contract shall be regarded as having failed to comply.

12 Type tests on cable systems

12.1 General

The tests specified in Clause 12 shall be carried out on the cable system to demonstrate satisfactory performance.

In case of interruption/deviations in the test parameters during the heating cycle voltage test or impulse withstand test, the heating cycle or voltage impulse(s) in question shall be repeated.

In case of insulation breakdown when testing several objects simultaneously, the faulty object may be removed and the incident shall be treated as an interruption. The faulty object is considered to have failed and needs to be retested. Any fault within an extension of 0,5 m from one accessory is considered to be associated with that accessory only, see Figure 1.

Dimensions in metres

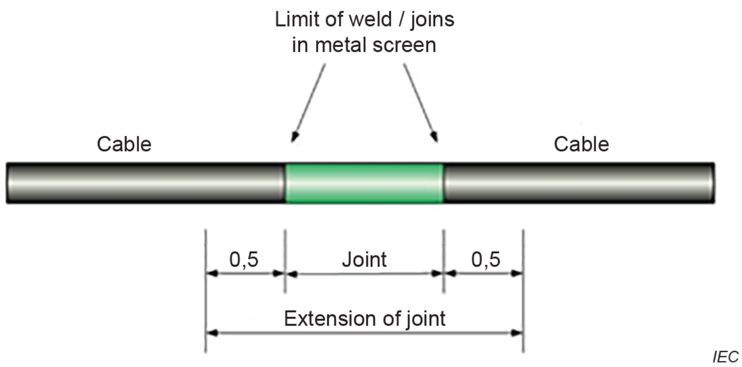


Figure 1 – Example of accessory length extension in the case of factory joint

NOTE Tests on termination insulators referring to environmental conditions are not specified in this document.

12.2 Range of type approval

Apart from a type test for a land cable system according to IEC 60502-2 or IEC 60840 which includes electrical and non-electrical tests, the submarine cable system type test includes a more extensive mechanical type test programme prior to electrical testing. A submarine cable system may consist of submarine cable(s), termination(s) and different types of joints. The submarine cable system (cable(s) and joint(s)) has to be mechanically tested to the highest expected mechanical loads during cable installation, laying and repair.

When type tests have been successfully performed on one or more submarine cable system(s) of specific cross-section(s), and of the same rated voltage and construction, the type approval shall be considered as valid for cable systems within the scope of this document with other cross-sections, rated voltages and constructions provided that all the conditions a) to k) are met:

a) the voltage group is not higher than that of the tested cable system(s);

NOTE 1 In this context, cable systems of the same rated voltage group are those of rated voltages having a common value of U_m, highest voltage for equipment, and the same test voltage levels (see Table 4, columns 1 and 2).

b) the conductor cross-section is not larger than that of the tested cable;

c) the cable and the accessories have the same or similar constructions as that of the tested cable system(s);

NOTE 2 Cables and accessories of similar construction are those of the same type and manufacturing process of insulation and semi-conducting screens. Repetition of the electrical type tests is only necessary due to differences in the material of the protective layers applied over the screened cores or over the main insulation part of the accessory, if these are likely to have a significant effect on the results of the test. In some instances, it can be appropriate to repeat one or more of the type tests (e.g. mechanical tests, heating cycle test and/or compatibility test).

d) the calculated nominal electrical stress and the impulse voltage stress calculated using nominal dimensions at the cable conductor screen do not exceed the respective calculated stresses of the tested cable system(s) by more than 10 %;
e) the calculated nominal electrical stress at the cable insulation screen and the impulse voltage stress calculated using nominal dimensions do not exceed the respective calculated stresses of the tested cable system(s);
f) the calculated nominal electrical stresses and the impulse voltage stresses calculated using nominal dimensions within the main insulation parts of the accessory and at the cable and accessory interfaces do not exceed the respective calculated stresses of the tested cable system(s);
g) the cable mechanical design is the same or similar, for example single or double wire armour, armour material and direction of application;
h) the cable system is subjected to the same or less severe mechanical stress (tension, bending, water pressure, etc.) than the tested cable system;
i) the design and method of conductor and/or screen/sheath water tightness is unchanged. Type tests carried out on cables with longitudinal watertightness are valid also for cables without longitudinal watertightness;
j) the design and method of assembly (or construction) of factory and repair (field) joints is unchanged;
k) the calculated nominal electrical stress and the impulse voltage stress calculated using nominal dimensions at the conductor screen in the flexible joint (factory joint) do not exceed the respective calculated stresses of the tested cable system(s) by more than 10 %.

The non-electrical type tests on cable components (see 12.7) only need to be carried out on samples from cables of different voltage ratings and/or conductor cross-sectional areas if different materials and/or different manufacturing processes are used to produce them. However, repetition of the ageing tests on pieces of completed cable to check compatibility of materials (see 12.7.5) may be required if the combination of materials applied over the screened core is different from that of the cable on which type tests have been carried out previously.

As a minimum, the test which is affected by the design change, (e.g. a water penetration test) shall be repeated.

A flexible joint with the approximately same diameter as the cable, shall be treated and tested as the cable, both from an electrical and mechanical point of view.

The type testing on submarine cables in the voltage range up to 72,5 kV as specified in this document, follows the system approach and tests on cables with installed accessories are recommended.

NOTE 3 This document does not include tests for the determination of the behaviour of the insulation in the presence of water.

A type test certificate signed by the representative of a competent witnessing body, or a report by the manufacturer giving the test results and signed by the appropriate qualified officer, or a type test certificate issued by an independent test laboratory shall be acceptable as evidence of type testing.

12.3 Summary of type tests

The type tests shall comprise the mechanical test, electrical type tests and longitudinal/radial water penetration test as specified in 12.4, 12.5, 12.6 and the appropriate non-electrical tests on cable components and complete cable as specified in 12.7.

The non-electrical tests on cable components and complete cable are listed in Table 5, indicating which tests are applicable to each insulation and oversheath material.

The minimum required complete test length and distance between factory joints for the mechanical tests are described in 12.4.

The tests listed in 12.5.2 shall be performed on one or more samples of complete cable, depending on the number of joints involved, at least 10 m cumulative in length excluding the accessories. The cable shall be taken from the sample which has been subjected to the mechanical tests in 12.4, and shall include factory joint(s) and flexible repair joint(s), where applicable. The minimum cable length between the accessories shall be 5 m (excluding 0,5 m at the accessories).

One sample of each accessory type shall be tested.

Each cable length and joint, which is to be part of the test assembly to be used for the electrical type test (with the exception of the resistivity of semi-conducting screens) and the longitudinal/radial water penetration (LWP, RWP) test, shall undergo the mechanical tests in accordance with 12.4 before the electrical type tests commence. The accessories, terminations and rigid repair (field) joints, shall be installed after the mechanical test on each cable length being part of the loop.

The shape of the cable shall have a U-bend in accordance with the diameter specified in 12.4.2 or a bending diameter specified by the manufacturer, whichever is smaller.

Cable and accessories shall be assembled in the manner specified by the manufacturer's instructions, with the grade and quantity of materials supplied, including lubricants if any.

Neither the cables nor the accessories shall be subjected to any form of conditioning not specified in the manufacturer's instructions which might modify the electrical, thermal or mechanical performance.

Measurement of resistivity of semi-conducting screens described in 12.5.8 shall be made on a separate sample.

12.4 Mechanical tests

12.4.1 Coiling test

12.4.1.1 Purpose/applicability

This test applies only to cables which are coiled during manufacturing, storage, transport or laying and does not apply to cables which are simply wound on drums or turntables. During a coiling operation, the cable experiences torsion. It is therefore important to check the cable construction after the coiling test.

12.4.1.2 Preparations/conditions

The coiling test shall be carried out on a cable of suitable length. This shall form at least six complete turns of the coil, unless there are two joints, in which case there shall be at least eight turns of the coil, with at least two turns between the joints.

A typical arrangement for the coiling test is shown in Figure 2 below:

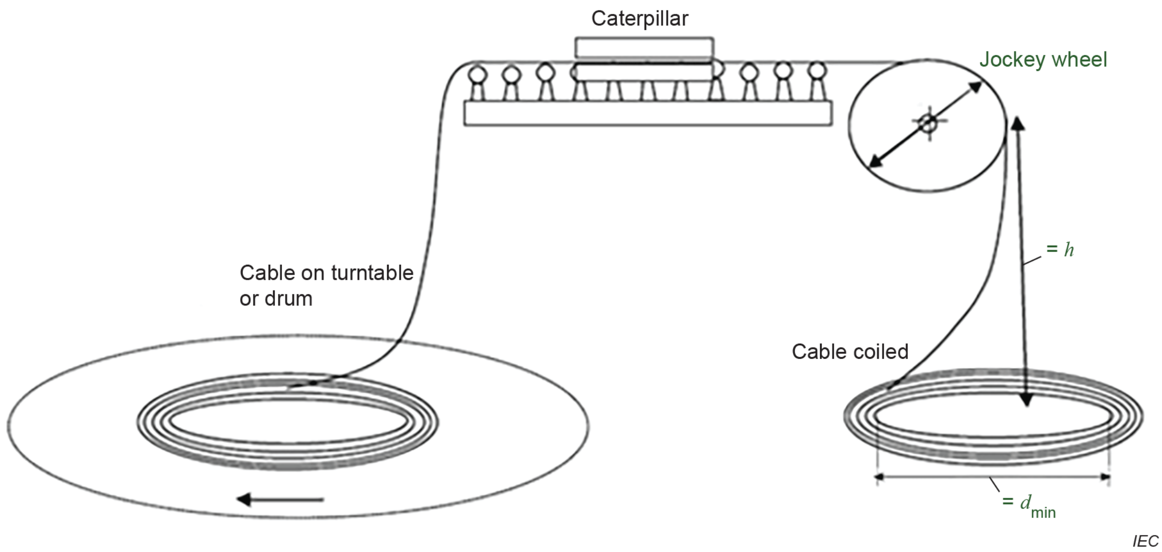


Figure 2 – Example of coiling test arrangement

The cable shall include at least one factory joint and a flexible repair (field) joint if applicable. The number of joint(s) and the distance(s) between them are determined in accordance with the following principles:

– Single-core cable

A minimum of two complete turns of the coil shall be kept between the joint end and the nearest end of the test cable length. If two or more joints are included in the test cable length, the distance between the ends of the special parts, or ends of other joints, shall be at least two complete turns of the coil.

– Three-core cable

The number of phase joints included in the test cable depends on the cable construction. The outer diameter of the armour layer(s) is normally increased over the phase joints due to a larger outer diameter of the joint compared to the unjointed core. This section of the cable, with increased outer diameter of the armour, is considered as a "mechanically special part". See also Figure 3.

Two "mechanically special parts" are considered to be mechanically independent if the distance between them is at least one lay length of the outer armour layer, see Figure 3a). Two mechanically independent sections will not affect each other during a coiling operation.

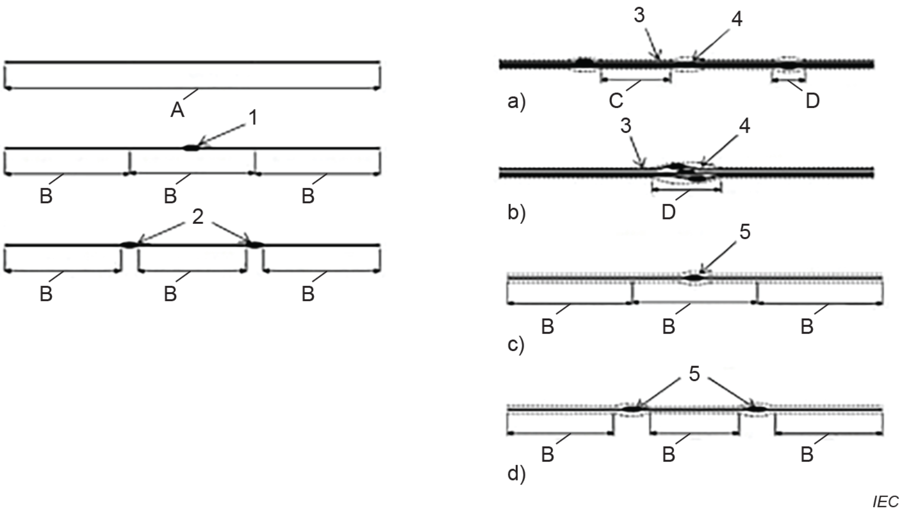
If all "mechanically special parts" on the delivery cable are sufficiently separated to ensure mechanical independence, the number of phase joints in the test cable and the distances between the phase joints can be determined in accordance with the same principle as for single-core cables.

If several (normally three) phase joints are installed in one continuous "mechanically special part", or if the separation between two "mechanically special parts" is less than one lay length of the outer armour layer, the phase joints shall be considered as "mechanically dependent", see Figure 3 b). In this case, the number of phase joints in the test cable shall be at least the same as the number of phase joints that are mechanically dependent in the delivery cable. The distance between the phase joints shall be representative for the minimum distance between the phase joints in the delivery cable. For example, if three phase joints are installed in one continuous "mechanically special part" in the delivery cable, at least three phase joints shall be included in the test cable.

In addition to the above, at least two turns of cable (which may include joints) shall be coiled at the declared minimum coiling diameter.

NOTE The two turns of cable at the minimum coiling diameter can be on top of one another.

A minimum of two complete turns of the coil shall be kept between the end of a “mechanically special part” and the nearest end of the test cable length. If two or more “mechanically special parts” are included in the test cable length, the distance between the ends of the special parts or ends of other joints shall be at least two complete turns of the coil.



Key

1	joint in the middle section	4	phase joint(s)
2	joints	5	phase joint or mechanically special part
3	armouring		
A	minimum 6 complete turns	C	at least one lay length of armouring
B	minimum 2 complete turns	D	mechanically special part

In the figure, a) and b) refer to three-core cables while c) and d) refer to single-core cables.

Figure 3 – Test cable length for coiling test

The manufacturer shall specify the minimum diameter and the direction of coiling to be used during any coiling operation. The test shall be performed in accordance with the specified diameter and direction. The actual diameter (equal to 2 x the radius measured from the centre of the coil to the nearest surface of the joint(s)) at the position of each joint shall be recorded, the test qualifies the joints for coiling down to this minimum coil diameter.

The coiling should be such that the joint is positioned to the minimum radius of the coil.

Before starting the coiling, a line parallel to the cable axis shall be marked on the cable in order to check the uniformity of twist in the cable during coiling operations.

The height of the jockey wheel (h in Figure 2) above the top layer of the coiled cable shall not exceed that to be used during any coiling operation.

If the cable contains optical fibre cable(s) with factory joints, at least one optical cable factory joint shall be included in the coiling test.

12.4.1.3 Test

With both ends held or with one additional turn at the start and at the end of the test in order to prevent rotation, the cable shall be coiled with a minimum coiling diameter (d_{min} in Figure 2) equal to the value specified by the manufacturer.

After coiling, the cable shall be rewound onto the storage facility. This cycle of operations shall be repeated for a number of times at least equal to the number of times that the coiling operation is expected to be carried out during manufacturing, storage, transport and laying of the cable.

During the coiling operation, the cable twist shall be substantially uniform, as assessed from the previously applied marker line.

12.4.1.4 Requirements and visual inspection

After the coiling test, the test cable and all joint(s) shall be inspected visually for deformation of the outer layer. A complete visual inspection shall be performed after the mechanical and electrical tests have been completed, see 12.5.7.

12.4.2 Tensile bending test

12.4.2.1 Purpose/applicability

This test is designed to take into account the forces that apply to cables during laying and normal recovering. The tensile bending test is applicable for cables which are intended to be installed, recovered or repaired with a method that comprises bending under tension, for example laying over lay wheels, lay chutes or around capstan wheels.

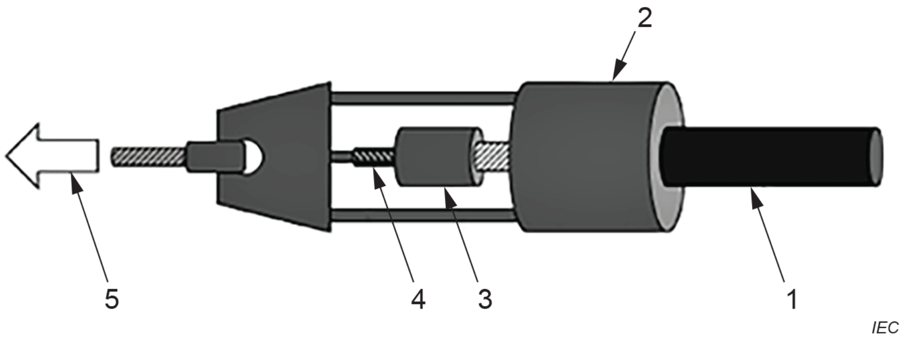
A rigid joint may also be part of the test length. In this case the rigid joint shall not be passed round the rotating drum, so only the cable on one side of the rigid joint will be subjected to the tensile bending test. Therefore, this latter part of the test length shall be sufficiently long to provide all the cable requiring the tensile bending test, see also 12.4.3.

12.4.2.2 Preparations/conditions

Factory and flexible repair (field) joints shall be included in the test sample, if they are a part of the cable system. If the test cable has been subjected to the coiling test of 12.4.1, the tensile bending test shall be performed on a sample taken from that test cable length. If the cable has earthing connections between the metal sheath and armour, the test sample shall also include one of these connections.

The length of the sample shall be at least 30 m. The sample shall be wound on a drum having a radius not larger than the smallest radius of the pay-off wheel, capstan, or chute, installed on the cable laying vessel. The length of the test sample in contact with the test drum shall not be less than half the circumference of the test drum.

For all mechanical tests, all the conductors and armouring shall be bonded together at both ends of the test sample by means of an anchoring head which prevents them from longitudinal movement and relative rotation inside it. The cable heads should be installed in a way that the resulting forces on the different cable components far from the ends, are equivalent to the distribution of forces during laying. One way to achieve this is to have separate anchoring devices for the armouring and core(s) of the test sample, where the relative load sharing can be controlled by a screw device or similar; an example is shown in Figure 4. Before the test, a small tensile load is applied to the test sample and the core anchoring position is adjusted, relative to the armour anchoring, to ensure that the core(s) is/are also loaded.



Key

1 cable under test
2 armour anchoring
3 conductor(s) anchoring
4 screw to adjust force on conductor
5 tensile force

Figure 4 – Illustration of an example of an anchoring head where relative load sharing between conductor and armour can be controlled

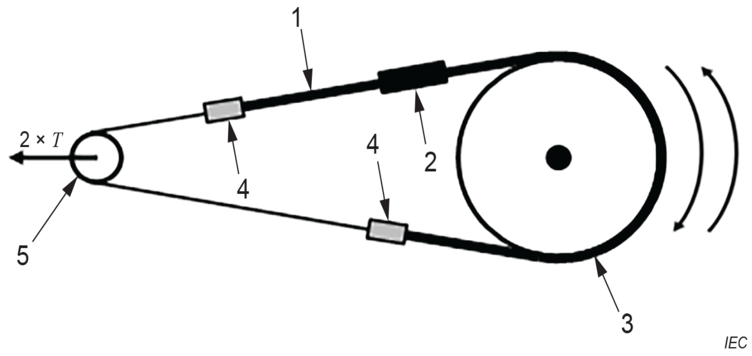
One head shall be free-rotating and one shall be fixed. The distance from a cable end to a flexible joint shall be at least 10 m or five times the lay length of the outer armour layer, whichever is greater.

If the cable contains optical fibre cable(s) with factory joints, at least one optical cable factory joint shall be included in the tensile bending test.

The test tension, T, used in the test shall be established based on the maximum expected tension during laying or recovery. The method for the calculation of T is reported in Annex G.

12.4.2.3 Test

The tension in the cable shall be brought up to the calculated value, T. Using suitable equipment, the cable sample, including the joints if applicable, shall be wound and unwound on a drum for three times consecutively without changing the direction of bending. When carrying out the test it is essential to ensure that all the cable to be used for subsequent tests is submitted to the full three bends. Cable that is on the drum at the beginning of the test or remains on the drum at the end of the test shall not be considered to have completed the test. Figure 5 shows an example of a device for carrying out the test.



Key

1	cable under test	4	cable heads
2	joint	5	pulley
3	rotating drum		

Figure 5 – Example of set-up for tensile bending test with a flexible or factory joint

If the test sample contains optical fibres, the integrity of all the optical fibres shall be verified by a continuity check.

12.4.3 Tensile test

12.4.3.1 Purpose/applicability

The purpose of this test is to verify the performance of the cable and joints when exposed to an axial tensile force without bending. The tensile test shall be performed if a rigid joint is included in the cable system. A separate tensile test is not required, if the rigid joint is included in the tensile bending test but not passed around the wheel.

This test qualifies the rigid joint up to the test tension, T, used in the tensile bending test.

12.4.3.2 Preparations/conditions

The length of the cable used for this test shall be at least five times the lay length of the outer armour layer. If a tensile bending test has been performed then this test may be performed on a sample taken from the cable tested according to 12.4.2.

The distance from the cable end to any joints shall be at least 10 m or five times the lay length of the outer armour layer, whichever is greater. The cable heads shall be installed so that the resulting forces on the different cable components far from the ends are equivalent to the distribution of forces during laying operations, in accordance with 12.4.2.2.

One head shall be free-rotating and the other shall be fixed.

If the cable has earthing connections between metallic sheath and armour, the test cable shall also include one of these connections.

If the cable contains optical fibre cable(s), at least one optical cable factory joint shall be included in the tensile test if the optical cable contains factory splices.

12.4.3.3 Test

The tension in the cable shall be gradually increased up to the specified tension, T. The load shall be held for a minimum of 30 min.

The applied load shall be continuously monitored during the test.

If the test sample contains optical fibres, the integrity of all the optical fibres shall be verified by a continuity check.

12.5 Electrical type tests

12.5.1 Test voltage values

Prior to the electrical type tests, the insulation thickness shall be measured by the method specified in IEC 60811-201 on a representative piece of the length to be used for the tests, to check that the thickness is not excessive compared with the nominal value.

If the average thickness of the insulation does not exceed the nominal value by more than 5 %, the test voltages shall be the values specified in Table 4 for the rated voltage of the cable.

If the average thickness of the insulation exceeds the nominal value by more than 5 % but by not more than 15 %, the test voltage shall be adjusted to give an electrical stress at the conductor screen equal to that applying when the average thickness of the insulation is equal to the nominal value, and the test voltages are the normal values specified for the rated voltage of the cable.

The cable length used for the electrical type tests shall not have an average insulation thickness exceeding the nominal value by more than 15 %.

12.5.2 Electrical type tests and sequence of tests

Samples for electrical type test shall be taken from the cable or cable system subjected to previous tensile bending tests and, if applicable, coiling tests as specified in 12.4. Where applicable, the sample containing the rigid joint shall be subjected to the tensile test prior to the electrical type test.

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

The following electrical tests shall be performed on the sample:

NOTE The sample can contain a factory joint, a repair (field) joint, an asymmetric joint, terminations, etc. depending on the scope of the type test approval required.

a) partial discharge test at ambient temperature (see 12.5.3);

b) tan δ measurement (see 12.5.4);

   this test may be carried out on a different sample, with special test terminations, from that used for the remainder of the sequence of tests;

c) heating cycle voltage test (see12.5.5);

d) partial discharge tests (see 12.5.3)

   – at ambient temperature and

   – at high temperature;

   The tests shall be carried out after the final cycle of item c) above or, alternatively, after the tests in item e) below.

e) lightning impulse voltage test followed by a power frequency voltage test (see 12.5.6);

f) partial discharge tests, if not previously carried out in item d) above (see 12.5.3);

g) examination of the cable system with cable and accessories on completion of the above tests;

h) the resistivity of the cable semi-conducting screens shall be measured on a separate sample.

Test voltages shall be in accordance with the values given in the appropriate column of Table 4.

Annex A describes the methods of heating the test cable and determination of the conductor temperature.

12.5.3 Partial discharge tests

The tests shall be performed in accordance with IEC 60885-3, the sensitivity being 5 pC or better. The test voltage shall be raised gradually to and held at 2 U_0 for 10 s and then slowly reduced to 1,73 U_0 (see Table 4, column 5).

When performed at high temperature, the test shall be carried out on the test assembly at a cable conductor temperature 5 K to 10 K above the maximum cable conductor temperature in normal operation. The conductor temperature shall be maintained within the stated temperature limits for at least 2 h.

The test assembly shall be heated by conductor current only, until the cable reaches the required temperature.

If, for practical reasons, the test temperature cannot be reached, additional thermal insulation may be applied.

There shall be no detectable discharge exceeding the declared sensitivity from the test assembly at 1,73 U_0.

12.5.4 Tan δ measurement

The sample shall be heated by conductor current only and the temperature of the conductor determined either by measuring its resistance or by temperature sensors on the surface of the screen/sheath, or by temperature sensors on the conductor of another sample of the same cable heated by the same means.

The sample shall be heated until the conductor reaches a temperature which shall be 5 K to 10 K above the maximum conductor temperature in normal operation, given in Table 2.

If, for practical reasons, the test temperature cannot be reached, additional thermal insulation may be applied.

The tan δ shall then be measured at a power frequency voltage of U_0 at the temperature specified above (see Table 4, column 6).

The measured value shall not exceed the relevant value given in Table 3.

12.5.5 Heating cycle voltage test

The cable shall have a U-bend with a diameter as specified in 12.4.2.2 or the bending diameter specified by the manufacturer, whichever is smaller.

The test assembly shall be heated by conductor current only, until the cable conductor reaches a steady temperature 5 K to 10 K above the maximum conductor temperature in normal operation, given in Table 2.

For a three-core cable, the heating current shall be passed through all conductors.

If for practical reasons, the test temperature cannot be reached, additional thermal insulation may be applied.

The heating shall be applied for at least 8 h. The conductor temperature shall be maintained within the stated temperature limits for at least 2 h of each heating period. This shall be followed by at least 16 h of natural cooling to a conductor temperature less than or equal to 30 °C or within 10 K of ambient temperature, whichever is higher. The conductor current during the last 2 h of each heating period shall be recorded.

The cycle of heating and cooling shall be carried out 20 times.

During the whole of the test period, a voltage of 2 U_0 shall be applied to the test assembly (see Table 4, column 7).

Interruption of the test is allowed provided 20 complete heating cycles in total under voltage are completed.

Heating cycles with a conductor temperature higher than 10 K above the maximum conductor temperature in normal operation, given in Table 2, are considered valid.

12.5.6 Lightning impulse voltage test followed by a power frequency voltage test

The test assembly shall be heated by conductor current only, until the cable conductor reaches a steady temperature 5 K to 10 K above the maximum conductor temperature in normal operation, given in Table 2.

The conductor temperature shall be maintained within the stated temperature limits for at least 2 h.

If, for practical reasons, the test temperature cannot be reached, additional thermal insulation may be applied.

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

The test assembly shall withstand without failure or flashover 10 positive and 10 negative voltage impulses of the appropriate value given in Table 4, column 8.

After the lightning impulse voltage test, the test assembly shall be subjected to a power frequency voltage test at the routine test voltage for 15 min, in accordance with Table 4, column 9. At the discretion of the manufacturer, this test may be carried out either during the cooling period or at ambient temperature.

No breakdown of the insulation or flashover shall occur.

12.5.7 Examination

12.5.7.1 General

The purpose of the visual inspection is to ensure that both the mechanical and electrical tests have not caused any damage to the cable system.

A sample, with a length of at least one armour lay length, taken from the central part of the test cable length, and if applicable, also including one of the joints or “mechanically special part”, shall be subjected to the visual inspection. Examination of the samples with normal or corrected vision without magnification shall not reveal any of the following, but not limited to:

– break, crossing or permanent bird caging of armour wires;

– harmful indentations in the cable core(s), for example, resulting in indentations or cracks in the lead sheath;
– damage to the insulation;
– damage to the conductor which could have a detrimental effect on the cable performance.

Particular attention should be paid to the same components in the joint including metal sheath connections.

12.5.7.2 Cable and accessories

Examination of the cable by dissection of a sample taken from the U-bend part and, whenever possible, of the accessories by dismantling, with normal or corrected vision without magnification, shall reveal no signs of deterioration (e.g. electrical degradation, leakage, corrosion or harmful shrinkage) which could affect the system in service operation.

12.5.7.3 Cables with a longitudinally applied metal tape or foil, bonded to the oversheath

A 1 m sample taken from the U-bend part of the type test loop shall be taken and subjected to the tests in 12.7.10.

12.5.8 Resistivity of semi-conducting screens

12.5.8.1 General

Measurement of resistivity of the cable semi-conducting screens shall be made on a separate sample.

The resistivity of extruded semi-conducting screens applied over the conductor and over the insulation shall be determined by measurements on test pieces taken from the core of a sample of cable as manufactured, and a sample of cable which has been subjected to the ageing treatment to test the compatibility of component materials specified in 12.7.4.

12.5.8.2 Procedure

The test procedure shall be in accordance with Annex C.

For semi-conducting screens the measurements shall be made at a temperature within ±2 K of the maximum conductor temperature in normal operation, given in Table 2.

12.5.8.3 Requirements

The resistivity of the semi-conducting screens, both before and after ageing, shall not exceed the following values:

conductor screen:	1 000	$\Omega \cdot m$
insulation screen:	500	$\Omega \cdot m$

NOTE The measurement procedure and the requirements of the resistivity of the polymeric oversheath are left for future consideration.

12.6 Longitudinal/radial water penetration (LWP, RWP) test

12.6.1 General

For submarine cables the water penetration tests are divided into three tests:

– LWP a: conductor longitudinal water penetration test (see 12.6.2);
– LWP b: metal screen longitudinal water penetration test (see 12.6.3);

– RWP: radial water penetration test of joints (see 12.6.4).

The tests have mechanical and thermal preconditioning as described below.

The mechanical preconditioning includes a tensile bending test and, if applicable, a coiling test before the tensile bending test.

The water used in the tests shall correspond to the application of the cable system and be either tap water in case the cable is installed in fresh water, or saltwater with a salinity of the specific area of the cable installation. If there is an absence of information concerning the application, then a concentration of 3,5 % by weight of NaCl shall be used.

The water pressure shall be raised to the test pressure as quickly as practicably possible.

For convenience, the following measures are defined:

d_1 = maximum declared distance for LWP in conductor;

d_2 = maximum declared distance for LWP in metal screen area.

The maximum water penetration distance(s) is (are) to be agreed between supplier and customer.

12.6.2 Conductor water penetration test

The test is applicable only to cables having a longitudinal water barrier in the conductor.

The cable sample has to be taken from the cable subjected to the mechanical test, see 12.4.

The length of the test sample, excluding any exposed conductor, shall be at least the distance d_1 + 1,0 m; the length of the test sample inside the test chamber is optional, see Figure 6.

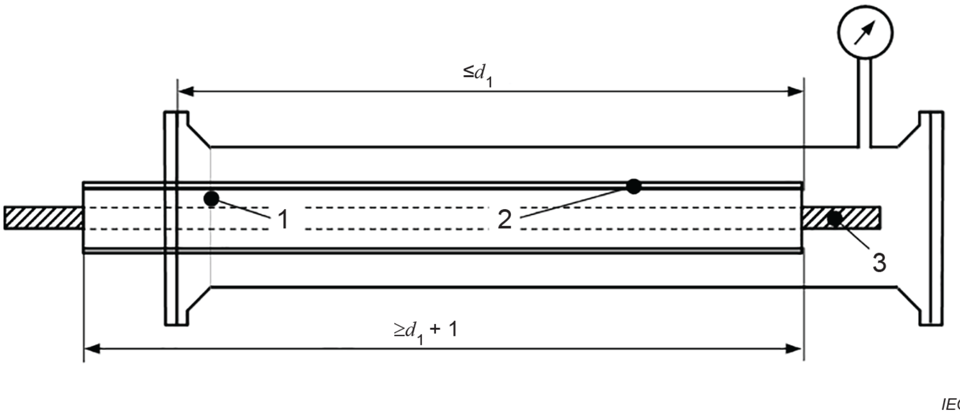
The complete cable shall be preconditioned by at least three heating cycles, ensuring that the cable has experienced thermal expansion.

Each heating cycle consists of at least 8 h of heating followed by at least 16 h of natural cooling. Current heating in the conductor shall be used to give a conductor temperature 5 K to 10 K above the maximum conductor temperature in normal operation, given in Table 2. The conductor temperature shall be kept within the above range for at least 2 h during each heating cycle.

After preconditioning, the cable shall be dismantled and the test continued on a single-core of the cable; in all cases the layers above the outer semi-conducting screen may be removed to facilitate the test.

The test object shall be prepared as follows. A length of (50 ± 10) mm of conductor shall be exposed at both ends of the sample. The test sample is placed inside a pressure vessel as indicated in Figure 6. As the force from the water pressure will tend to drive the cable (or its internal components) out of the chamber, suitable mechanical restraints shall be applied to prevent such movement.

Dimensions in metres



Key

1 insulation

2 outer semi-conducting layer

3 (50 ± 10) mm of exposed conductor

Figure 6 – Set-up for the conductor water penetration test

The test object is pressurized while submerged with a water pressure corresponding to the declared maximum laying depth in water, see Clause 6. The pressure shall be raised as fast as practicably possible to simulate a cable fault at the deepest part of the cable section. The test continues for 10 days with water at ambient temperature.

When the test time has elapsed, the test object is removed from the water. A cut is made in the conductor at a distance d_1 to check for the presence of water. This can be established by visual examination of the end(s) and by use of absorbent paper. No presence of water shall be detected.

12.6.3 Metal screen water penetration test

The test is applicable only to cables with core(s) having a metal sheath or an oversheath and a longitudinal water barrier in the screen area.

The length of the test sample, excluding any extending outside the test chamber, shall be at least the distance d_2 + 1,0 m, see Figure 7.

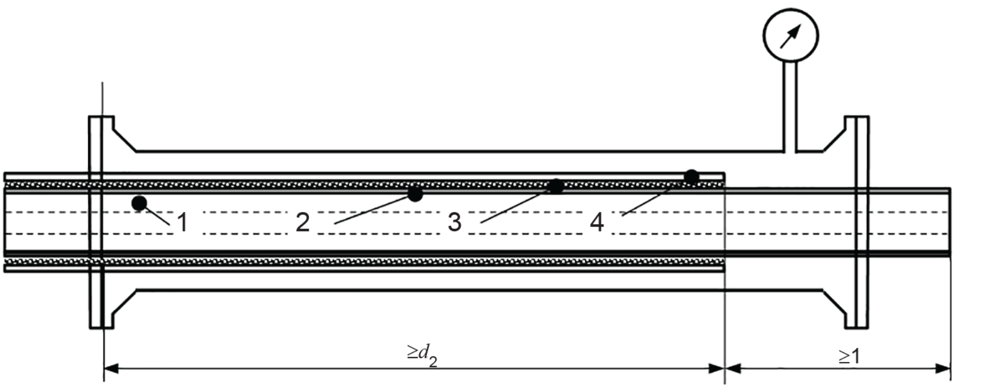
The complete cable used to provide the test object shall be preconditioned by carrying out three heating cycles. Each heating cycle shall consist of at least 8 h of heating followed by at least 16 h of cooling. Current heating in the conductor shall be used to give a conductor temperature 5 K to 10 K above the maximum temperature in normal operation, given in Table 2. The conductor temperature shall be kept within the above range for at least 2 h during each heating cycle.

After preconditioning, the cable shall be dismantled, and the test continued on a single core of the cable.

NOTE In the case of three-core cables, the core can be taken from the same sample of completed cable used for the conductor water penetration test.

All the layers external to the outer semi-conducting screen for at least 1,0 m from one end of the sample shall be removed, exposing the outer semi-conducting screen to the water. The test sample is placed inside a pressure vessel as shown in Figure 7. The temperature of the conductor shall be measured inside the pressure vessel. The temperature sensor position shall be selected in order to limit the end effect.

Dimensions in metres



Key

1 insulation

2 outer semi-conducting layer

3 metal screen

4 oversheath

Figure 7 – Set-up for the metal screen water penetration test

The pressure vessel shall be filled with water at ambient temperature and the pressure set to a value corresponding to the specified maximum laying depth with a maximum of 3 bar. The test object shall be subjected to 10 heating cycles while pressurized. The test assembly shall be heated by conductor current only, until the cable conductor reaches a steady temperature 5 K to 10 K above the maximum conductor temperature in normal operation, given in Table 2. The heating shall be applied for at least 8 h. The conductor temperature shall be maintained within the stated temperature limits for at least 2 h of each heating period. This shall be followed by at least 16 h of natural cooling.

When the test time has elapsed, the test object shall be removed from the water. The underside of the oversheath or metal sheath, which is in contact with the longitudinal water barrier, is exposed at a distance d_2 from the end exposed to the water to check for the presence of water. This can be established by visual examination and by use of absorbent paper. No presence of water shall be detected.

12.6.4 Radial water penetration test for joints

The test is applicable to factory, repair and field joints.

The joint shall be subjected to the applicable mechanical tests (see 12.4), and at least 10 heating cycles shall be applied. The test assembly shall be heated by conductor current only, until the cable conductor reaches a steady temperature 5 K to 10 K above the maximum conductor temperature in normal operation, given in Table 2. The heating shall be applied for at least 8 h. The conductor temperature shall be maintained within the stated temperature limits for at least 2 h of each heating period. This shall be followed by at least 16 h of natural cooling.

The test is to be performed on the pressurized part of the joint and not necessarily to the whole joint body for rigid repair (field) joints. For three-core cables at least one core factory joint shall be tested.

On completion of the heating cycles the test sample shall be placed inside a pressure vessel. The cable ends may exit the vessel through seals or be sealed inside the vessel by means of caps.

NOTE The pressurized part does not include mechanical devices connected to the joint to restrict the bending, which do not have any functions related to water sealing.

The test object is submerged in pressurized water corresponding to the specified maximum laying depth. The test continues for 48 h with water at ambient temperature.

When the test time has elapsed the water pressure may be reduced to atmospheric pressure. If the cable ends were sealed by caps then the ends shall be prepared to allow application of the test voltage. The sample may be removed from the water only for a time long enough to allow this operation to be carried out. Whilst still immersed in water, a test voltage of 25 kV DC shall be applied between the conductor(s) of the joint and the water. No breakdown shall occur.

The test object shall then be removed from the water and examined. It shall meet the following requirements:

a) No water shall be present under the water blocking barrier of the joint.
b) No appreciable shape irregularity shall be visible in the metal sheath. In case of metal screens composed of copper wires, tapes or laminated foils or a combination of them, no cracks of the metallic components shall be visible.

12.7 Non-electrical type tests on cable components and on complete cable

12.7.1 General

The tests are as follows and tests b) to n) shall be carried out on all cores:

a) check of cable construction (see 12.7.2);
b) tests for determining the mechanical properties of insulation before and after ageing (see 12.7.3);
c) tests for determining the mechanical properties of oversheaths before and after ageing (see 12.7.4);
d) ageing tests on pieces of complete cable to check compatibility of materials (see 12.7.5);
e) pressure test at high temperature for ST_7 oversheaths (see 12.7.6);
f) ozone resistance test for EPR and HEPR insulations (see 12.7.7);
g) hot set test for EPR, HEPR and XLPE insulations (see 12.7.8);
h) measurement of carbon black content for black PE oversheaths (see 12.7.9);
i) tests on components of cables with a longitudinally applied metal tape or foil, bonded to the oversheath (see 12.7.10 and IEC TR 61901);
j) water absorption test for insulation (see 12.7.11);
k) shrinkage test for XLPE insulation (see 12.7.12);
l) determination of hardness for HEPR insulation (see 12.7.13);
m) determination of elastic modulus for HEPR insulation (see 12.7.14);
n) shrinkage test for PE oversheath (see 12.7.15).

12.7.2 Check of cable construction

The examination of the conductor and measurements of insulation, oversheath, metal sheath or screen, and armour shall be carried out in accordance with and shall comply with the requirements given in 10.4, 10.6, 10.7, 10.8, 10.9 and the values declared by the manufacturer as required in Clause 6.

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

12.7.3.1 Sampling

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

12.7.3.2 Ageing treatment

The ageing treatment shall be carried out as described in IEC 60811-401 under the conditions specified in Table 6.

12.7.3.3 Conditioning and mechanical tests

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

12.7.3.4 Requirements

The test results for unaged and aged test pieces shall comply with the requirements given in Table 6.

12.7.4 Tests for determining the mechanical properties of oversheaths before and after ageing

12.7.4.1 Sampling

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

12.7.4.2 Ageing treatment

The ageing treatment shall be carried out as described in IEC 60811-401 under the conditions given in Table 7.

12.7.4.3 Conditioning and mechanical tests

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

12.7.4.4 Requirements

The test results for unaged and aged test pieces shall comply with the requirements given in Table 7.

12.7.5 Ageing tests on pieces of complete cable to check compatibility of materials

12.7.5.1 General

The ageing test on pieces of complete cable shall be carried out to check that the insulation, the extruded semi-conducting layers and the oversheath are not liable to excessive deterioration in operation due to contact with other components in the cable.

The test is applicable to cables of all types.

12.7.5.2 Sampling

Samples for the test on insulation and oversheath shall be taken from the complete cable as described in IEC 60811-501.

12.7.5.3 Ageing treatment

The ageing treatment of the pieces of cable shall be carried out in an air oven, as described in IEC 60811-401 under the following conditions:

– temperature: (10 ± 2) K above the maximum conductor temperature of the cable in normal operation (see Table 6);

– duration: 7 × 24 h.

12.7.5.4 Mechanical tests

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

12.7.5.5 Requirements

The variations between the median values of tensile strength and elongation at break after ageing, and the corresponding values obtained without ageing (see 12.7.3 and 12.7.4), shall not exceed the values applying to the test after ageing in an air oven as given in Table 6 for insulations and in Table 7 for oversheaths.

12.7.6 Pressure test at high temperature for ST_7 oversheaths

12.7.6.1 Procedure

The pressure test at high temperature for ST_7 oversheaths shall be carried out as described in IEC 60811-508, employing the test conditions given in the test method and in Table 7.

12.7.6.2 Requirements

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

12.7.7 Ozone resistance test for EPR and HEPR insulation

12.7.7.1 Procedure

EPR and HEPR insulation shall be tested for resistance to ozone using the sampling and test procedure described in IEC 60811-403. The ozone concentration and test duration shall be in accordance with Table 8.

12.7.7.2 Requirements

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

12.7.8 Hot set test for EPR, HEPR and XLPE insulations

EPR, HEPR and XLPE insulations shall be subjected to the hot set test described in 10.10 and shall comply with its requirements.

12.7.9 Measurement of carbon black content of black PE oversheaths

12.7.9.1 Procedure

The carbon black content of ST_7 oversheaths shall be carried out in accordance with IEC 60811-605, except for semi-conductive oversheaths which shall be excluded.

12.7.9.2 Requirements

The nominal value of the carbon black content shall be (2,5 ± 0,5) %.

Lower values are allowed for special application not exposed to UV.

12.7.10 Tests on components of cables with a longitudinally applied metal tape or foil, bonded to the oversheath

The sample shall be subjected to the following tests:

a) visual examination (see Clause D.1);
b) adhesion strength of metal foil (see D.2.2);
c) peel strength of overlapped metal foil (see D.2.3).

The apparatus, test procedure and requirements shall be in accordance with Annex D.

12.7.11 Water absorption test on insulation

12.7.11.1 Procedure

The sampling and the test procedure shall be carried out in accordance with IEC 60811-402 employing the conditions specified in Table 8.

12.7.11.2 Requirements

The results of the test shall comply with the requirements specified in Table 8.

12.7.12 Shrinkage test for XLPE insulation

12.7.12.1 Procedure

The sampling and the test procedure shall be carried out in accordance with IEC 60811-502 employing the conditions specified in Table 8.

12.7.12.2 Requirements

The results of the test shall comply with the requirements specified in Table 8.

12.7.13 Determination of hardness of HEPR insulation

12.7.13.1 Procedure

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

12.7.13.2 Requirements

The results of the test shall comply with the requirements specified in Table 8.

12.7.14 Determination of the elastic modulus of HEPR insulation

12.7.14.1 Procedure

The sampling and the test procedure shall be carried out in accordance with IEC 60811-501.

The load required for 150 % elongation shall be measured. The corresponding stresses shall be calculated by dividing the loads measured by the cross-sectional areas of the unstretched test pieces. The ratios of the stresses to strains shall be determined to obtain the elastic moduli at 150 % elongation

The elastic modulus shall be the median value.

12.7.14.2 Requirements

The results of the test shall comply with the requirements specified in Table 8.

12.7.15 Shrinkage test for PE oversheath

12.7.15.1 Procedure

The sampling and the test procedure shall be carried out in accordance with IEC 60811-503 employing the conditions specified in Table 7.

12.7.15.2 Requirements

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

13 Electrical tests after installation

13.1 General

Tests on new installations are carried out when the installation of the cable system has been completed.

13.2 DC voltage test of the oversheath

The voltage level and duration specified in IEC 60229:2007, Clause 5 shall be applied between each metal screen and earth. This test is not applicable in the case of semi-conductive sheaths.

13.3 AC voltage test of the insulation

By agreement between the purchaser and the contractor, an AC voltage test between each conductor and the metal screen in accordance with IEC 60060-3 as detailed in item a), b) or c) below may be used:

a) for $U_m \leq 36$ kV, test for 15 min with the voltage according to Table 4, column 10 and a frequency between 10 Hz and 500 Hz;

   for $U_m > 36$ kV, test for 60 min with the voltage according to Table 4, column 10 and a frequency between 10 Hz and 500 Hz;

b) for $U_m \leq 36$ kV, test for 15 min with the RMS rated voltage value of 3 U_0 at a frequency of 0,1 Hz;

c) test for 24 h with the rated voltage U_0 of the system.

For installations which have been in use, lower voltages and/or shorter durations may be used. Values should be negotiated, taking into account the age, environment, history of breakdowns and the purpose of carrying out the test.

13.4 DC voltage test of the insulation

A DC voltage test may endanger the insulation system under test. Where possible an AC test as described above should be used.

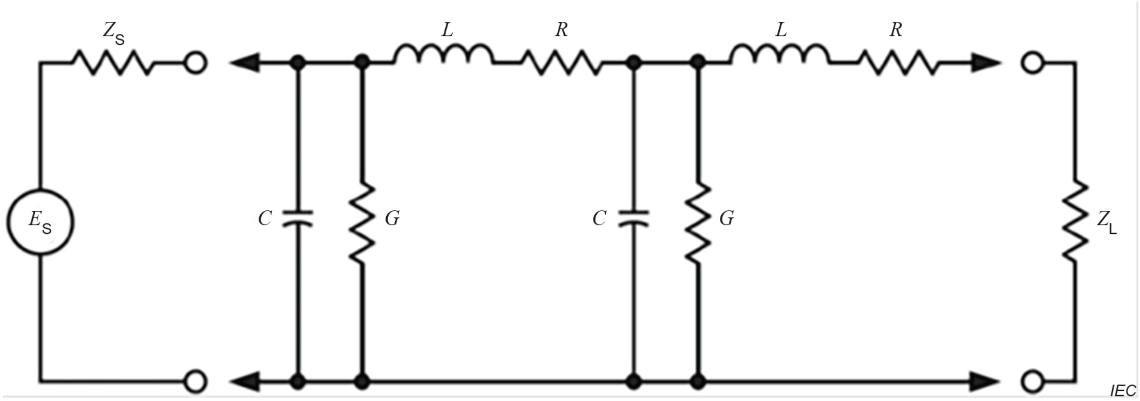
DC testing is not recommended, however, for a previously used test protocol, see Annex H.

13.5 Time domain reflectometry (TDR)

A TDR (time domain reflectometry) measurement could be performed for engineering information.

If TDR equipment is to be used with the cable link, it is advisable to perform a TDR measurement to obtain a “fingerprint” of the wave propagation characteristics of the cable.

The propagation of the pulses used during TDR measurements is dependent upon resistance, capacitance and inductance of the cable, see Figure 8.



Key

E_S and Z_S source voltage and impedance (DTR instrument)

L and R inductance and resistance of an element of cable conductor

C and G capacitance and conductance (dielecric loss) of an element of cable insulation

Z_L terminal (load) impedance

Figure 8 – Circuit diagram for TDR testing (traditional transmission line diagram, π-model)

Table 3 – Tan δ requirements for insulating compounds for cables

Designation of compound (see 4.2)	EPR/HEPR	XLPE
Maximum tan δ	50×10^{-4}	10×10^{-4} [a]
[a] For cables produced with an XLPE compound containing special additives, the maximum tan δ is 50×10^{-4}.		

Table 4 – Test voltages

1	2	3	4 [a]		5 [a]	6 [a]	7 [a]	8 [a]	9 [a]	10 [b]
Rated voltage U	Highest voltage for equipment U_m	Value of U_0 for determination of test voltages U_0	Voltage test of 9.2.2 and 9.4.2	Duration of the voltage test	Partial discharge test of 9.2.1, 9.4.3 and 12.5.3 1,73 U_0	Tan δ measurement of 12.5.4 U_0	Heating cycle voltage test of 12.5.5 2 U_0	Lightning impulse voltage test of 12.5.6	Voltage test of 12.5.6 for 15 min	Voltage test after installation of 13.3 a)
kV	kV	kV	kV	min	kV	kV	kV	kV	kV	kV
6 to 6,6	7,2	3,6	12,5	5	6,2	3,6	7,2	60	12,5	6,2
10 to 11	12	6	21	5	10,4	6	12	75	21	10,4
13,8 to 15	17,5	8,7	30,5	5	15,1	8,7	17,5	95	30,5	15,1
20 to 22	24	12	42	5	20,8	12	24	125	42	20,8
30 to 33	36	18	63	5	31,1	18	36	170	63	31,1
45 to 47	52	26	65	30	45	26	52	250	65	52
60 to 69	72,5	36	90	30	62,3	36	72	325	90	72
[a] If necessary, these test voltages shall be adjusted as stated in 12.5.1.										
[b] If necessary, these test voltages shall be adjusted as stated in 13.3.										

Table 5 – Non-electrical type tests for insulating and oversheath compounds for cables

Designation of compound (see 4.2 and 5.6)	**Insulation**			**PE sheath**
	EPR	**HEPR**	**XLPE**	**ST_7**
Checks on construction Water penetration test [a]	Applicable irrespective of insulation and oversheathing materials			
Dimensions Measurements of thicknesses	x	x	x	x
Mechanical properties (Tensile strength and elongation at break)				
a) without ageing	x	x	x	x
b) after ageing in air oven	x	x	x	x
c) after ageing of the complete cable (compatibility test)	x	x	x	x
Pressure test at high temperature	–	–	–	x
Ozone resistance test	x	x		
Hot set test	x	x	x	–
Water absorption	x	x	x	–
Shrinkage test	–	–	x	x
Carbon black content [b]	–	–	–	x
Determination of hardness	–	x	–	–
Determination of elastic modulus	–	x	–	–

x indicates that the type test shall be applied.

[a] LWP a, LWP b, and RWP to be applied as applicable, see 12.6.1.

[b] For black oversheaths where applicable only, see 12.7.9.

Table 6 – Test requirements for mechanical characteristics of insulating compounds for cables (before and after ageing)

Designation of compounds (see 4.2)		**EPR**	**HEPR**	**XLPE**
Maximum conductor temperature in normal operation (see 4.2)	°C	90	90	90
Without ageing (IEC 60811-501)				
Tensile strength, minimum	N/mm^2	4,2	8,5	12,5
Elongation-at-break, minimum	%	200	200	200
After ageing in air oven (IEC 60811-401)				
After ageing without conductor				
Treatment:				
– temperature	°C	135	135	135
– tolerance	°C	±3	±3	±3
– duration	h	168	168	168
Tensile strength:				
a value after ageing, minimum	N/mm^2	–	–	–
b variation*, maximum	%	±30	±30	±25
Elongation-at-break:				
a value after ageing, minimum	%	–	–	–
b variation*, maximum	%	±30	±30	±25
* Variation: difference between the median value obtained after ageing and the median value obtained without ageing expressed as a percentage of the latter.				

Table 7 – Test requirements for mechanical characteristics of oversheathing compounds for cables (before and after ageing)

Designation of compound (see 5.6)	**Unit**	**ST_7**
Without ageing (IEC 60811-501)		
Minimum tensile strength	N/mm^2	12,5
Minimum elongation at break	%	300
After ageing in air oven (IEC 60811-401)		
Treatment: temperature	°C	110
tolerance	K	±2
duration	h	240
Elongation at break		
minimum value after ageing	%	300
Shrinkage test (IEC 60811-503)		
Temperature (tolerance ±2 K)	°C	80
Heating, duration	h	5
Heating cycles		5
Maximum shrinkage	%	3
Pressure test at high temperature (IEC 60811-508)		
Test temperature	°C	110
Tolerance	K	±2
Maximum indentation	%	50

Table 8 – Test requirements for particular characteristics of insulating compounds for cables

Designation of compounds (see 4.2)		EPR	HEPR	XLPE
Ozone resistance (IEC 60811-403)				
Ozone concentration (by volume)	%	0,025 to 0,030	0,025 to 0,030	–
Test duration without cracks	h	24	24	–
Hot set test (IEC 60811-507)				
Treatment:				
– air temperature (tolerance ±3 °C)	°C	250	250	200
– mechanical stress	N/cm^2	20	20	20
Maximum elongation under load	%	175	175	175
Maximum permanent elongation after cooling	%	15	15	15
Water absorption (IEC 60811-402)				
Gravimetric method:				
temperature (tolerance ±2 °C)	°C	85	85	85
duration	h	336	336	336
Maximum increase of mass	mg/cm^2	5	5	1 [a]
Shrinkage test (IEC 60811-502)				
Distance L between marks	mm	–	–	200
temperature (tolerance ±3 °C)	°C	–	–	130
duration	h	–	–	1
Maximum shrinkage	%	–	–	4
Determination of hardness (see Annex E)				
IRHD [b], minimum		–	80	–
Determination of elastic modulus (see 12.7.14)				
Modulus at 150 % elongation, minimum	N/mm^2	–	4,5	–

[a] An increase greater than 1 mg/cm^2 is being considered for densities of XLPE greater than 1 g/cm^3.

[b] IRHD: international rubber hardness degree.

Annex A
(normative)

Methods of heating the test cable and determination of the cable conductor temperature

A.1 Purpose

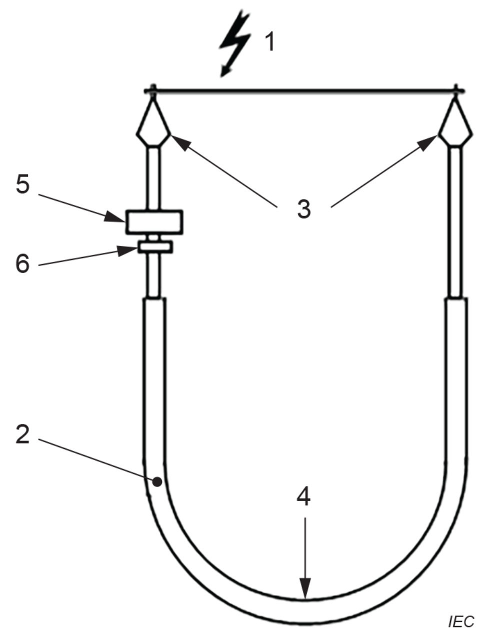
For some tests, it is necessary to raise the cable conductor to a temperature 5 K to 10 K above the maximum temperature in normal operation, while the cable is energized, either at power frequency or under impulse conditions. It is therefore not possible to have access to the conductor to enable direct measurement of the temperature.

For both single- and three-core cables, all cores shall be heated by conductor current using one of the methods described in Clause A.2. The temperature of the conductor(s) should be maintained within a restricted range (5 K) for the period of time specified whereas the ambient temperature may vary over a wider range. Therefore, the relevant method (for single- or three-core cables) specified in Annex A shall be used, in which the conductor temperature can be monitored and controlled throughout the duration of the test.

A.2 Methods of heating armoured cables for the electrical test

A.2.1 Single-core cables

Single-core cables shall be heated by conductor current only. The arrangement is shown in Figure A.1.



Key

1	test voltage	4	cable in U bend
2	cable under test	5	current inducing transformer
3	terminations	6	current measuring transformer

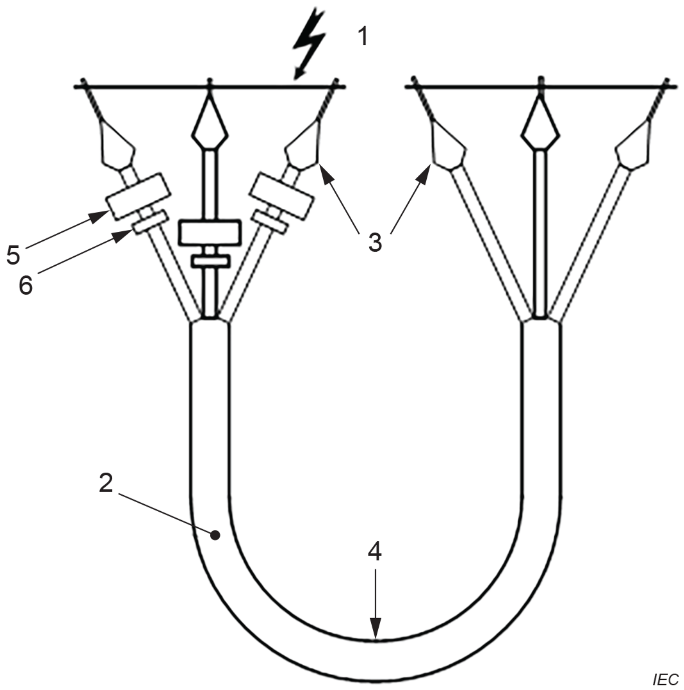
Figure A.1 – Arrangement for heating of single-core armoured cables

A.2.2 Three-core cables

Three-core cables will usually be armoured with galvanized steel wires which are magnetic and thus are very susceptible to heating of the armour, due to induced eddy currents. Thus, to heat the cable for testing, a balanced 3-phase current shall be applied to the conductors to minimize this effect.

One of the following two arrangements shall be used:

a) 3-phase heating with loading transformers on each core (in a section where the individual cores have been separated at the end of the test cable) and with all the conductors connected together at both ends. The loading transformers shall be fed such that the current in the cable cores is 3-phase and of equal magnitude in each conductor to within ±2 %. See Figure A.2.



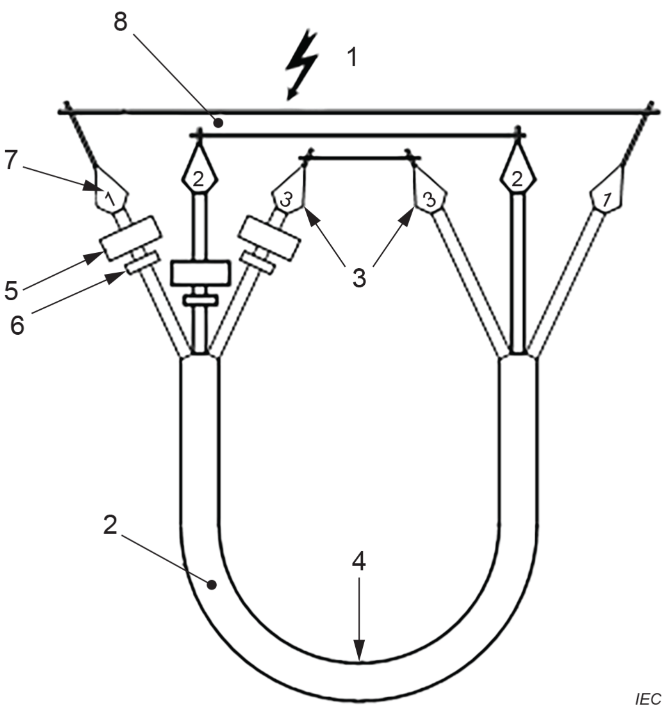
Key

1	test voltage connected at one end only	4	cable in U bend
2	cable under test	5	current inducing transformer
3	terminations	6	current measuring transformer

Figure A.2 – Arrangement 1 for heating of three-core armoured cables

b) As method a) but with the ends of each conductor connected together to carry the heating current (normally using a busbar at high voltage). A single connection is then made between the cores to apply the high voltage to all cores for AC tests. For the lightning impulse test, in the case when it is preferred to carry out a separate lightning impulse test on each core of the cable, then the single connection between the cores may be removed and the impulse voltage test applied to one core at a time. However, in all cases the loading transformers shall be fed such that the current in the cores is 3-phase and of equal magnitude in each core to within ±2 %. See Figure A.3.

Method b) may be chosen for example when it is desired to reduce the load capacitance for the impulse test due to the equipment available.



Key

1	test voltage connected to 1 or 3 cores as required	5	current inducing transformer
2	cable under test	6	current measuring transformer
3	terminations	7	core number
4	cable in U bend	8	clearance between busbars suitable to withstand lightning impulse test voltage

Figure A.3 – Arrangement 2 for heating of three-core armoured cables

A.3 Measurement of the temperature of the test cable

A.3.1 General

The conductor temperature of the test cable is determined by direct measurement of the temperature of the conductor(s) of a second length of cable which is carrying the same current and is in the same thermal environment as the cable under test.

The cable used for temperature measurement (hereafter called the reference cable) shall be taken from the same length as the test cable.

A.3.2 Installation of cable and temperature sensors

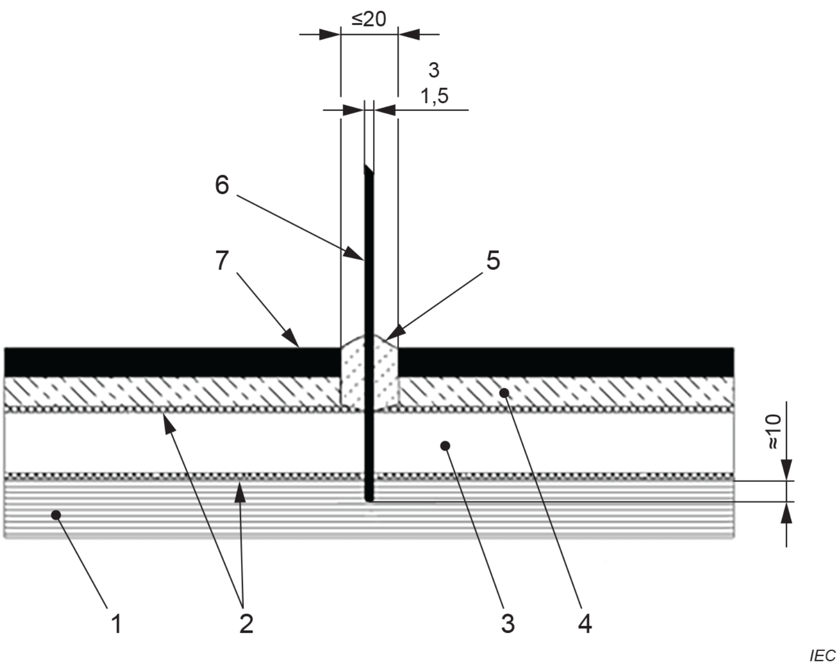
A.3.2.1 General

The reference cable shall have a length of at least 10 m and shall be such that the longitudinal heat transfer to the cable ends does not affect the temperature in the centre 2 m of cable by more than 2 K.

The reference cable shall be a straight length and it may be installed outside the high voltage bay but in the same ambient conditions as the test cable.

In order to install temperature sensors in the reference cable conductor it is necessary to cut through the outer layers of the cable to reach the conductor. Removal or unwinding of the outer serving and armour layers, followed by their replacement, is not allowed as this is likely to alter the thermal behaviour of the cable. A hole of no more than 20 mm diameter may be cut in the outer serving and armour in order to fit the temperature sensors. Any hole cut in this way shall be reinstated after installation of the temperature sensor.

Dimensions in millimetres



Key

1	conductor	5	flexible thermal insulating compound
2	semi-conducting screen	6	temperature sensor
3	insulation	7	outer serving and armour
4	metal screen		

Figure A.4 – Installation of the temperature sensors in the conductor(s) of the reference cable

A.3.2.2 Single-core cable

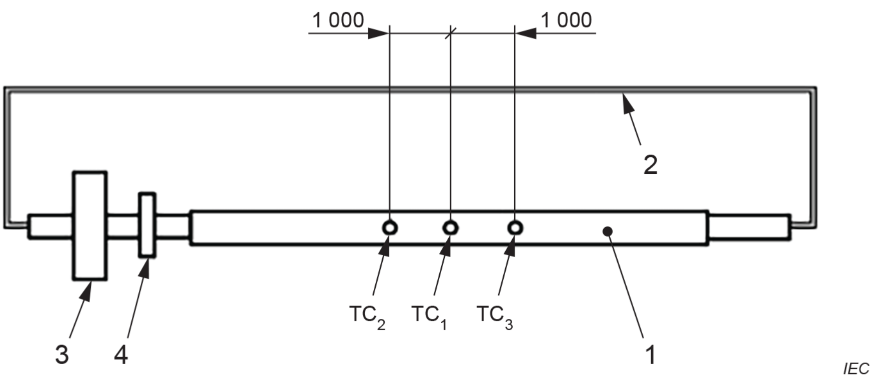
A temperature sensor shall be installed in the conductor at the centre of the reference cable (TC_1).

Two other temperature sensors, TC_2 and TC_3, shall be installed on the conductor of the reference cable (see Figure A.5), each one about 1 m away from the centre.

The temperature sensors should be attached to the conductor by mechanical means since they may move due to vibration of the cable during heating. Care should be taken to maintain good thermal contact with the conductor during the tests and to prevent leakage of heat to the surrounding environment. It is recommended that the temperature sensor(s) are installed as shown in Figure A.4. To enable access to the conductor in the middle of the reference cable, a small hatch may be made by careful removal of the layers above the conductor. After installing the temperature sensor(s), the layers that have been removed may be replaced to restore the thermal behaviour of the reference cable.

To prove a negligible heat transfer towards the cable ends, the difference between the readings of TC_1, TC_2 and TC_3 should be less than 2 K when the cable is at high temperature.

Dimensions in millimetres



Key

1	reference cable	3	current inducing transformer
2	current connection	4	current measuring transformer

Figure A.5 – Reference cable for heating of single-core armoured cables

A.3.2.3 Three-core cable

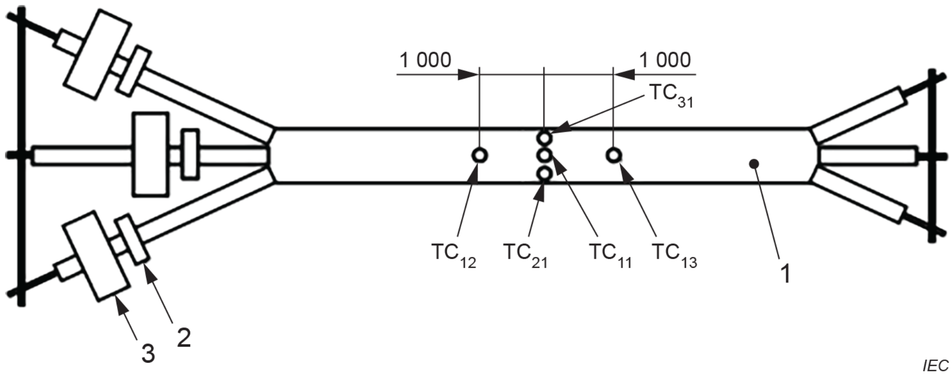
The installation of temperature sensors on a three-core cable shall be carried out as described in A.3.2.2 above, but with the following differences (see Figure A.6):

– three temperature sensors shall be installed in one of the conductors of the reference cable, one at the centre (TC_{11}) and two, each 1 m away from the centre, on each side (TC_{12} and TC_{13}). In addition, one temperature sensor shall be installed in the conductor of each of the other two cores at the centre of the length (TC_{21} and TC_{31}).

– In the case of a three-core cable it is necessary to determine the radial position of the cores at the positions at which temperature sensors are to be installed, before the installation can be carried out. The following method is recommended:

- Adjust the current in the conductors of the reference cable for an estimated conductor temperature of approximately 60 °C.
- Use thermal imaging equipment to locate the hottest circumferential positions on the outer serving of the cable at the centre of the length and at 1 m on either side of the centre.
- Install temperature sensors in the conductors at positions as specified above in A.3.2.3.
- Increase the current in the conductors of the reference cable to determine the current necessary to achieve a temperature for the cable equal to 5 K above the maximum temperature in normal operation. Either manual or automatic control of the conductor current can be used to control the temperature within the specified range for the required time. The system used can be set up and adjusted at this time.

Dimensions in millimetres



Key

1 reference cable

2 current measuring transformer

3 current inducing transformer

Figure A.6 – Reference cable for heating of three-core armoured cables

A.4 Heating for the test

The installation of the cable under test, the reference cable and temperature sensors shall be performed as given in Figure A.1 to Figure A.6.

The test shall be carried out in a draught-free area at ambient temperature.

The temperature measured with temperature sensor TC_{11} on the conductor(s) of a single-core reference cable or TC_{11}, TC_{21} and TC_{31} of a three-core reference cable shall be considered to be the same as the conductor temperature of the energized test cable. In the case of a three-core cable the average of the three values of conductor temperature measured at the centre of the reference cable shall be taken as the temperature of the conductors of the cable under test.

All temperature sensors shall be connected to an instrument to record the temperatures. The heating current in each conductor of both the reference and test cables shall also be recorded throughout the duration of the test.

Before commencing the test, both reference and test cables shall be at ambient temperature.

The average current of the three phases of the cable under test shall be the same as the average current of the three phases of the reference cable with a tolerance of ±2 %.

Both the reference and test cables shall be heated until the conductor temperatures, indicated by temperature sensor TC_{11} of Figure A.5 or temperature sensors TC_{11}, TC_{21} and TC_{31} of Figure A.6, have stabilized and reached the temperature between 5 K and 10 K above the maximum conductor temperature of the cable in normal operation (taking the average of the three temperatures in the case of a three-core cable), as given in Table 2.

The heating current(s) of both loops should be adjusted such that the conductor temperature (taking the average of the three temperatures in the case of a three-core cable) is kept within the specified limits for the time necessary for the test being carried out.

Annex B
(normative)

Rounding of numbers

When values are to be rounded to a specified number of decimal places, for example in calculating an average value from several measurements or in deriving a minimum value by applying a percentage tolerance to a given nominal value, the procedure shall be as follows.

If the figure in the last place to be retained is followed, before rounding, by 0, 1, 2, 3 or 4, it shall remain unchanged (rounding down).

If the figure in the last place to be retained is followed, before rounding, by 9, 8, 7, 6 or 5, it shall be increased by one (rounding up).

EXAMPLE

2,449	≈	2,45	rounded to two decimal places
2,449	≈	2,4	rounded to one decimal place
2,453	≈	2,45	rounded to two decimal places
2,453	≈	2,5	rounded to one decimal place
25,047 8	≈	25,048	rounded to three decimal places
25,047 8	≈	25,05	rounded to two decimal places
25,047 8	≈	25,0	rounded to one decimal place

Annex C
(normative)

Method of measuring resistivity of semi-conducting screens

Each test piece shall be prepared from a 150 mm sample of completed cable.

The conductor screen test piece shall be prepared by cutting a sample of core in half longitudinally and removing the conductor and separator, if any (see Figure C.1a)). The insulation screen test piece shall be prepared by removing all the coverings from a sample of core (see Figure C.1b)).

The procedure for determining the volume resistivity of the screens shall be as follows.

Four silver-painted electrodes A, B, C and D (see Figures C.1a) and C.1b)) shall be applied to the semi-conducting surfaces. The two potential electrodes, B and C, shall be 50 mm apart and the two current electrodes, A and D, shall be each placed at least 25 mm beyond the potential electrodes.

Connections shall be made to the electrodes by means of suitable clips. In making connections to the conductor screen electrodes, it shall be ensured that the clips are insulated from the insulation screen on the outer surface of the test sample.

The assembly shall be placed in an oven preheated to the specified temperature and, after an interval of at least 30 min, the resistance between the electrodes shall be measured by means of a circuit, the power of which shall not exceed 100 mW.

After the electrical measurements, the diameters over the conductor screen and insulation and the thickness of the conductor screen and insulation screen shall be measured at ambient temperature, each being the average of six measurements made on the sample shown in Figure C.1b).

The volume resistivity ρ in ohm metres shall be calculated as follows:

a) conductor screen:

$$\rho_c = \frac{R_c \times \pi \times (D_c - T_c) \times T_c}{2\,L_c}$$

where

ρ_c is the volume resistivity, in ohm metres ($\Omega \cdot m$);

R_c is the measured resistance, in ohms (Ω);

L_c is the distance between potential electrodes, in metres (m);

D_c is the diameter over the conductor screen, in metres (m);

T_c is the average thickness of the conductor screen, in metres (m).

b) Insulation screen:

$$\rho_i = \frac{R_i \times \pi \times (D_i - T_i) \times T_i}{L_i}$$

where

ρ_i is the volume resistivity, in ohm metres ($\Omega \cdot$ m);

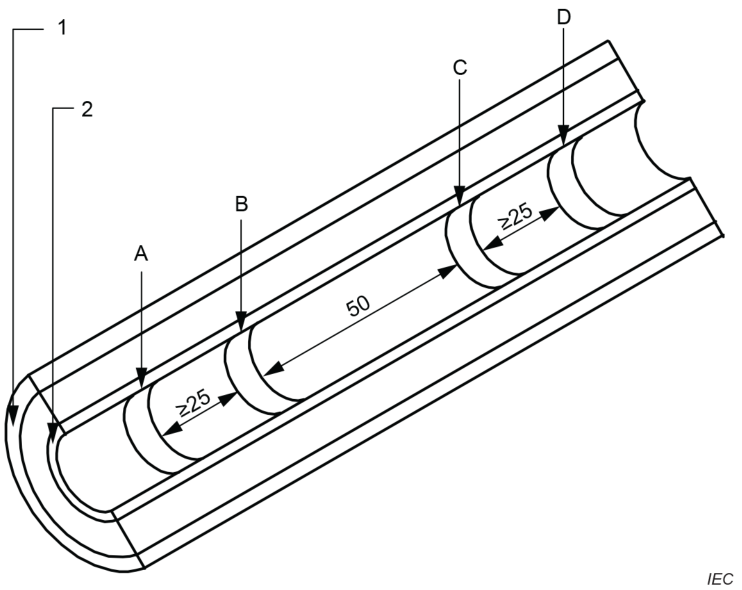
R_i is the measured resistance, in ohms (Ω);

L_i is the distance between potential electrodes, in metres (m);

D_i is the diameter over the insulation screen, in metres (m);

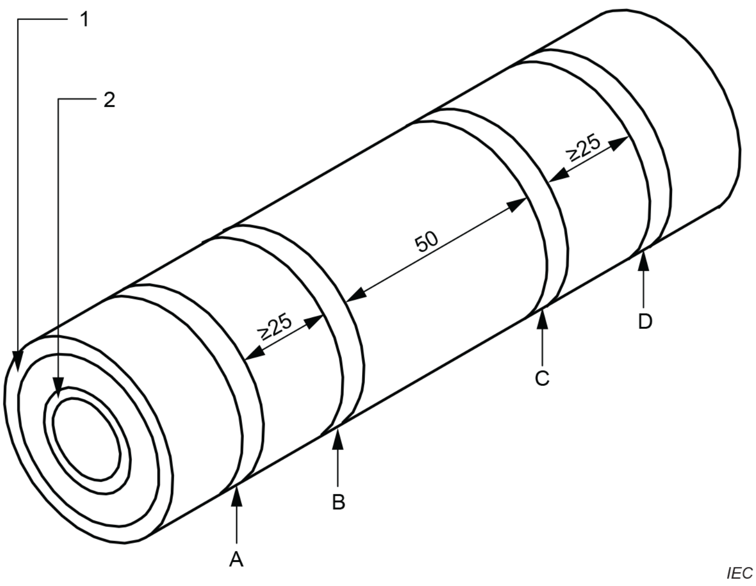
T_i is the average thickness of the insulation screen, in metres (m).

Dimensions in millimetres



a) Measurement of the volume resistivity of the conductor screen

Dimensions in millimetres



Key

1	insulation screen	B, C	potential electrodes
2	conductor screen	A, D	current electrodes

b) Measurement of the volume resistivity of the insulation screen

Figure C.1 – Preparation of samples for measurement of resistivity of conductor and insulation screens

Annex D
(normative)

Tests on components of cables with a longitudinally applied metal tape or foil, bonded to the oversheath

D.1 Visual inspection

The cable shall be dissected and visually examined. Examination of the samples with normal or corrected vision without magnification shall reveal no delamination, folding, cracking or tearing of the metal foil, or buckling or crossing of the screen wires.

D.2 Adhesion and peel strength of metal foil

D.2.1 General

Adhesion and peel strength are defined as F/w

where

F is the force (N);

w is the width of tape (mm).

In the case of a CD design (combined design – CD metal screen that combines radial watertightness and electrical properties), the concern is that delamination could damage the metal component and alter the electric functionality of the screen. Therefore, higher values of adhesion strength and peel strength of the laminated covering are required than for the SD design.

In the case of an SD design (separate design – SD design with radial watertightness and electrical properties, managed by different metal components), there is no concern that delamination will alter the electric functionality of the screen. The cable can be operated with short-circuit capability provided by the presence of the screen wires. However, the adhesion strength and peel strength shall be high enough to preserve the laminate from folding and buckling.

NOTE Examples of the different designs as described above can be found at IEC TR 61901:2016, Annex A.

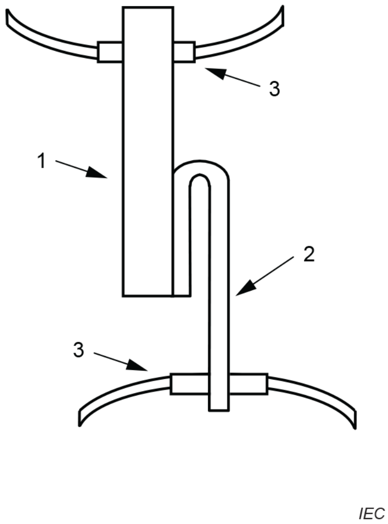
D.2.2 Adhesion strength test

The test specimens shall be taken from the cable covering where the metal foil adheres to the oversheath.

There shall be a total of five test specimens, three of them on the overlap or the weld of the metal screen and two of them on the opposite side.

The length and width of the test specimen shall be approximately 200 mm and 10 mm respectively.

One end of the test specimen shall be peeled between 50 mm and 120 mm and inserted in a tensile testing machine by clamping the free end of the oversheath in one grip. The free end of the metal foil shall be turned back and clamped in the other grip as shown in Figure D.1.



Key

1 oversheath

2 metal foil

3 grip

Figure D.1 – Adhesion of metal foil

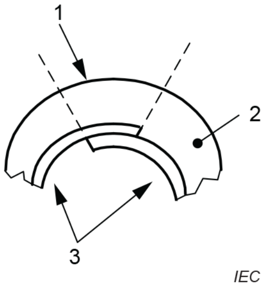
The specimen should be held approximately vertically in the plane of the grips during the test.

After adjusting the continuous recording device, the metal foil shall be stripped from the specimen at an angle of approximately 180° and the separation continued for a sufficient distance to indicate the adhesion strength value. At least one half of the remaining bonded area shall be peeled at a speed of approximately 50 mm/min.

When the adhesion strength is greater than the tensile strength of the metal foil so that the latter breaks before peeling, the test shall be terminated and the break point shall be recorded.

D.2.3 Peel strength test of overlapped metal foil

A sample specimen 200 mm in length shall be taken from the cable including the overlapped portion of the metal foil. The test specimen shall be prepared by cutting only the overlapped portion from this sample as shown in Figure D.2.



Key

1 specimen

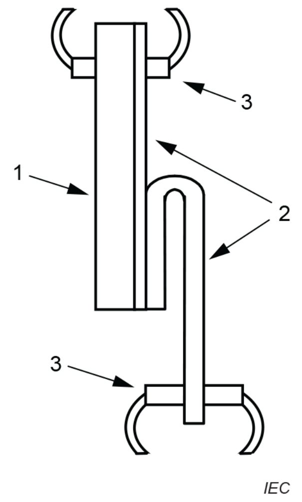
2 oversheath

3 metal foil or laminated metal foil

Figure D.2 – Example of overlapped metal foil

The test shall be conducted in the same manner as described for the adhesion strength test. The arrangement of the test specimen is shown in Figure D.3.

The test shall be performed on a total of 3 specimens.



Key

1 oversheath

2 metal foil or laminated metal foil

3 grip

Figure D.3 – Peel strength of overlapped metal foil

The strength shall be recorded against the spacing of the grips. Typical recordings are shown in Figure D.4 and Figure D.5.

The first part of the curve is linked to the sample preparation. The decreasing end part corresponds to the end of the sample. In between, a relatively steady state is achieved. The minimum strength F_{min} per mm of sample width shall not be less than the one specified in Table D.1.

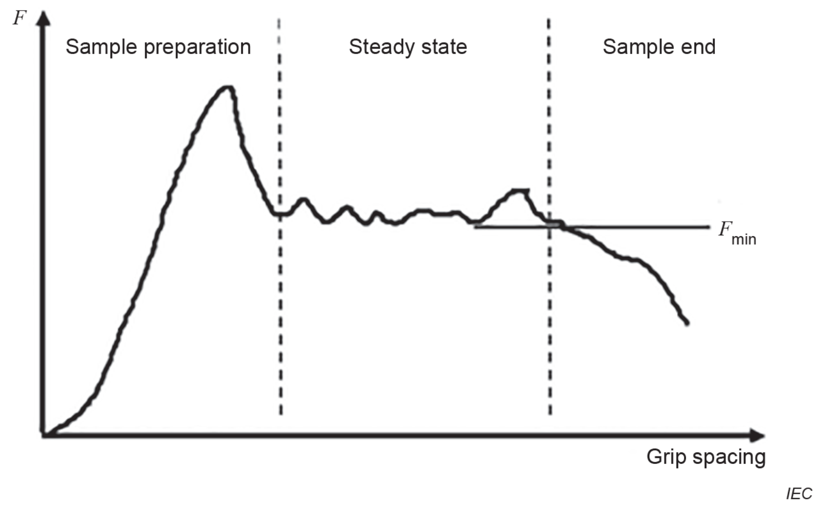


Figure D.4 – Example 1 of strength versus grip spacing curve

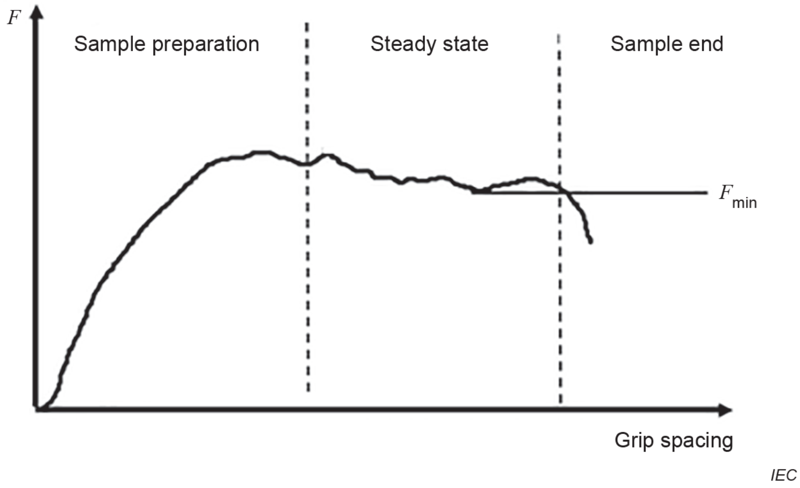


Figure D.5 – Example 2 of strength versus grip spacing curve

D.2.4 Requirements for adhesion and peel strength

Table D.1 lists the minimum adhesion and peel strength requirements as a function of the type of screen, i.e. CD or SD.

Table D.1 – Minimum acceptable adhesion or peel strength forces

Adhesion or peel strength F_{min}/mm	**Type of screen**			
	CD		**SD**	
N/mm	Copper	1,5	Copper	1,0
N/mm	Aluminium	1,5	Aluminium	1,0
N/mm	Overlap	1,5	Overlap	1,0

Annex E
(normative)

Determination of hardness of HEPR insulations

E.1 Test piece

The test piece shall be a sample of completed cable with all the coverings, external to the HEPR insulation to be measured, carefully removed. Alternatively, a sample of insulated core may be used.

E.2 Test procedure

E.2.1 General

Tests shall be made in accordance with ISO 48-2 with exceptions as indicated below.

E.2.2 Surfaces of large radius of curvature

The test instrument, in accordance with ISO 48-2, shall be constructed so as to rest firmly on the HEPR insulation and permit the presser foot and indenter to make vertical contact with this surface. This is done in one of the following ways:

a) the instrument is fitted with feet moveable in universal joints so that they adjust themselves to the curved surface;

b) the base of the instrument is fitted with two parallel rods A and A' at a distance apart depending on the curvature of the surface (see Figure E.1).

These methods may be used on surfaces with a radius of curvature down to 20 mm.

When the thickness of HEPR insulation tested is less than 4 mm, an instrument as described in the method in ISO 48-2 for thin and small test pieces shall be used.

E.2.3 Surfaces of small radius of curvature

On surfaces with too small a radius of curvature for the procedures described in E.2.2, the test piece shall be supported on the same rigid base as the test instrument, in such a way as to minimize bodily movement of the HEPR insulation when the indenting force increment is applied to the indenter and so that the indenter is vertically above the axis of the test piece. Suitable procedures are as follows:

a) by resting the test piece in a groove or trough in a metal jig (see Figure E.2a));

b) by resting the ends of the conductor of the test piece in V-blocks (see Figure E.2b)).

The smallest radius of curvature of the surface to be measured by these methods shall be at least 4 mm.

For smaller radii, an instrument as described in the method in ISO 48-2 for thin and small test pieces shall be used.

E.2.4 Conditioning and test temperature

The minimum time between manufacture i.e. vulcanization and testing, shall be 16 h.

The test shall be carried out at a temperature of (20 ± 2) °C and the test pieces shall be maintained at this temperature for at least 3 h immediately before testing.

E.2.5 Number of measurements

One measurement shall be made at each of three or five different points distributed around the test piece. The median of the results shall be taken as the hardness of the test piece, reported to the nearest whole number in international rubber hardness degrees (IRHD).

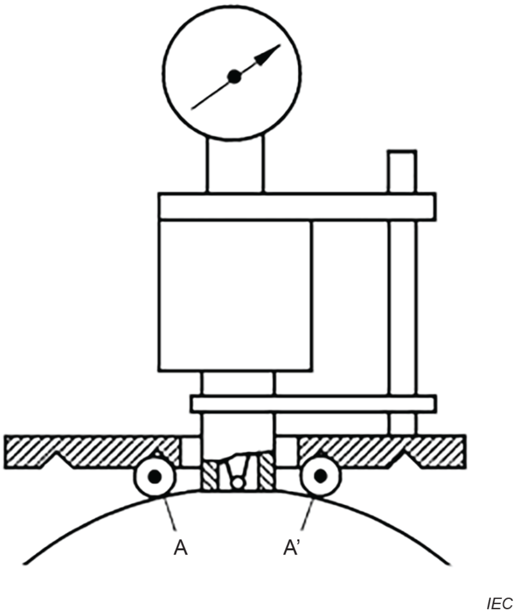
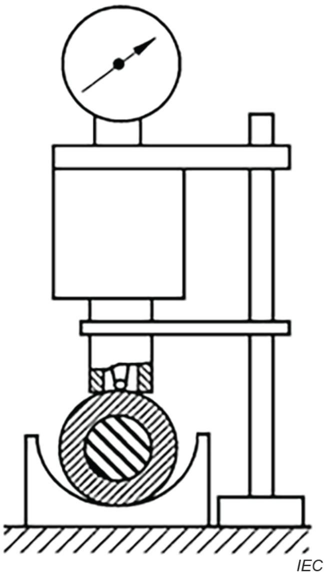
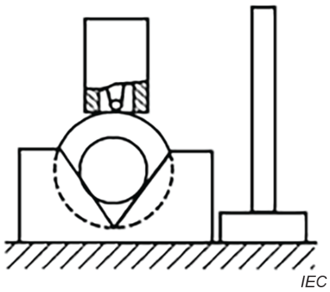


Figure E.1 – Test on surfaces of large radius of curvature



a) Test piece in groove



b) Test piece in V-blocks

Figure E.2 – Test on surfaces of small radius of curvature

Annex F
(informative)

Tests on factory joints

There are at least three available methods today for checking the quality of the factory joint insulation system:

– AC voltage test,
– PD measurement,
– X-ray inspection.

Each joint, manufactured in the factory, may be PD-tested according to IEC 60270. The PD-test may be performed before the restoration of the outer semi-conducting screen.

If it is impossible to perform a PD-measurement according to IEC 60270, for example due to noisy environment, practical reasons, then alternative PD-measurement techniques (acoustic, etc.) or quality procedures may be agreed between manufacturer and customer.

X-ray inspection gives information regarding the quality of interfaces and possible metal inclusions.

All joints in the complete delivery length will be AC voltage tested in the high voltage test described in 9.2.2. However, an AC voltage test directly after jointing will reduce the time delay in case the joint fails at a later stage in the production process.

If conductors are jointed by welding it is recommended that they are checked by an X-ray inspection.

Even if each factory joint is routine tested, the joint should be installed by experienced personnel. The supplier is recommended to show qualification records of jointers. Dimension control, check of temperatures and pressures during joint manufacturing, etc. shall be recorded and carried out according to instructions.

Annex G
(normative)

Tensile bending and tensile tests load calculation

The tensile load used in the tensile bending and the tensile tests (see 12.4.2 and 12.4.3) shall be chosen on the basis that the test tension is larger than the tensile force that will be experienced during all steps of the installation (and repair if applicable). The equation below covers the tensile force experienced during cable laying or repair where the cable is suspended from a vessel. If applicable, the tensile force required during pull-in operations in J-tubes or pipes at landing, should also be analysed.

Potential increases in maximum installation tensions during deployment of rigid joints or other accessories should be considered when establishing the maximum expected installation tension. The increase in tension due to friction when performing recovery over a fixed chute or similar should also be considered.

The test tension, T, shall be calculated as follows:

$$T = 1{,}3 \times w \times d + H \tag{G.1}$$

where:

w is the submerged weight of 1 m cable (N/m);

d is the maximum laying depth; the value of d shall not be taken as less than 50 (m);

H is the maximum expected bottom tension during installation; the value of H shall not be taken as less than $40 \cdot w$ (N).

The test tension, T, is to be rounded up to the nearest 1 kN. The applied test tension shall be at least equal to the calculated test tension.

Formula (G.1) is applicable if the significant wave height, H_s (see 3.4.11), during installation operations is less than or equal to 2 m. The factor of 1,3 caters for dynamic forces and includes a safety factor for a value of H_s of up to 2 m.

NOTE CIGRE TB 623 gives guidance for the evaluation of tensions occurring under adverse weather conditions, when H_s can be greater than 2 m.

Annex H
(informative)

DC voltage test of the insulation

A DC voltage test may endanger the insulation system under test. Where possible an AC test as described in 13.3 should be used.

The test procedure which has been used for cables up to U_m = 36 kV, was as follows:

– a DC test voltage equal to 4 U_0 was applied for 15 min.

For installations which had been in use, lower voltages and/or shorter durations could have been used. Test values could be reduced, taking into account the age, environment, operational history and the purpose of carrying out the test.

Bibliography

IEC 60038, *IEC standard voltages*

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

IEC 60060-3*, High-voltage test techniques – Part 3: Definitions and requirements for on-site testing*

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

IEC 60270, *High-voltage test techniques – Partial discharge measurements*

IEC 60287 (all parts), *Electric cables – Calculation of the current rating*

IEC 60287-3-1, *Electric cables – Calculation of the current rating – Part 3-1: Operating conditions – Site reference conditions*

IEC 60811-100, *Test methods for non-metallic materials – Part 100: General*

IEC 60853 (all parts), *Calculation of the cyclic and emergency current rating of cables*

IEC 60949, *Calculation of thermally permissible short-circuit currents, taking into account non-adiabatic heating effects*

IEC 60986, *Short-circuit temperature limits of electric cables with rated voltages from 6 kV (U_m = 7,2 kV) up to 30 kV (U_m = 36 kV)*

IEC 61443, *Short-circuit temperature limits of electric cables with rated voltages above 30 kV (U_m = 36 kV)*

IEC TR 61901:2016*, Tests recommended on cables with a longitudinally applied metal foil for rated voltages above 30 kV (U_m = 36 kV) up to and including 500 kV (U_m = 550 kV)*

Electra No. 128, *Guide to the protection of specially bonded cable systems against sheath overvoltages*, January 1990, pp 46-62

Electra No. 157, CIGRE Technical Brochure, *Accessories for HV extruded cables*, December 1994, pp 84-89

Electra No. 173, *After laying tests on high-voltage extruded insulation cable systems*, August 1997, pp 32-41

Electra No. 171, *Recommendations for mechanical tests on Submarine cables,* April 1997, pp 5`-66

CIGRE TB 490, *Recommendations for testing of long AC submarine cables with extruded insulation for system voltage above 30 (36) to 500 (550) kV, February 2012*

CIGRE TB 610, *Offshore generation cable connections, February 2015*

CIGRE TB 623, *Recommendations for mechanical testing of submarine cables, June 2015*

CIGRE TB 722, *Recommendations for additional testing for submarine cables from 6 kV (U_m = 7,2 kV) up to 60 kV (U_m = 72,5 kV)*

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