IEC 62067

Edition 3.0 2022-04
REDLINE VERSION

INTERNATIONAL STANDARD

colour inside

Power cables with extruded insulation and their accessories for rated voltages above 150 kV (U_m = 170 kV) up to 500 kV (U_m = 550 kV) – Test methods and requirements

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POWER CABLES WITH EXTRUDED INSULATION AND THEIR ACCESSORIES FOR RATED VOLTAGES ABOVE 150 kV (U_m = 170 kV) UP TO 500 kV (U_m = 550 kV) – TEST METHODS AND REQUIREMENTS

FOREWORD

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This redline version of the official IEC Standard allows the user to identify the changes made to the previous edition IEC 62067:2011. A vertical bar appears in the margin wherever a change has been made. Additions are in green text, deletions are in strikethrough red text.

IEC 62067 has been prepared by IEC technical committee 20: Electric cables. It is an International Standard.

This third edition cancels and replaces the second edition published in 2011. This edition constitutes a technical revision.

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

a) A new material class (ST_{12}) is introduced which has fire performance requirements.

b) A full range of fire performance tests is available which can be selected on the basis of claimed cable performance characteristics.

c) The range of cable metal screen designs and the bending test has been revised in line with IEC TR 61901 [1][1].

d) Requirements are introduced for outdoor termination insulators.

e) Design and testing requirements for gas immersed terminations (and their separating insulating barriers) are coordinated with IEC 62271-209. An additional type test is required where the separating insulating barrier is installed by the switchgear manufacturer.

f) A separate water penetration test for the cable conductor is required.

g) AC voltage testing of the insulation after installation has been revised in line with recently published CIGRE recommendations.

h) Tests have been added for a change in the type of insulating gas used in the cable connection enclosure of a gas immersed termination.

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

Draft	Report on voting
20/2017/FDIS	20/2020/RVD

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

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/standardsdev/publications.

[1] Numbers in square brackets refer to the bibliography.

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

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

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

As a result of major developments in cable systems with extruded insulation for voltages above 150 kV, CIGRE Study Committee (SC) 21 set up Working Group (WG) 21.03 in 1990. The terms of reference of WG 21.03 were "*to prepare recommendations for electrical type tests, sample and routine tests, based on extending IEC 60840:1988 up to 400 kV and to make proposals for prequalification/development tests which, as a minimum, should be performed*".

WG 21.03 reported that the extension of IEC 60840 [2] to voltages above 150 kV needed extra consideration because of the following factors:

1) such cables form part of the backbone of the transmission system and, therefore, reliability considerations are of the highest priority;
2) these cables and their accessories operate with higher electrical stresses than cables up to 150 kV and, as a result, have a smaller safety margin with respect to the intrinsic performance boundaries of the cable system;
3) such cables and accessories have a thicker insulation wall than those up to 150 kV and, as a result, are subjected to greater thermo-mechanical effects;
4) the design and coordination of the cables and accessories become more difficult with increasing system voltage levels.

The recommendations of the WG 21.03 were published in Electra No. 151 [3] [4] in December 1993 and taken into account by IEC in 1995 in the preparation of this standard for cable systems with extruded insulation for voltages above 150 kV. IEC considered that the new standard should also cover the 500 kV level. Thus, at its meeting in September 1996, CIGRE SC 21 set up a task force 21.18 to study the extension of the initial recommendations to the 500 kV level. The resulting updated recommendations were ~~cited in Electra No. 193 in December 2000 and thus were also~~ taken into account by IEC Technical Committee (TC) 20 in the preparation of the first edition of this standard.

On the advice of CIGRE, a long term accelerated ageing test was introduced in the first edition, in order to gain some indication of the long term reliability of a cable system. This test, known as the "prequalification test", was to be performed on the complete system comprising the cable, joints and terminations in order to demonstrate the performance of the system.

In addition, CIGRE WG 21.09, published recommendations for "tests after installation on high-voltage extruded insulation cable systems" in Electra No. 173 [5] in August 1997. These recommendations (which state, amongst other things, that DC tests should be avoided on the main insulation, as they are both ineffective and potentially damaging) were also taken into account in the first edition of this standard.

At its meeting in November 2004, TC 20 concluded that the next revision of IEC 62067 should include the recommendation for testing of HV and EHV extruded cables that was under preparation by the CIGRE SC B1 (previously SC 21) WG B1.06. This was made available as a CIGRE Technical Brochure 303 [6] before the meeting of TC 20 in October 2006, which confirmed this view. Therefore, Technical Brochure 303 has been considered by TC 20 and major parts have been implemented in this standard. This has resulted in some modifications to the prequalification test requirements, a major change being the addition of the extension of the prequalification test. The latter test requires approximately one quarter of the time to complete when compared with the full prequalification test.

This third edition of IEC 62067 has been produced as part of the normal periodic review and updating procedures of IEC taking into account progress and developments within the energy industry.

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

POWER CABLES WITH EXTRUDED INSULATION AND THEIR ACCESSORIES FOR RATED VOLTAGES ABOVE 150 kV (U_m = 170 kV) UP TO 500 kV (U_m = 550 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 installations, for rated voltages above 150 kV (U_m = 170 kV) up to and including 500 kV (U_m = 550 kV).

The requirements apply to single-core cables and to their accessories for usual conditions of installation and operation, but not to special cables and their accessories, such as submarine cables, for which modifications to the standard tests ~~may~~ can be necessary or special test conditions that may need to be devised.

This document does not cover transition joints between cables with extruded insulation and paper insulated cables.

2 Normative references

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

~~NOTE The IEC 60811 series is currently undergoing a revision, which will lead to a restructuring of its parts. A description of this, as well as a cross-reference table between the current and planned parts will be given in IEC 60811-100.~~

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 60137, *Insulated bushings for alternating voltages above 1000 V*

~~IEC 60183, *Guide to the selection of high-voltage cables*~~

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 60332-1-2, *Tests on electric and optical fibre cables under fire conditions – Part 1-2: Test for vertical flame propagation for a single insulated wire or cable – Procedure for 1 kW pre-mixed flame*

IEC 60332-1-3, *Tests on electric and optical fibre cables under fire conditions – Part 1-3: Test for vertical flame propagation for a single insulated wire or cable – Procedure for determination of flaming droplets/particles*

IEC 60332-3-24, *Tests on electric and optical fibre cables under fire conditions – Part 3-24: Test for vertical flame spread of vertically-mounted bunched wires or cables – Category C*

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

IEC 60754-3, *Test on gases evolved during combustion of materials from cables – Part 3: Measurement of low level of halogen content by ion chromatography*

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

~~IEC 60811-1-2:1985, *Common test methods for insulating and sheathing materials of electric cables – Part 1: Methods for general application – Section Two: Thermal ageing methods*~~
~~Amendment 1 (1989)~~
~~Amendment 2 (2000)~~

~~IEC 60811-1-3:1993, *Common test methods for insulating and sheathing materials of electric cables – Part 1-3: General application – Methods for determining the density – Water absorption tests – Shrinkage test*~~
~~Amendment 1 (2001)~~

~~IEC 60811-1-4:1985, *Common test methods for insulating and sheathing materials of electric cables – Part 1: Methods for general application – Section Four: Tests at low temperature*~~
~~Amendment 1 (1993)~~
~~Amendment 2 (2001)~~

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

~~IEC 60811-3-1:1985, *Common test methods for insulating and sheathing materials of electric cables – Part 3: Methods specific to PVC compounds – Section 1: Pressure test at high temperature – Tests for resistance to cracking*~~
~~Amendment 1 (1994)~~
~~Amendment 2 (2001)~~

~~IEC 60811-3-2:1985, *Common test methods for insulating and sheathing materials of electric cables – Part 3: Methods specific to PVC compounds – Section two: Loss of mass test – Thermal stability test*~~
~~Amendment 1 (1993)~~
~~Amendment 2 (2003)~~

~~IEC 60811-4-1:2004, *Insulating and sheathing materials of electric and optical cables – Common test methods – Part 4-1: Methods specific to polyethylene and polypropylene compounds – Resistance to environmental stress cracking – Measurement of the melt flow index – Carbon black and/or mineral filler content measurement in polyethylene by direct combustion – Measurement of carbon black content by thermogravimetric analysis (TGA) – Assessment of carbon black dispersion in polyethylene using a microscope*~~

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

IEC 60811-202:2012, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 202: General tests – Measurement of thickness of non-metallic sheath*
IEC 60811-202:2012/AMD1:2017

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

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

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

IEC 60811-409, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 409: Miscellaneous tests – Loss of mass test for thermoplastic insulations and sheaths*

IEC 60811-501:2012, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 501: Mechanical tests – Tests for determining the mechanical properties of insulation and sheathing compounds*
IEC 60811-501:2012/AMD1:2018

IEC 60811-505, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 505: Mechanical tests – Elongation at low temperature for insulations and sheaths*

IEC 60811-506, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 506: Mechanical tests – Impact test at low temperature for insulations and sheaths*

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

IEC 60811-508:2012, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 508: Mechanical tests – Pressure test at high temperature for insulations and sheaths*
IEC 60811-508:2012/AMD1:2017

IEC 60811-509, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 509: Mechanical tests – Tests for resistance of insulations and sheaths to cracking (heat shock test)*

IEC 60811-605:2012, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 605: Physical tests – Measurement of carbon black and/or mineral filler in polyethylene compounds*

IEC 60811-606, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 606: Physical tests – Methods for determining the density*

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

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

IEC 61462, *Composite hollow insulators – Pressurized and unpressurized insulators for use in electrical equipment with rated voltage greater than 1 000 V – Definitions, test methods, acceptance criteria and design recommendations*

IEC 62155, *Hollow pressurized and unpressurized ceramic and glass insulators for use in electrical equipment with rated voltages greater than 1 000 V*

IEC 62271-209, *High-voltage switchgear and controlgear – Part 209: Cable connections for gas-insulated metal-enclosed switchgear for rated voltages above 52 kV – Fluid-filled and extruded insulation cables – Fluid-filled and dry-type cable-terminations*

3 Terms and definitions

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

IEC and ISO 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 relating to 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 this document, 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.~~

Type tests are of such a nature that, after they have been made, they need not be repeated unless changes are made in the materials, design or type of manufacturing process of cable or accessory which might change the performance characteristics.

3.2.4
prequalification test
PQ test
test made before supplying, on a general commercial basis, a type of cable system covered by this document, in order to demonstrate satisfactory long term performance of the complete cable system

3.2.5
extension of prequalification test
EQ test
test made before supplying, on a general commercial basis, a type of cable system covered by this document, in order to demonstrate satisfactory long term performance of the complete cable system, taking into account an already prequalified cable system

3.2.6
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 purchaser request. Tests to be defined on agreement between purchaser 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

Note 1 to entry: The equations for calculation of the stresses are given in Clause 6, item n).

Note 2 to entry: Electrical stress is expressed in kV/mm.

3.3.3
combined design
CD
metal screen design that combines radial watertightness and electrical properties

Note 1 to entry: Details of the construction are given in 4.3.

3.3.4
separate design
SD
metal screen design that uses different metal components for radial watertightness and electrical properties

Note 1 to entry: Details of the construction are given in 4.3.

3.3.5
separate semi-conductive design
SscD
metal screen design that has separated electrical and radial watertightness properties and uses semi-conductive plastic-coated foil

Note 1 to entry: Details of the construction are given in 4.3.

3.3.6
nominal conductor cross-sectional area
size of the cable conductor in accordance with IEC 60228

3.3.7
maximum mechanical load
MML
highest mechanical cantilever load which is expected to be applied to a composite outdoor termination insulator in service and for which it is designed

3.3.8
maximum service pressure
MSP
highest difference between the maximum absolute internal pressure, when the equipment (of which a composite hollow insulator is a part) is carrying its rated normal current at maximum operational temperature and the normal outside pressure

3.3.9
cable accessory with screen or metal sheath interruption
cable accessory where the metal screen/sheath and insulation screen of the cable are electrically interrupted

3.3.10
joint with screen or metal sheath interruption
joint where the metal screen/sheath and insulation screen of the cable are electrically interrupted

3.3.11
termination with an insulated screen
termination where the metal screen/sheath and insulation screen of the cable are electrically interrupted to the ground

4 Voltage designations, materials and rounding of numbers

4.1 Rated voltages

In this document, the symbols U_0, U and U_m are used to designate the rated voltages of cables and accessories where these symbols have the meanings given in IEC 60183 [7].

4.2 Cable insulating ~~materials~~ compounds

This document applies to cables insulated with one of the ~~materials~~ compounds listed in Table 1, which also specifies, for ~~cables with~~ each type of insulating compound, the maximum operating conductor temperatures on which the specified test conditions are based.

It is recommended that cable cores with a cross-linked insulation system should have been degassed.

4.3 Cable metal screens/sheaths

This document applies to the various designs in use. It covers designs providing a radial watertightness and ~~other~~ designs that do not provide radial watertightness.

In all cases the metal screen/sheath shall be able to meet the screen short circuit rating.

Designs that provide radial watertightness mainly consist of:

– seamless or longitudinally welded metal sheaths;

– longitudinally applied metal tapes or foils bonded to the oversheath:

  - CD: a metal screen design using a metal tape or foil, with either a welded or glued overlap, that carries part or all of the screen short circuit current with, if necessary, metal wires to carry part of the short circuit current;
  - SD: a metal screen design using a laminated metal foil (coated on one or both sides) for radial watertightness, and metal wires for carrying the full screen short circuit current;
  - SscD: a metal screen design using a thin lead or aluminium foil coated with glue on the outer side and semi-conductive plastic on the underside, over a layer of semi-conductive tape, which is in turn over a layer of round copper wires.

  NOTE Definitions of CD, SD, and SscD are given in 3.3.3, 3.3.4 and 3.3.5

– composite screens, involving a ~~bunch~~ layer of wires and~~, in addition,~~ either a metal sheath or a metal tape or foil bonded to the oversheath, acting as a radial water impermeable barrier (see Clause 5),

  During development of the cable and cable system, with a longitudinally applied metal tape or foil bonded to the oversheath, the tests as specified in IEC TR 61901 [1] are recommended.

~~and other designs such as~~ Designs which do not provide radial watertightness include:

– metal tapes or foils not bonded to the oversheath,
– ~~bunch~~ a layer of metal wires only.

~~NOTE In all cases the metal screen/sheath should be able to carry the total fault current.~~

4.4 Cable oversheathing ~~materials~~ compounds

Tests are specified for ~~four~~ five types of oversheath, as follows:

– ST_1 and ST_2 based on polyvinyl chloride (PVC);
– ST_3 and ST_7 based on polyethylene (PE);
– ST_{12} based on low smoke halogen free material (LSHF).

The choice of the type of oversheath depends on the design of the cable and the mechanical ~~and~~, thermal and fire ~~constraints~~ performance required during installation and operation.

The maximum conductor temperatures in normal operation for the different types of oversheathing ~~materials~~ compounds covered by this document are given in Table 2.

If there is concern that the oversheath will be deteriorated by UV radiation, the oversheath shall be protected against UV radiation, which will be mutually agreed with the purchaser. Black PE oversheaths containing the required amount of a suitable and well-dispersed grade of carbon black (see Table 5) are protected against UV radiation.

NOTE 1 For installation in air as for example in tunnels or buildings, it is preferable for the cable to have some fire performance and low smoke and halogen free properties. For such applications, an ST_{12} (LSHF) oversheath can be applied.

NOTE 2 For some applications, the oversheath ~~may~~ can be covered by a functional layer (e.g. semi-conductive).

4.5 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 Precautions against water penetration in cables

When cable systems are installed in the ground, in ~~easily flooded galleries~~ locations with a risk of water ingress or corrosion or in water, a radial water impermeable barrier ~~around the cable~~ is recommended.

~~NOTE A test for radial water penetration is not currently available.~~

Longitudinal water barriers ~~may~~ can also be applied in order to avoid the need to replace long sections of cable in case of damage in the presence of water.

A test for longitudinal water penetration is given in 12.5.15.

NOTE No test for radial water penetration is currently available.

6 Cable characteristics

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

The following characteristics shall be ~~known or~~ declared by the manufacturer:

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) fire performance: if ST_1, ST_2 or ST_{12} oversheath material is used (see 4.4 and Table 2), then the subclauses of 12.5.14.3, if any, to which compliance is claimed, shall be declared;

NOTE Fire performance is dependent on the cable design as well as the oversheath material.

d) type of conductor, its material and nominal cross-sectional area, in square mm; conductor construction; presence, if any, and nature of measures taken to reduce skin effect; presence, if any, and nature of measures taken to achieve longitudinal watertightness; if the nominal cross-sectional area is not in accordance with IEC 60228, the maximum DC conductor resistance, corrected to 1 km length and to 20 °C ~~shall be declared~~;

e) ~~Material~~ compound (as defined in Table 1) and nominal thickness of insulation (t_n) (see 4.2);

f) type of manufacturing process for insulation system;

g) presence, if any, and nature of watertightness measures in the screening area;

h) metal screen/sheath:

- constructional details of metal screen/sheath, for example, material and construction of metal screen, ~~e.g.~~ number and diameter of wires~~. (The d.c. resistance of the metal screen shall be declared.)~~; material, construction and nominal thickness of metal sheath, or longitudinally applied metal tape or foil bonded to the oversheath, if any. For cables with longitudinal applied metal tape or foil bonded to the oversheath whether the type is CD or SD or SscD;
- maximum DC resistance of the metal screen/sheath, corrected to 1 km length and to 20 °C;

i) ~~Material~~ compound (as defined in 4.4 and Table 2) and nominal thickness of oversheath, and if applicable, nature and material of semi-conductive covering;

j) nominal diameter of the conductor (d);

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

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

m) nominal capacitance, corrected to 1 km length, between conductor and metal screen/sheath;

n) calculated nominal electrical stress 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

U_0 is the value declared in item b) above in kV;

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;

~~The value of U_0 is given in Table 4;~~

o) the design of any integrated optical element(s), if applicable.

7 Accessories characteristics

7.1 Gas immersed cable terminations

Gas immersed cable terminations shall be designed in accordance with IEC 62271-209.

7.2 Insulators for outdoor cable terminations

Insulators for outdoor cable terminations shall comply with the requirements given in Table 11 for Level I or II maximum cantilever operating load in service (or MML in the case of composite insulators). Level I refers to a normal load and shall be generally applied, unless a purchaser specifies a heavy load of Level II. Alternatively, a different value of maximum cantilever operating load or MML can be agreed between the purchaser and manufacturer.

7.3 Accessory characteristics to be declared

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 by the manufacturer:

a) cables used for testing accessories shall be correctly identified as in Clause 6;

b) a drawing shall be provided in which all relevant features tested under Annex H are shown, see Clause H.1;

c) ~~conductor~~ current carrying connections used within the accessories shall be correctly identified, ~~where applicable~~ for both the conductor and metal screen/sheath, 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;

d) accessories to be tested shall be correctly identified with respect to

- name of manufacturer,
- type, designation and manufacturing date or date code,
- rated voltage (see Clause 6, item b)),
- material type of rubber mouldings forming the main insulation (e.g. silicone rubber or EPDM),
- material type of dielectric fluid filling, if any,
- type of outer protection,
- whether the design includes sheath sectionalizing insulation,
- installation instructions (reference and date);

e) additional requirements for gas immersed terminations:

- design pressure for the outside of the termination insulator, see IEC 62271-209,
- type of insulating gas to be used in the cable connection enclosure. (SF_6 or details of alternative gas type),
- whether or not the termination insulator is suitable for supply to the switchgear manufacturer, in order to confirm compatibility and performance for the installation in the switchgear before delivery to site, see IEC 62271-209,
- if suitable, the measures which are required to allow the switchgear routine test to be carried out without the cable present;

f) additional requirements for composite outdoor termination insulators:

- the MML value for the composite insulator, see 7.2,
- for insulators which will be pressurized in service, the MSP value;

g) additional requirements for ceramic outdoor termination insulators:

- the maximum cantilever operating load in service,
- for insulators which will be pressurized in service, the design pressure.

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.

~~**8.2 Frequency and waveform of power frequency test voltages**~~

~~Unless otherwise indicated in this standard, the frequency of the alternating test voltages shall be in the range 49 Hz to 61 Hz. The waveform shall be substantially sinusoidal. The values quoted are r.m.s. values.~~

8.2 High voltage tests

Unless otherwise indicated in this document, high voltage tests shall be carried out in accordance with IEC 60060-1. All high voltage tests in this document are withstand voltage tests.

No "atmospheric correction in dry tests" (IEC 60060-1) shall be applied to the test voltage values specified in this document.

8.3 Waveform of impulse test voltages

~~#### 8.3.1 Lightning impulse voltage~~

~~In accordance with IEC 60230, the front time of the standard lightning impulse voltage shall be between 1 μs and 5 μs. The time to half value shall be 50 μs ± 10 μs as specified in IEC 60060-1.~~

~~#### 8.3.2 Switching impulse voltage~~

~~In accordance with IEC 60060-1, the standard switching impulse voltage shall have a time to peak of 250 μs ± 50 μs and a time to half value of 2 500 μs ± 1 500 μs.~~

The waveforms of lightning and switching impulse tests shall be as given in 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 the determination of test voltages ~~may~~ can 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 associated test voltages shall be established by calculation using the multipliers given in Table 4 or interpolation where no multiplier is given.

The test voltages in this document are based on the assumption that the cables and accessories are used on a system of category A, as defined in IEC 60183 [7].

8.5 Determination of the cable conductor temperature

It is recommended that one of the test methods described in Annex A is used to determine the actual conductor temperature.

8.6 Tests on gas immersed terminations

Electrical tests on gas immersed terminations shall be carried out in a cable connection enclosure with the diameter specified in IEC 62271-209 for the relevant value of rated voltage. The gas pressure requirements for electrical type tests given in IEC 62271-209 shall also be complied with.

9 Routine tests on cables and ~~on the main insulation of prefabricated~~ accessories

9.1 General

The following tests shall be carried out on each manufactured length of cable:

a) partial discharge test (see 9.2);

b) voltage test (see 9.3);

c) electrical test on oversheath of the cable, if required (see 9.4).

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

The main insulation of prefabricated accessories shall undergo partial discharge (see 9.2) and voltage (see 9.3) routine tests according to either 1), 2) or 3) below:

1) on the main insulation of prefabricated accessories installed on the cable;
2) by using a host accessory into which a component of an accessory is substituted for the test;
3) by using a simulated accessory rig in which the electrical stress environment of a main insulation component is reproduced.

In cases 2) and 3), the test voltage shall be selected so as to obtain ~~stresses~~ at least the same electrical stresses as those on the component in a complete accessory when subjected to the test voltages specified in 9.2 and 9.3.

The insulator of a gas immersed termination shall also be subjected to the routine tests given in IEC 62271-209.

Outdoor termination insulators, which will be subjected to internal gas pressure in service, shall be subjected to the routine pressure test according to IEC 61462 for composite insulators, or IEC 62155 for ceramic insulators. No failure shall occur.

Routine tests do not apply to accessories taped and/or moulded on-site.

NOTE The main insulation of prefabricated accessories consists of the components that come in direct contact with the cable insulation ~~and~~ or are necessary ~~and essential~~ to control the ~~electrical field~~ electric stress distribution in the accessory. Examples are pre-moulded or precast elastomer or filled epoxy resin insulating components that ~~may~~ can be used singly or jointly to provide the necessary insulation or screening of accessories.

9.2 Partial discharge test

The partial discharge test shall be carried out in accordance with IEC 60885-3 for cables~~, except that~~ and the sensitivity as defined in IEC 60885-3 shall be 10 pC or better. Testing of accessories follows the same principles, but the sensitivity shall be 5 pC or better.

The test voltage shall be raised gradually to and held at 1,75 U_0 for 10 s and then slowly reduced to 1,5 U_0 (see Table 4, column 5).

There shall be no detectable discharge exceeding the declared sensitivity from the test object at 1,5 U_0.

9.3 Voltage test

The voltage test shall be made at ambient temperature using an alternating test voltage at power frequency.

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

No breakdown of the insulation shall occur.

9.4 Electrical test on oversheath of the cable

~~When the test is required by the particular contract~~ Subject to agreement between purchaser and manufacturer, the cable oversheath shall be subjected to the electrical test specified in Clause 3 of IEC 60229:2007.

10 Sample tests on cables

10.1 General

The following tests shall be carried out on samples which, for the tests in items b) and g) below, ~~may~~ shall be complete drum lengths of cable, taken to represent batches:

a) conductor examination (see 10.4);
b) measurement of electrical resistance of conductor and of metal screen/sheath (see 10.5);
c) measurement of thickness of insulation and oversheath (see 10.6);
d) measurement of thickness of metal sheath (see 10.7);
e) measurement of diameters, if required (see 10.8);
f) hot set test for XLPE and EPR insulations (see 10.9);
g) measurement of capacitance (see 10.10);
h) measurement of density of HDPE insulation (see 10.11);
i) lightning impulse voltage test (see 10.12);
j) water penetration test, if applicable (see 10.13);
k) tests on components of cables with longitudinally applied metal tape or foil, bonded to the oversheath (see 10.14).

10.2 Frequency of tests

The sample tests in items a) to h) and k) of 10.1 shall be carried out on one length from each batch (manufacturing series) of the same type and cross-section of cable but shall be limited to not more than 10 % of the number of lengths in any contract, rounded to the nearest whole number.

The frequency of the tests in items i) and j) of 10.1 shall be in accordance with agreed quality control procedures. In the absence of such an agreement, one test shall be made for contracts with a cable length between 4 km and 20 km and two tests for contracts with longer cable lengths.

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/sheath

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/sheath 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~~ can be measured on a sample of conductor or metal screen/sheath, conditioned for at least 1 h in a temperature-controlled liquid bath.

The DC resistance of the conductor or metal screen/sheath shall be corrected to a temperature of 20 °C and a 1 km length in accordance with the formula ~~and factors~~ given in IEC 60228:

– using the temperature coefficients given in IEC 60228 for a conductor or metal screen/sheath of copper or aluminium or

– for a metal screen/sheath other than copper or aluminium, using temperature coefficients ~~and correction formulae shall be taken respectively from Table 1 and 2.1.1 of~~ given in IEC 60287-1-1~~:2006~~.

The corrected DC resistance of the conductor at 20 °C shall not exceed either the appropriate maximum value specified in IEC 60228 or, when a value for maximum DC conductor resistance is declared in Clause 6, item d), then the corrected DC resistance of the conductor at 20 °C shall not exceed the declared value.

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

10.6 Measurement of thickness of insulation and ~~cable~~ oversheath

10.6.1 General

The test method shall be in accordance with ~~Clause 8 of IEC 60811-1-1:1993 and Amendment 1:2001~~ IEC 60811-201 for the insulation. For the oversheath the test method in accordance with IEC 60811-202:2012 and IEC 60811-202:2012/AMD1:2017 shall be applied, except that for sheaths where the underlying surface is not irregular the measurement can be made with a micrometer having a ball nose radius of 2,5 mm to 3 mm. The accuracy of the micrometer shall be ±0,01 mm.

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~~ can have suffered damage.

In 10.6 the following symbols are used:

t_{max} is the maximum measured thickness, in mm;

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

t_n is the nominal thickness, in mm.

10.6.2 Requirements for the insulation

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

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

and additionally:

$$\frac{t_{max} - t_{min}}{t_{max}} \leq 0{,}10$$

~~where~~

~~t_{max} is the maximum thickness, in millimetres;~~

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

~~t_n is the nominal thickness, in millimetres.~~

~~NOTE~~ t_{max} and t_{min} ~~are~~ 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.

10.6.3 Requirements for the cable oversheath

The ~~lowest~~ minimum measured thickness shall not be less than 85 % of the nominal thickness ~~by more than~~ minus 0,1 mm:

$$t_{min} \geq 0{,}85\ t_n - 0{,}1$$

~~where~~

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

~~t_n is the nominal thickness, in millimetres.~~

In addition, for oversheaths applied onto a substantially smooth surface, the average of the measured values rounded to 0,1 mm ~~in accordance with Annex B~~ shall not be less than the nominal thickness.

The latter requirement does not apply to oversheaths applied onto an irregular surface, such as one formed by metal screens of wires and/or tapes or corrugated metal sheath.

10.7 Measurement of thickness of metal sheath

10.7.1 General

The following tests apply if the cable has a metal sheath of lead, lead alloy, copper or aluminium. Foils which are applied for radial watertightness purposes only are excluded from these tests.

In 10.7 the following symbols are used:

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

t_n is the nominal thickness, in mm.

10.7.2 Lead or lead alloy sheath

10.7.2.1 General

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

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

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

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

10.7.2.3 Ring method

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

The measurements shall be made on a ring of the ~~lead~~ 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.

10.7.3 ~~Plain or corrugated~~ Copper or aluminium sheath

The minimum measured thickness of the sheath shall not ~~fall below~~ be less than 90 % of the nominal thickness ~~by more than~~ minus 0,1 mm for ~~plain~~ non-corrugated copper or aluminium sheath:

$$t_{min} \geq 0{,}9\ t_n - 0{,}1$$

and not less than 85 % of the nominal thickness ~~by more than~~ minus 0,1 mm for corrugated copper or aluminium sheath:

$$t_{min} \geq 0{,}85\ t_n - 0{,}1$$

The measurements shall be made with a micrometer having ball noses of radii about 3 mm. The accuracy of the micrometer shall be ±0,01 mm.

The measurements shall be made on a ring of the ~~aluminium~~ sheath, about 50 mm wide, carefully removed from the ~~complete~~ cable. 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.

10.7.4 Metal tape for CD design

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

$$t_{min} \geq 0{,}9\ t_n$$

The measurements shall be made with a micrometer having ball noses of radii about 3 mm. The accuracy of the micrometer shall be ±0,01 mm.

The measurements shall be made on a ring of the tape and oversheath, about 50 mm wide, carefully removed from the cable. The thickness shall be determined at a number of points around the circumference and on the side ends of the ring to ensure that the minimum thickness is measured.

10.8 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 ~~8.3 of IEC 60811-1-1:1993 and Amendment1:2001~~ IEC 60811-203.

10.9 Hot set test for XLPE and EPR insulations

10.9.1 Procedure

The sampling and test procedure shall be carried out in accordance with ~~Clause 9 of IEC 60811-2-1:1998 and Amendment 1:2001~~ 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.

10.9.2 Requirements

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

10.10 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 %.

10.11 Measurement of density of HDPE insulation

10.11.1 Procedure

The density of HDPE shall be measured using the sampling and test procedure given in ~~Clause 8 of IEC 60811-1-3:1993 and Amendment 1:2001~~ IEC 60811-606.

10.11.2 Requirements

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

10.12 Lightning impulse voltage test

The test shall be performed on a ~~complete~~ cable at least 10 m in length excluding test accessories, at a conductor temperature 5 K to 10 K above the maximum conductor temperature in normal operation.

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

~~NOTE~~ If, for practical reasons, the test temperature cannot be reached, additional thermal insulation ~~may~~ can be applied. The conductor temperature shall be maintained within the stated temperature limits for at least 2 h.

The lightning impulse voltage shall be applied, according to the procedure given in IEC 60230, after the completion of the above 2 h heating period and while the conductor temperature is within the limits stated above.

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

No breakdown of the insulation shall occur.

10.13 Water penetration test

If applicable, samples shall be taken from the ~~complete~~ cable, the test shall be applied and the requirements shall be met as described in 12.5.15.

10.14 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 12.5.16.

11 Sample tests on accessories

11.1 Tests on components of accessory

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

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~~ manufacturer to another, it is not possible to define common sample tests on components in this document.

11.2 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 a fully assembled accessory:

a) partial discharge test (see 9.2);

b) voltage test (see 9.3).

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

NOTE Examples of main insulations that are not routine tested are insulations taped and/or moulded on site.

These tests shall be performed on one accessory of each type per contract if the number of that type in the contract is above 50.

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 are intended to demonstrate the satisfactory performance of cable systems.

Once successfully completed, type 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.

~~A table of~~ The clause or subclause references to be considered during a type test on a cable system are given in Annex C.

Type tests on gas immersed cable terminations shall be carried out according to IEC 62271-209 in addition to the tests specified in this document.

Additional electrical type tests are required in IEC 62271-209, for the case where the gas immersed termination insulator is to be supplied to the switchgear manufacturer, to demonstrate that the termination can meet the switchgear routine and on-site tests.

NOTE Tests on terminations ~~referring to~~ under environmental conditions such as precipitation and/or pollution are not specified in this document.

12.2 Range of type approval

When type tests have been successfully performed on one or more 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 following conditions of a) to ~~f~~ h) are met.

~~NOTE 1~~ Type tests which have been successfully performed according to previous editions of this standard are valid if the following conditions are met:

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

   ~~NOTE 2 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 nominal conductor cross-sectional area 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 3~~ 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 not necessary on account of the differences in the conductor or connector type or material or of the protective layers applied over the screened cores or over the main insulation part of the accessory, unless these are likely to have a significant effect on the results of the test. In some instances, it ~~may~~ can be appropriate to repeat one or more of the type tests (e.g. bending test, 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 and the impulse voltage stress, calculated using nominal dimensions, at the cable insulation screen, 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 same type of gas or gas mixture and pressure is used in the cable connection enclosure of a gas immersed termination.

   NOTE Clause H.6 gives requirements for approval of a gas immersed termination with an alternative type of gas.

h) A gas immersed termination has the same separating insulating barrier, stress cone assembly and cable as are used in the type test, taking into account the relevant allowances and requirements of a) to g) above.

The type tests on cable components (see 12.5) need not be carried out on samples from cables of different voltage ratings and/or nominal conductor cross-sectional areas unless 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 12.5.5) ~~may~~ can be ~~required~~ mutually agreed with the purchaser 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.

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 electrical tests on the complete cable system as specified in 12.4 and the appropriate non-electrical tests on cable components and completed cable specified in 12.5.

The non-electrical tests on cable components and ~~complete~~ cable are listed in Table 5 to Table 10, indicating which tests are applicable to each insulation and oversheath ~~material~~ compound. The tests under fire conditions, as listed in Table 10, are only required if the manufacturer wishes to claim compliance with these tests as a special feature of the design of the cable.

The tests listed in 12.4.2 shall be performed on one or more samples of ~~complete~~ cable, depending on the number of accessories involved~~, at least 10 m in length excluding the accessories~~.

~~The minimum length of free cable between accessories shall be 5 m.~~

~~The accessories shall be installed after the bending test on the cable. One sample of each accessory type shall be tested.~~

A sufficient length of cable shall be subjected to the bending test of 12.4.2 a) in order to allow construction of a test assembly for the tests of 12.4.2 c) to g) and the test of 12.4.2 b) where applicable.

The partial discharge test of 12.4.2 a) and the tests in 12.4.2 c) to g) shall be carried out on a test assembly comprising at least one sample of each accessory type to be tested. The accessories shall be installed on a cable such that there is a length of at least 5 m of free cable (i.e. excluding that contained within the length of any accessory) between adjacent accessories and at least 10 m of free cable in total.

The tan δ measurement of 12.4.2 b) can be carried out using the test assembly described above or on a separate cable sample taken from the same manufacturing batch. In the latter case, a bending test is not required on the cable and the test terminations can be different from those used for the other tests. There shall be at least 10 m of free cable in total. For the tests in 12.4.2 c) to g), accessories shall be installed after the bending test on the cable.

Cables 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.

The external surface of accessories shall be dry and clean, but 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.

If any joints are included in the cable system to be tested, during tests c) to g) of 12.4.2, it is necessary to test ~~joints~~ them with the outer protection fitted. ~~If it can be shown that the outer protection does not influence the performance of the joint insulation, e.g. there are no thermo-mechanical or compatibility effects, the protection need not be fitted.~~

Measurement of resistivity of semi-conducting screens described in 12.4.9 shall be made on a separate sample.

12.4 Electrical type tests on complete cable systems

12.4.1 Test voltage values

Prior to the electrical type tests, the insulation thickness of the cable shall be measured by the method specified in ~~8.1 of IEC 60811-1-1:1993 and Amendment 1:2001~~ IEC 60811-201 on a representative ~~piece of~~ sample taken from the length to be used for the tests, to check that the average 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~~ determined according to 8.4 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 %.

12.4.2 Tests and sequence of tests

The tests in items a) to i) shall be made in the following sequence (see also 12.3):

a) bending test on the cable followed by visual examination, where applicable, (see 12.4.3). The installation of the accessories shall then be carried out by the manufacturer and a partial discharge test carried out at ambient temperature (see 12.4.4);

b) tan δ measurement (see 12.4.5 and 12.3);

   ~~NOTE 1 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 (see 12.4.6);

d) partial discharge tests (see 12.4.4):

   - 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 lightning impulse voltage test in~~ item f) below;

e) switching impulse voltage test (required for U_m ≥ 300 kV, see 12.4.7.1);

f) lightning impulse voltage test followed by a power frequency voltage test (see 12.4.7.2);

g) partial discharge tests, if not previously carried out in item d) above;

h) ~~tests of outer protection for joints (see Annex G);~~

~~NOTE 2 These tests may be applied to a joint which has passed test in item c), heating cycle voltage test, or to a separate joint which has passed at least three thermal cycles (see Annex G).~~

~~NOTE 3 If the cable and joint are not to be subjected to wet conditions in service (i.e. not directly buried in earth or not intermittently or continuously immersed in water), the tests in Clauses G.3 and G.4.2 may be omitted.~~

additional tests for accessories (see Annex H);

i) examination of the cable system with cable and accessories on completion of the above tests (see 12.4.8);

j) resistivity of the cable semi-conducting screens (see 12.4.9) that shall be measured on a separate sample. No bending test is required on the test sample.

Test voltages shall be determined in accordance with ~~the values given in the appropriate column of Table 4~~ 8.4 and adjusted according to 12.4.1 if required.

12.4.3 Bending test

The cable sample shall be bent around a test cylinder (for example, the hub of a cable drum) at ambient temperature for at least one complete turn and unwound, without axial rotation. The sample shall then be rotated through 180° and the process repeated.

This cycle of operations shall be carried out three times in total.

The nominal diameter of the test cylinder shall ~~not~~ be ~~greater than~~:

– for cables with ~~plain~~ non-corrugated copper or non-corrugated aluminium sheaths:
  - 36 (d + D) ~~+ 5 % for single-core cables~~;
– for cables with lead, lead-alloy or corrugated metal sheaths ~~or with longitudinally applied metal tapes or foils (overlapped or welded) bonded to the oversheath~~:
  - 25 (d + D) ~~+ 5 % for single-core cables~~;
– for cables with longitudinally applied metal tape or foils (overlapped or welded) bonded to the oversheath:
  - 20 (d + D) for CD,
  - 25 (d + D) for SD and CD + wires,
  - 10 D_s for SscD.
– for other cables:
  - 20 (d + D) ~~+ 5 % for single-core cables~~;

where

d is the nominal diameter of the conductor, in mm (see Clause 6, item j));

D is the nominal overall diameter of the cable, in mm (see Clause 6, item k)).

D_s is the nominal diameter of the metal screen layer, in mm.

~~NOTE A negative tolerance is not specified, but testing at diameters below the specified values should only be done by agreement with the manufacturer.~~

The diameter of the test cylinder is the nominal diameter with a tolerance of 0 % to +5 %. Smaller bending diameters can be used at the discretion of the manufacturer.

In the case of cables with a laminated metal tape or foil, a visual examination according to Clause G.1 shall be carried out, after completion of the three bending cycles.

12.4.4 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 1,75 U_0 for 10 s and then slowly reduced to 1,5 U_0 (see Table 4, column 5).

When performed at high temperature, the test shall be ~~performed~~ carried out on the assembly at a cable conductor temperature 5 K to 10 K above the maximum cable conductor temperature in normal operation. The assembly shall be heated by conductor current only. The conductor temperature shall be maintained within the stated temperature limits for at least 2 h before the partial discharge measurement is carried out.

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

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

There shall be no detectable discharge, exceeding the declared sensitivity, from the test object at 1,5 U_0.

12.4.5 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.

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

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

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 value given in Table 3.

12.4.6 Heating cycle voltage test

The cable shall have a U-bend with a diameter not greater than the test cylinder diameter for the bending test of 12.4.3. The diameter and allowed tolerances shall be as specified in 12.4.3.

The 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.

~~NOTE 1~~ If, for practical reasons, the test temperature cannot be reached, additional thermal insulation ~~may~~ can 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 15 K of ambient temperature, whichever is the higher, but with a maximum of 45 °C. The conductor current during the last 2 h of each heating period shall be recorded.

If the cable exhibits excessive dielectric loss at the test voltage, this can affect cooling. In extreme cases this could prevent cooling of the conductor to within the specified temperature range. This behaviour shall be considered a test failure.

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 assembly (see Table 4, column 7).

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

Interruption of the test is allowed, provided 20 complete heating cycles in total under voltage are completed. Guidance concerning interruption of the test and the determination of valid heating cycles is given in Annex J.

12.4.7 Impulse voltage tests

12.4.7.1 Switching impulse voltage test

A switching impulse voltage test shall be carried out on the assembly for systems, cables and accessories of voltage U_m ≥ 300 kV.

The 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.

The conductor temperature shall be maintained within the stated temperature limits for at least 2 h before the first switching impulse voltage is applied. The temperature shall be maintained within the above limits until the test is completed.

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

The switching impulse voltage shall be applied according to the procedure given in IEC 60230 with standard switching impulse withstand voltage levels according to Table 4, column 10.

The assembly shall withstand, without failure or flashover, 10 positive and 10 negative voltage impulses.

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

The 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.

The conductor temperature shall be maintained within the stated temperature limits for at least 2 h before the first lightning impulse voltage is applied. The temperature shall be maintained within the above limits until the test is completed.

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

The lightning impulse voltage shall be applied according to the procedure given in IEC 60230, while the conductor temperature is within the limits stated above.

The 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 assembly shall be subjected to a power frequency voltage test at 2 U_0 for 15 min (see Table 4, column 9). At the discretion of the manufacturer, this test ~~may~~ can be carried out either during the cooling period or at ambient temperature.

No breakdown of the insulation or flashover shall occur.

12.4.8 Examination

12.4.8.1 Cable and accessories

Examination of the cable by dissection of a sample 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.

Additional guidance on the examination of cable and accessories is given in informative Annex I.

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

A 1 m sample shall be taken from the U-bend part of the cable length and subjected to the tests in 12.5.16.

12.4.9 Resistivity of semi-conducting screens

12.4.9.1 General

Measurement of resistivity of the cable semi-conducting screens shall be made on ~~a separate~~ samples from the same manufacturing batch as the cable under test.

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 12.5.5.

12.4.9.2 Procedure

The test procedure shall be in accordance with Annex D.

The measurements shall be made at a temperature within ±2 K of the maximum conductor temperature in normal operation.

12.4.9.3 Requirements

The resistivity, both before and after ageing, shall not exceed the following values:

– conductor screen: 1 000 Ω · m;
– insulation screen: 500 Ω · m.

12.5 Non-electrical type tests on cable and on cable components ~~and on complete cable~~

12.5.1 General

The tests are as follows:

a) check of cable construction (see 12.5.2);
b) tests for determining the mechanical properties of insulation before and after ageing (see 12.5.3);
c) tests for determining the mechanical properties of oversheaths before and after ageing (see 12.5.4);
d) ageing tests on pieces of ~~complete~~ cable to check compatibility of materials (see 12.5.5);
e) loss of mass test on PVC oversheaths of type ST_2 (see 12.5.6);
f) pressure test at high temperature for oversheaths (ST_1, ST_2, ST_7, and ST_{12}) (see 12.5.7);
g) tests for PVC and LSHF oversheaths (ST_1, ST_2, and ST_{12}) at low temperature (see 12.5.8);
h) heat shock test for PVC oversheaths (ST_1 and ST_2) (see 12.5.9);
i) ozone resistance test for EPR insulation (see 12.5.10);
j) hot set test for EPR and XLPE insulations (see 12.5.11);
k) measurement of density for HDPE insulation (see 12.5.12);
l) measurement of carbon black content for black PE oversheaths (ST_3 and ST_7) (see 12.5.13);
m) test under fire conditions (ST_1, ST_2 and ST_{12}) (see 12.5.14);
n) water penetration test (see 12.5.15);
o) tests for components of cables with a longitudinally applied metal tape or foil, bonded to the oversheath (see 12.5.16).

12.5.2 Check of cable construction

The examination of the conductor and measurements of insulation, oversheath and metal sheath thicknesses shall be carried out in accordance with, and shall comply with the requirements given in 10.4, 10.6 and 10.7.

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

12.5.3.1 Sampling

Sampling and preparation of test pieces shall be carried out in accordance with ~~9.1 of IEC 60811-1-1:1993 and Amendment 1:2001~~ IEC 60811-501:2012 and IEC 60811-501:2012/AMD1:2018.

12.5.3.2 Ageing treatment

The ageing treatment shall be carried out in accordance with ~~8.1 of IEC 60811-1-2:1985 and Amend.1:1989 and Amend.2:2000~~ IEC 60811-401 under the conditions specified in Table 6.

12.5.3.3 Conditioning and mechanical tests

Conditioning and measurement of mechanical properties shall be carried out in accordance with ~~9.1 of IEC 60811-1-1:1985~~ IEC 60811-501:2012 and IEC 60811-501:2012/AMD1:2018, except that:

a) it is not compulsory to carry out tensile tests on the aged and unaged test pieces in immediate succession, and

b) any suitable measuring instrument can be used, for example a micrometer.

12.5.3.4 Requirements

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

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

12.5.4.1 Sampling

Sampling and preparation of test pieces shall be carried out in accordance with ~~9.2 of IEC 60811-1-1:1993 and Amend.1:2001~~ IEC 60811-501:2012 and IEC 60811-501:2012/AMD1:2018.

12.5.4.2 Ageing treatment

The ageing treatment shall be carried out in accordance with ~~8.1 of IEC 60811-1-2:1985 and Amend.1:1989 and Amend.2:2000~~ IEC 60811-401 under the conditions given in Table 7.

12.5.4.3 Conditioning and mechanical tests

Conditioning and the measurement of mechanical properties shall be carried out in accordance with ~~9.2 of IEC 60811-1-1:1993 and Amendment 1:2001~~ IEC 60811-501:2012 and IEC 60811-501:2012/AMD1:2018, except that:

a) it is not compulsory to carry out tensile tests on the aged and unaged test pieces in immediate succession, and

b) any suitable measuring instrument can be used, for example a micrometer.

12.5.4.4 Requirements

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

12.5.5 Ageing tests ~~on~~ for pieces of ~~complete~~ cable to check compatibility of materials

12.5.5.1 General

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

The test is applicable to cables of all types.

12.5.5.2 Sampling

Samples for the test on insulation and oversheath shall be taken from the completed cable as described in ~~8.1.4 of IEC 60811-1-2:1985 and Amendment 1:1989 and Amendment 2:2000~~ IEC 60811-401.

12.5.5.3 Ageing treatment

The ageing treatment of the pieces of cable shall be carried out in an air oven, as described in ~~8.1.4 of IEC 60811-1-2:1985 and Amendment 1:1989 and Amendment 2:2000~~ 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~~ Table 1);

– duration: 7 × 24 h.

12.5.5.4 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 ~~8.1.4 of IEC 60811-1-2:1985 and Amend.1:1989 and Amend.2:2000~~ IEC 60811-401.

12.5.5.5 Requirements

The variations between the median values of tensile strength and elongation at break after ageing and the corresponding values obtained without ageing (see 12.5.3 and 12.5.4) shall not exceed the values applying to the test after ageing in an air oven given in Table 6 for insulations and in Table 7 for oversheaths.

12.5.6 Loss of mass test on PVC oversheaths of type ST_2

12.5.6.1 Procedure

The loss of mass test for ST_2 oversheaths shall be carried out as described in ~~8.2 of IEC 60811-3-2:1985 and Amendment 1:1993 and Amendment 2:2003~~ IEC 60811-409 under the conditions given in Table 9.

12.5.6.2 Requirements

The results shall comply with the requirements given in Table 9.

12.5.7 Pressure test at high temperature on oversheaths

12.5.7.1 Procedure

~~The pressure test at high temperature for ST_1, ST_2 and ST_7 oversheaths shall be carried out as described in 8.2 of IEC 60811-3-1:1985 and Amend.1:1994 and Amend.2:2001, employing the test conditions given in the test method and in Table 7.~~

The pressure test at high temperature for ST_1, ST_2, ST_7 and ST_{12} oversheaths shall be carried out as described in IEC 60811-508:2012 and IEC 60811-508:2012/AMD1:2017, except that:

a) either an oven with natural air circulation or one with fan assisted circulation can be used. In the latter case better temperature control is possible, however the test sample shall not be subjected to vibration, and

b) if the oversheath is solidly bonded to a metal sheath then the oversheath shall not be removed from the metal sheath but shall be tested as if the metal sheath were the mandrel. The metal sheath shall be supported so that it is not deformed during the test.

The test conditions given in the test method and Table 7 shall be used.

12.5.7.2 Requirements

~~The results shall comply with the requirements given in 8.2 of IEC 60811-3-1:1985 and Amend.1:1994 and Amend.2:2001.~~

The results shall comply with the requirements given in Table 7.

12.5.8 Test ~~on~~ for PVC oversheaths (ST_1 and ST_2) and LSHF oversheaths (ST_{12}) at low temperature

12.5.8.1 Procedure

The test at low temperature for ST_1, ST_2 and ST_{12} oversheaths shall be carried out as described in ~~Clause 8 of IEC 60811-1-4:1985 and Amendment 1:1993 and Amendment 2:2001~~ IEC 60811-505 and IEC 60811-506, employing the test temperature given in Table 9.

12.5.8.2 Requirements

The results of the test shall comply with the requirements given in ~~Clause 8 of IEC 60811-1-4:1985 and Amendment 1:1993 and Amendment 2:2001~~ Table 9.

12.5.9 Heat shock test for PVC oversheaths (ST_1 and ST_2)

12.5.9.1 Procedure

The heat shock test on ST_1 and ST_2 oversheaths shall be carried out as described in ~~9.2 of IEC 60811-3-1:1985 and Amendment 1:1994 and Amendment 2:2001~~ IEC 60811-509, the test temperature and duration being in accordance with Table 9.

12.5.9.2 Requirements

The results of the test shall comply with the requirements given in ~~9.2 of IEC 60811-3-1:1985 and Amendment 1:1994 and Amendment 2:2001~~ Table 9.

12.5.10 Ozone resistance test for EPR insulation

12.5.10.1 Procedure

EPR insulation shall be tested for resistance to ozone using the sampling and test procedure described in ~~Clause 8 of IEC 60811-3-1:1998 and Amend.1:2001~~ IEC 60811-403. The ozone concentration and test duration shall be in accordance with Table 8.

12.5.10.2 Requirements

The results of the test shall comply with the requirements given in ~~Clause 8 of IEC 60811-2-1:1998 and Amend.1:200~~ Table 8.

12.5.11 Hot set test for EPR and XLPE insulations

EPR and XLPE insulations shall be subjected to the hot set test described in 10.9 and shall comply with its requirements.

12.5.12 Measurement of density ~~of~~ for HDPE insulation

The density of HDPE insulation shall be measured in accordance with 10.11 and shall comply with its requirements.

12.5.13 Measurement of carbon black content ~~of~~ for black PE oversheaths (ST_3 and ST_7)

12.5.13.1 Procedure

The carbon black content of ST_3 and ST_7 black oversheaths shall be measured using the sampling and test procedure described in ~~Clause 11 of IEC 60811-4-1:2004~~ IEC 60811-605:2012, except that after the final heating stage (in which the remaining carbon is burnt), the sample shall not be allowed to cool in the test assembly but shall be cooled in a desiccator,

using the same procedure as used for the previous cooling stage (but with air or oxygen instead of nitrogen gas flow).

If there is an extruded semi-conductive layer applied to the oversheath, this shall not be included in the test sample.

12.5.13.2 Requirements

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

~~NOTE~~ By agreement between manufacturer and purchaser lower values are allowed for special applications not exposed to UV radiation in service.

12.5.14 Test under fire conditions

~~The test under fire condition in accordance with IEC 60332-1-2 shall be carried out on a sample of completed cable, if the manufacturer wishes to claim that the particular design of cable complies with the requirements.~~

~~The results shall comply with the requirements given in IEC 60332-1-2.~~

12.5.14.1 General

The tests in 12.5.14.2 shall be carried out on ST_{12} (LSHF) oversheath material.

The tests in 12.5.14.3 shall be carried out in accordance with the fire performance claimed for the cable, see Clause 6, item c).

12.5.14.2 Tests on gases evolved during combustion of ST_{12} (LSHF) oversheath material

12.5.14.2.1 Determination of acidity (by pH measurement) and conductivity of gases evolved during combustion

The test according to IEC 60754-2 shall be carried out on the oversheath of the cable.

The results shall comply with the requirements given in Table 10.

12.5.14.2.2 Measurement of halogen content of gases evolved during combustion

The value for the oversheath, H_i, of the individual halogen content for each of the four halogens F, Cl, Br, and I, shall be determined by carrying out the test according to IEC 60754-3.

The values for each of the four individual halogens, H_i, and the sum of the values for the oversheath for the four halogens, i.e. $\sum H_i$, shall comply with the requirements given in Table 10.

12.5.14.3 Fire performance tests for the cable

12.5.14.3.1 Vertical flame propagation test for single cable

The test under fire conditions in accordance with IEC 60332-1-2 shall be carried out on a sample of completed cable. During the test, the determination of flaming droplets and particles shall be carried out in accordance with IEC 60332-1-3.

The results for IEC 60332-1-2 shall comply with the requirements given in Table 10 and the filter paper (IEC 60332-1-3) shall not ignite during the test duration.

If a failure to meet the requirements of either standard is recorded, two more tests shall be carried out. If both tests result in passes, the cable shall be deemed to have passed the test.

12.5.14.3.2 Test for vertical flame spread of vertically-mounted cables

The test for vertical flame spread of vertically-mounted cables shall be carried out in accordance with IEC 60332-3-24, on samples of completed cable.

NOTE Higher performance to meet the requirements of IEC 60332-3-22 [8] or IEC 60332-3-23 [9] can be agreed between the purchaser and manufacturer. The fire performance level achieved depends on cable design as well as material performance.

The results shall comply with the requirements given in Table 10.

12.5.14.3.3 Measurement of smoke density of cables burning under defined conditions

The test for measurement of smoke density of cables burning under defined conditions shall be carried out in accordance with IEC 61034-2 on a sample of completed cable.

The results shall comply with the requirements given in Table 10.

12.5.14.3.4 Determination of acidity (by pH measurement) and conductivity of gases evolved during combustion of the non-metallic materials in the cable

The test according to IEC 60754-2 shall be carried out on the non-metallic components of the cable. Non-metallic components with a mass less than or equal to 1 % of the total non-metallic mass need not be tested.

The weighted values of pH and conductivity of the non-metallic components of the cable shall be calculated according to IEC 60754-2 and shall comply with the requirements given in Table 10.

12.5.14.3.5 Measurement of halogen content of gases evolved during combustion of the non-metallic materials in the cable

The weighted value for the cable, H_i', for the four halogens F, Cl, Br, and I, shall be determined by carrying out the test according to IEC 60754-3 either:

– individually on each non-metallic component of the cable, and calculating the weighted value for the cable, for each halogen, as described in Annex K, or
– on a sample representative of the cable construction prepared as described in Annex K, in which case the result for each halogen shall be taken as the weighted value for the cable.

Non-metallic components with a mass less than or equal to 1 % of the total non-metallic mass need not be tested.

The weighted value for the cable, H_i', for each of the four individual halogens and the sum of the weighted values for the non-metallic components of the cable for the four halogens, i.e. $\sum H_i'$ shall comply with the requirements given in Table 10.

12.5.15 Water penetration test

The water penetration test shall be applied to those designs of cable where barriers to longitudinal water penetration have been included as declared in Clause 6, item d) and Clause 6, item g). The test is designed to meet the requirements for buried cables and is not intended to apply to cables which are constructed for use as submarine cables.

The test consists of two parts, one for the complete cable and all its design elements and one for the water penetration in the conductor. The apparatus, sampling, test procedure and requirements shall be in accordance with Annex E and Annex F.

12.5.16 Tests ~~on~~ for 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 G.1);

b) adhesion strength of the laminated metal tape or foil (see Clause G.2);

c) peel strength of ~~overlapped~~ the laminated metal tape or foil (see Clause G.2).

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

13 Prequalification test of the cable system

13.1 General and range of prequalification test approval

When a PQ test has been successfully performed on a cable system, it qualifies the manufacturer as a supplier of cable systems of the same family with the same or lower voltage ratings, as long as the calculated nominal electrical stresses at the cable insulation screen are equal to or lower than for the tested cable system.

The PQ test shall be performed except:

– if cable systems with the same construction and accessories of the same family have been prequalified for an equal or higher rated voltage, or

– if the manufacturer can demonstrate good service experience with cable systems with equal or higher calculated electrical stresses on the conductor and insulation screens, in the main insulation part(s) and in boundaries of the accessories and of accessories of the same family, or

– if the manufacturer has fulfilled the requirements of an equivalent long-term test, on a cable system at an equal or higher voltage rating with the same construction and accessories of the same family, following a national or purchaser specification.

When a prequalified cable system is changed by exchanging a cable and/or accessory with another one that is already prequalified in another cable system with the same or higher calculated nominal electrical stresses at the insulation screen of the subjected system, the current prequalification shall be extended with this ~~or other~~ cable and/or accessory when the requirements of 13.3 are all met.

When a prequalified cable system is changed by using another cable and/or accessory that is not part of a prequalified cable system or is already prequalified in another cable system with lower calculated nominal electrical stresses at the insulation screen of the subjected system, the PQ test on this new complete cable system shall be performed by meeting all requirements of 13.2.

~~A list of prequalification and of extension of prequalification tests is given in Annex C.~~

~~NOTE 1~~ The PQ test need only be carried out once unless there is a substantial change in the cable system with respect to material, manufacturing process, design or design electrical stress levels.

~~NOTE 2~~ A substantial change is defined as that which might adversely affect the performance of the cable system. The ~~supplier~~ manufacturer should provide a detailed case, including test evidence, if modifications are introduced which are claimed not to constitute a substantial change.

~~NOTE 3~~ It is recommended ~~to carry out a prequalification test using a cable of~~ that a PQ test should use a cable with a large conductor cross-section in order to cover thermo-mechanical aspects.

~~NOTE 4 The prequalification test may be omitted if an alternative long term test has been carried out and satisfactory service experience can be demonstrated.~~

~~NOTE 5~~ Prequalification tests which have been successfully performed according to the previous edition of this standard are valid.

A list of PQ tests and EQ tests is given in Annex C.

A PQ or EQ 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 PQ or EQ test certificate issued by an independent test laboratory shall be acceptable as evidence of PQ or EQ testing. Such a certificate or report shall include details of the indoor test arrangement or outdoor installation and shall specify details of laying conditions and how the cable system was installed.

For a more detailed understanding of the need for a PQ or EQ tests, reference should be made to CIGRE TB 303 [6].

13.2 Prequalification test on complete cable system

13.2.1 Summary of prequalification tests

The PQ test shall comprise the electrical tests on the complete cable system with approximately 100 m of full-sized cable, including at least one of each type of accessory. The minimum length of free cable between accessories shall be 10 m. The sequence of tests shall be as follows:

a) heating cycle voltage test (see 13.2.4);

b) lightning impulse voltage test (see 13.2.5);

c) examination of the cable system after completion of the tests above (see 13.2.6).

It could be the case that one or more of the accessories do not fulfil all the requirements of the PQ tests in 13.2. After repair of the test assembly the PQ tests ~~may~~ can be continued on the remaining cable system (cable with the remaining accessories). If all the requirements of the tests in 13.2 are met by this remaining cable system, this remaining system is prequalified. The accessory or accessories that did not fulfil the requirements are excluded from this prequalification.

The test ~~may~~ can be continued for prequalification of the cable with the replaced accessory until all requirements of 13.2 are met. If the manufacturer decides to include the repaired accessory in the cable system prequalification, the beginning of the PQ test of the complete system is considered to start after the repair.

13.2.2 Test voltage values

Prior to the PQ test of the cable system, the insulation thickness of the cable shall be measured and the test voltage values ~~adjusted~~ determined, ~~if necessary,~~ as stated in 8.4 and 12.4.1.

13.2.3 Test arrangement

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.

The test arrangement shall be representative of the installation design conditions, for example rigidly fixed, flexible and transition arrangements, underground and in air. In particular, special attention shall be paid to thermo-mechanical aspects of accessories.

Ambient conditions ~~may~~ can vary between installations and during the test and are not considered to have any major influence. The temperature limits of 8.1 do not apply.

If the cable system includes sections installed under different conditions (e.g. directly buried and in an air-filled chamber) then the manufacturer shall select one part of the cable system to be used for determination of cable conductor temperature. Temperatures shall be determined at this fixed position for the duration of the test. If a reference cable is used for determination of conductor temperature (see Annex A) then the reference cable shall be installed in conditions representative of the cable system under test.

13.2.4 Heating cycle voltage test

The assembly shall be heated by conductor current only, until the cable conductor reaches a temperature 0 K to 5 K above the maximum conductor temperature in normal operation. Variable ambient conditions ~~may~~ can require adjustment of the conductor current during the test.

The heating arrangements shall be selected so that the cable conductor attains the temperature specified above, remote from the accessories. The surface temperature of the cable shall be recorded for information.

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.

~~NOTE 1~~ If, for practical reasons, the test temperature cannot be reached, additional thermal insulation ~~may~~ can be applied.

A voltage of 1,7 U_0 and heating cycles shall be applied to the assembly during the whole of the test period of at least 8 760 h. The cycles of heating and cooling shall be carried out at least 180 times. Heating cycles with a conductor temperature higher than 5 K above the maximum conductor temperature in normal operation are considered valid. Up to a maximum of 10 cycles, in which the period at high temperature is between 1 h and 2 h can also be counted as valid cycles. At least 180 valid heating cycles, with applied voltage, shall be completed.

As an example, in order to comply with the above requirements, if the heating cycles are of 24 h duration then 365 cycles (8 760/24) would be necessary. If cycles are of a longer duration then a reduced number is permissible.

Interruption of the heating cycles or the test voltage is allowed during the test, however the required minimum number of cycles shall be carried out irrespective of interruptions.

No breakdown shall occur.

~~NOTE 2~~ Partial discharge measurements are recommended, to provide an early warning of possible degradation and to enable the possibility of a repair before failure.

~~NOTE 3 The total number of cycles shall be carried out irrespective of interruptions.~~

~~NOTE 4 Heating cycles with a conductor temperature higher than 5 K above the maximum conductor temperature in normal operation are considered valid.~~

13.2.5 Lightning impulse voltage test

The test shall be performed on the complete assembly or one or more cable samples, with a minimum total active length of 30 m, cut from the assembly. ~~with~~ The cable conductor temperature shall be 0 K to 5 K above the maximum conductor temperature in normal operation. ~~The conductor temperature~~ and shall be maintained within the stated temperature limits for at

least 2 h before the first lightning impulse voltage is applied. The temperature shall be maintained within the above limits while the lightning impulse voltages are applied.

~~NOTE As an alternative, the test may be carried out on the whole test assembly.~~

The lightning impulse voltage shall be applied according to the procedure given in IEC 60230, except that the maximum front time is increased to 8 µs.

The test assembly or cable samples shall withstand without failure 10 positive and 10 negative voltage impulses of the appropriate value given in ~~Table 4, column 8~~ 13.2.2.

13.2.6 Examination

The examination of the cable system (cable and accessories) and the requirements shall be as stated in 12.4.8.

13.3 Tests for the extension of the prequalification of a cable system

13.3.1 Summary of the extension of prequalification test

The EQ tests shall comprise the electrical part of the tests on the complete cable system as specified in 13.3.2 and the non-electrical tests on the cable as specified in 12.5 ~~when the cable is subject to extension of prequalification~~.

For a more detailed understanding of the need for a PQ or EQ tests, reference should be made to CIGRE TB 303 [6].

13.3.2 Electrical part of the extension of prequalification tests on complete cable system

13.3.2.1 General

The tests listed in 13.3.2.3 shall be performed on one or more samples of ~~complete~~ cable, of the already prequalified cable system or having minor changes from an already prequalified design, depending on the number of accessories involved. ~~The sample of the cable system shall contain at least one accessory of each type that need the extension of the prequalification. The test may be performed in a laboratory and not necessarily in a situation simulating the real installation conditions.~~ The test shall include at least one accessory of each type that needs the extension of the prequalification. The accessories, if any, shall already have been prequalified on a different cable system (with an insulation screen stress at least as high as the value for the EQ test) or had minor changes from the prequalified design. The test can be performed in a laboratory and not necessarily in a situation simulating the real installation conditions.

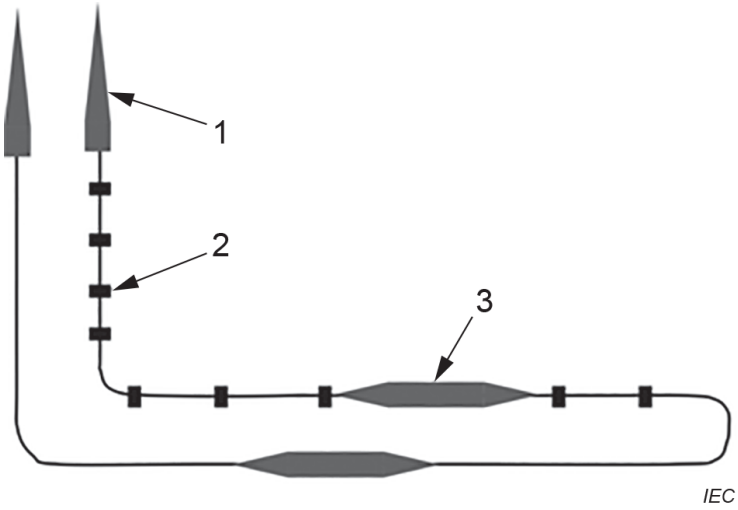
The minimum total cable length shall be 20 m, not including that inside accessories. The minimum length of cable between accessories shall be 5 m.

A bending test shall be carried out on the cable, according to 12.4.3, before the installation of the accessories. The same diameter tolerances given in 12.4.3 shall apply.

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.

The cable shall have a U-bend with a diameter not greater than the test cylinder diameter, including the +5 % tolerance, as specified in 12.4.3.

If the prequalification of a joint is to be extended for use both in flexible and in rigid installations, one joint shall be installed in a flexible configuration and the other one in a rigid configuration, see Figure 1.



Key

1 termination

2 cleat

3 joint

Figure 1 – Example of EQ test arrangement for the prequalification of a system with another joint, designed for rigid as well as for flexible installation

~~The test loop shall have a U-bend with a diameter specified in 12.4.3.~~

With the exception of the provisions of 13.3.2.2 all the tests listed in 13.3.2.3 shall be applied successively to the same sample. ~~The accessories shall be installed after the bending test on the cable.~~

The measurement of the resistivity of semi-conducting screens, described in 12.4.9, shall be made on a separate sample from the same manufacturing batch of cable.

~~U-bends and measurement of resistivity of semi-conducting screens is not required if the extension of the prequalification is only for accessories.~~

13.3.2.2 Test voltage values

Prior to the electrical EQ tests, the insulation thickness of the cable shall be measured, and the test voltage values ~~adjusted~~ determined, ~~if necessary,~~ as stated in 8.4 and 12.4.1.

13.3.2.3 Sequence of the electrical part of the extension of prequalification tests

The ~~normal~~ sequence of the electrical part of the EQ tests shall be as follows:

a) ~~bending test (see 12.4.3) without final partial discharge test followed by~~ installation of the accessories that ~~are part of the tests for the extension of the prequalification~~ shall be carried out by the manufacturer;

b) partial discharge test at ambient temperature (see 12.4.4) ~~is applied after the bending test~~, to check the installation and the quality of the installed accessories;

c) heating cycle test without voltage (see 13.3.2.4);

d) tan δ measurement, if the extension to prequalification is for the cable (see 12.4.5)

~~NOTE 1~~ This test ~~may~~ can be carried out on a different cable sample from that used for the remainder of the sequence of tests, taken from the same manufacturing batch, with special test terminations;

e) heating cycle voltage test (see 12.4.6);

f) partial discharge tests (see 12.4.4) at ambient temperature and at high temperature. These tests shall be carried out after the final cycle of item e) above or, alternatively, after the lightning impulse voltage test in item h) below;

g) switching impulse test (required for U_m ≥ 300 kV, see 12.4.7.1);

h) lightning impulse voltage test followed by a power frequency voltage test (see 12.4.7.2);

i) partial discharge tests, if not previously carried out in item ~~e~~ f) above;

j) ~~tests of outer protection for joints (see Annex G);~~

~~NOTE 2 These tests may be applied to a joint which has passed the test in item c), heating cycle voltage test, or to a separate joint which has passed at least three thermal cycles (see Annex G).~~

~~NOTE 3 If the cable and joint are not to be subjected to wet conditions in service (i.e. not directly buried in earth or not intermittently or continuously immersed in water), the tests in Clauses G.3 and G.4.2 may be omitted.~~

additional tests for accessories (see Annex H);

k) examination of the cable ~~system with cable~~ and/or accessories, as applicable, shall be carried out after completion of the tests above (see 12.4.8).

~~l) the resistivity of semi-conducting screens (see 12.4.9) shall be measured on a separate sample.~~

~~The test voltage values shall be in accordance with the values given in the appropriate column of Table 4 with the eventual adjustments of 13.3.2.2.~~

13.3.2.4 Heating cycle test without voltage

The assembly shall be heated by conductor current only, until the cable conductor reaches a temperature 0 K to 5 K above the maximum conductor temperature in normal operation.

If, for practical reasons, the test temperature cannot be reached, additional thermal insulation can 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 15 K of ambient temperature, whichever is the higher, but with a maximum of 45 °C. The conductor current during the last 2 h of each heating period shall be recorded.

~~NOTE~~ Heating cycles with a conductor temperature higher than 5 K above the maximum conductor temperature in normal operation are considered valid.

The cycle of heating and cooling shall be carried out 60 times.

Interruption of the test is allowed, provided 60 complete heating cycles in total are completed. Guidance concerning interruption of the test and the determination of valid heating cycles is given in Annex J.

14 Type test on cables

Cables will be type tested as part of a cable system.

15 Type test on accessories

Accessories will be type tested as part of a cable system.

16 Electrical test after installation (on-site tests)

16.1 General

Tests on new installations (on-site tests) are carried out when the installation of the cable system has been completed. The tests carried out shall be in accordance with IEC 60060-3.

A DC oversheath test according to 16.2 and/or an AC insulation test according to 16.3 are recommended.

For installations where only the oversheath test according to 16.2 is carried out, quality assurance procedures during installation of accessories ~~may~~ can, by agreement between the purchaser and ~~contractor~~ manufacturer, replace the insulation test according to 16.3.

The use of very low frequency (VLF) and damped AC (DAC) waveforms for on-site tests are not recommended, as further studies of these test methods are required.

16.2 DC voltage test of the oversheath

~~The voltage level and duration specified in Clause 5 of IEC 60229:2007 shall be applied between each metal sheath or metal screen and the ground.~~ The electrical test after installation shall be carried out on the oversheath according to IEC 60229:2007.

For the test to be effective, it is necessary that the ground makes good contact with all of the outer surface of the oversheath. ~~A conductive layer on the oversheath can assist in this respect.~~ The test cannot be carried out unless the oversheath has an outer electrode, for example moist backfill or a conductive layer.

16.3 Tests using AC voltage

16.3.1 AC voltage test of the insulation

The AC test voltage to be applied shall be subject to agreement between the purchaser and the ~~contractor~~ manufacturer.

The waveform shall be substantially sinusoidal and the frequency shall be between 20 Hz and 300 Hz. ~~A voltage either according to Table 4, column 11 or with 1,7 U_0, depending on practical operational conditions, shall be applied for 1 h.~~ In particular cases, the minimum frequency can be reduced to 10 Hz subject to agreement between the purchaser and the manufacturer.

A voltage according to Table 12, column 4 shall be applied for 1 h, except in cases where this is not practicable, for example, for very long circuit lengths. In such cases the alternative lower voltage according to Table 12, column 6 shall be applied for 1 h.

Alternatively, a voltage of U_0 ~~may~~ can be applied for 24 h.

~~NOTE~~ For installations which have been in use, lower voltages than given in Table 12 and/or shorter durations ~~may~~ can be used. Values should be negotiated, taking into account the age, environment, history of breakdowns and the purpose of carrying out the test.

16.3.2 Partial discharge test

A partial discharge (PD) test under AC voltage is recommended and can be carried out by agreement between the purchaser and the manufacturer. Distributed PD measurements can be carried out along the cable route. Typical pass criteria for such measurements are no detectable PD from the cable system at 1,5 U_0, or at the test voltage, if lower. When applicable, the test procedure and pass criteria should be agreed. The PD test can be carried out during the AC

voltage test of the insulation (at the voltage used for that test) or as a separate test. PD tests shall not be considered to replace the AC voltage test of the insulation.

Table 1 – Insulating compounds for cables

Insulating compound		Maximum conductor temperature °C	
		Normal operation	Short-circuit (maximum duration 5 s)
Low density thermoplastic polyethylene	(PE)	70	130[a]
High density thermoplastic polyethylene	(HDPE)	80	160[a]
Cross-linked polyethylene	(XLPE)	90	250
Ethylene-propylene rubber[b]	(EPR)	90	250

[a] For PE and HDPE, a short-circuit temperature~~s~~ rise up to 20 ~~°C~~ K in excess of those shown ~~may~~ can be acceptable with suitable semi-conducting layers over the conductor and the insulation and by agreement between purchaser and manufacturer.

[b] Only for cables with rated voltage U_m ≤ 245 kV.

Table 2 – Oversheathing compounds for cables

Oversheathing compound	Abbreviated designation	Maximum conductor temperature in normal operation °C
Polyvinyl chloride (PVC)	ST_1	80
	ST_2	90
Polyethylene (PE)	ST_3	80
	ST_7	90
Low smoke halogen free (LSHF)	ST_{12}	90

Table 3 – Tan δ requirements for insulating compounds for cables

Designation of compound (see 4.2)		PE	HDPE	EPR	XLPE
Maximum tan δ	10^{-4}	10	10	30	10

Table 4 – Test voltages

1[c]	2	3	4[a]		5[a]	6[a]	7[a]	8[a]	9[a]	10[a]	~~11~~
Rated voltage	**Highest voltage for equip-ment**	**Value of U_0 for determin-ation of test voltages**	**Voltage test of 9.3**		**Partial discharg e test of 9.2 and 12.4.4**	**Tan δ measure-ment of 12.4.5**	**Heating cycle voltage test of 12.4.6**	**Lightnin g impulse voltage test of 10.12, 12.4.7.2 and 13.2.5**	**Voltage test after impulse voltage test of 12.4.7.2**	**Switchin g impulse voltage test of 12.4.7.1**	**~~Voltage test after installa-tion of 16.3~~**
U	U_m	U_0	Volt-age[b]	Dura-tion[b]	1,5 U_0	U_0	2 U_0		2 U_0		
kV	kV	kV	kV	min	kV	kV	kV	kV	kV	kV	~~kV~~
220 to 230	245	127	318	30	190	127	254	1 050	254	–	~~180~~
275 to 287	300	160	400	30	240	160	320	1 050	320	850	~~210~~
330 to 345	362	190	420	60	285	190	380	1 175	380	950	~~250~~
380 to 400	420	220	440	60	330	220	440	1 425	440	1 050	~~260~~
500	550	290	580	60	435	290	580	1 550	580	1 175	~~320~~

Subject to agreement between purchaser and manufacturer, the voltage test of 9.3 ~~may~~ can be replaced by a test at lower voltage and longer duration, even if the maximum stress in the insulation is lower than 30 kV/mm. However, the voltage level shall not be below 1,5 U_0 and the duration not longer than 10 h.

Test voltages for the voltage test after installation of 16.3 are given in Table 12.

[a] If necessary, these test voltages shall be adjusted as stated in 12.4.1.

[b] A threshold limit of 27 kV/mm to 30 kV/mm should not be exceeded for some insulations (as specified by the ~~supplier~~ manufacturer), in order to avoid any possible weakening of the insulation prior to delivery which might later cause a failure in service. At the voltage test of 9.3, for example for a rated voltage 330 kV to 500 kV, the voltage is lowered, combined with a longer testing time in order to avoid too high stresses. For insulations where a threshold limit is not a problem, the ~~supplier may~~ manufacturer can increase the test voltage and reduce the testing time. However, the duration should be at least 30 min.

[c] For rated voltages not listed in column 1, see 8.4.

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

Designation of compound (see 4.2 and 4.4)	Insulation				Oversheath				
	PE	HDPE	EPR	XLPE	ST_1	ST_2	ST_3	ST_7	ST_{12}
Check of cable construction Water penetration test[a]	Applicable irrespective of insulation and oversheathing ~~materials~~ compounds								
Mechanical properties (Tensile strength and elongation at break)									
a) without ageing	x	x	x	x	x	x	x	x	x
b) after ageing in air oven	x	x	x	x	x	x	x	x	x
~~c) after ageing in air bomb~~	~~–~~	~~–~~	~~x~~	~~–~~	~~–~~	~~–~~	~~–~~	~~–~~	~~–~~
c) after ageing of the complete cable (compatibility test)	x	x	x	x	x	x	x	x	x
Pressure test at high temperature	–	–	–	–	x	x	–	x	x
Behaviour at low temperature									
a) cold elongation test	–	–	–	–	x	x	–	–	x
b) cold impact test	–	–	–	–	x	x	–	–	x
Loss of mass in air oven	–	–	–	–	–	x	–	–	–
Heat shock test	–	–	–	–	x	x	–	–	–
Ozone resistance test	–	–	x	–	–	–	–	–	–
Hot set test	–	–	x	x	–	–	–	–	–
Measurement of density	–	x	–	–	–	–	–	–	–
Carbon black content[b]	–	–	–	–	–	–	x	x	–
pH value (12.5.14.2.1)	–	–	–	–	–	–	–	–	x
Conductivity test (12.5.14.2.1)	–	–	–	–	–	–	–	–	x
Halogen content (12.5.14.2.2)	–	–	–	–	–	–	–	–	x

~~NOTE x indicates that the type test is to be applied.~~

Key

x: the test shall be applied

–: the test shall not be applied

[a] ~~To~~ Shall be applied to those designs of cable where the manufacturer claims that barriers to longitudinal water penetration have been included.

[b] For black oversheaths only.

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

Designation of compound (see ~~4.2~~ Table 1)	Unit	PE	HDPE	XLPE	EPR
Maximum conductor temperature in normal operation	°C	70	80	90	90
Without ageing ~~(9.1 of IEC 60811-1-1)[a]~~ (IEC 60811-501:2012 and IEC 60811-501:2012/AMD1:2018)					
Minimum tensile strength	N/mm^2	10,0	12,5	12,5	4,2
Minimum elongation at break	%	300	350	200	200
After ageing in air oven ~~(8.1 of IEC 60811-1-2)[a]~~ (IEC 60811-401)					
Treatment: temperature	°C	100	110	135	135
tolerance	K	±2	±2	±3	±3
duration	h	240	240	168	168
Tensile strength					
a) minimum value after ageing	N/mm^2	–	–	–	–
b) maximum variation[~~b~~a]	%	–	–	±25	±30
Elongation at break					
a) minimum value after ageing	%	300	350	–	–
b) maximum variation[a]	%	–	–	±25	±30
~~*After ageing in air bomb at (55 ± 2) N/cm²*~~ ~~(8.2 of IEC 60811-1-2)[a]~~					
~~a) Treatment: temperature~~	~~°C~~	~~–~~	~~–~~	~~–~~	~~127~~
~~tolerance~~	~~K~~	~~–~~	~~–~~	~~–~~	~~± 1~~
~~duration~~	~~h~~	~~–~~	~~–~~	~~–~~	~~40~~
~~Maximum variation[b] of:~~					
~~b) Tensile strength~~	~~%~~	~~–~~	~~–~~	~~–~~	~~± 30~~
~~c) Elongation at break~~	~~%~~	~~–~~	~~–~~	~~–~~	~~± 30~~

~~[a] All documents cited in this table refer to the dated editions that are listed in the normative references clause.~~

[~~b~~a] 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 4.4)	Unit	ST_1	ST_2	ST_3	ST_7	ST_{12}
Without ageing ~~(9.2 of IEC 60811-1-1)[a]~~ (IEC 60811-501:2012 and IEC 60811-501:2012/AMD1:2018)						
Minimum tensile strength	N/mm^2	12,5	12,5	10,0	12,5	12,5
Minimum elongation at break	%	150	150	300	300	300
After ageing in air oven ~~(8.1 of IEC 60811-1-2)[a]~~ (IEC 60811-401)						
Treatment: temperature	°C	100	100	100	110	110
tolerance	K	±2	±2	±2	±2	±2
duration	h	168	168	240	240	240
Tensile strength:						
a) minimum value after ageing	N/mm^2	12,5	12,5	–	–	10,0
b) maximum variation[~~b~~a]	%	±25	±25	–	–	±30
Elongation at break:						
a) minimum value after ageing	%	150	150	300	300	300
b) maximum variation[~~b~~a]	%	±25	±25	–	–	–
Pressure test at high temperature ~~(8.2 of IEC 60811-3-1)[a]~~ (IEC 60811-508:2012 and IEC 60811-508:2012/AMD1:2017)						
Test temperature	°C	80	90	–	110	110
Tolerance	K	±2	±2	–	±2	±2
Maximum indentation	%	50	50	–	50	50

~~[a] All documents cited in this table refer to the dated editions that are listed in the normative references clause.~~

[~~b~~a] Variation: difference between the median value obtained after ageing and the median value obtained without ageing, expressed as a percentage of the latter.

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

Designation of compound (see 4.2)		Unit	PE	HDPE	XLPE	EPR
Ozone resistance test ~~(Clause 8 of IEC 60811-2-1)~~[a] (IEC 60811-403)						
Ozone concentration (by volume)		%	–	–	–	0,025 to 0,030
Test duration without cracks		h	–	–	–	24
Hot set test ~~(Clause 9 of IEC 60811-2-1)~~[a] (IEC 60811-507)						
Treatment:	air temperature	°C	–	–	200	250
	tolerance	K	–	–	±3	±3
	~~time under load~~	~~min~~	~~–~~	~~–~~	~~15~~	~~15~~
	~~mechanical~~ tensile stress	N/cm^2	–	–	20	20
Maximum elongation under load		%	–	–	175	175
Maximum permanent elongation after cooling		%	–	–	15	15
Density ~~(Clause 8 of IEC 60811-1-3)~~[a] (IEC 60811-606)						
Minimum density		g/cm^3	–	0,940	–	–

~~[a] All documents cited in this table refer to the dated editions that are listed in the normative references clause.~~

Table 9 – Test requirements for particular characteristics of PVC and LSHF oversheathing for cables

Designation of compound (see 4.4)		Unit	ST_1	ST_2	ST_{12}
Loss of mass in air oven ~~(8.2 of IEC 60811-3-2)[a]~~ (IEC 60811-409)					
Treatment:	temperature	°C	–	100	–
	tolerance	K	–	±2	–
	duration	h	–	168	–
Maximum permissible loss of mass		mg/cm^2	–	1,5	–
Behaviour at low temperature~~[b]~~[a] ~~(Clause 8 of IEC 60811-1-4)[a]~~					
Tests to be carried out without previous ageing:					
a) Cold elongation test on dumb-bells (IEC 60811-505)					
	test temperature	°C	−15	−15	−15
	tolerance	K	±2	±2	±2
Requirement		%	≥ 20	≥ 20	≥ 20
b) Cold impact test (IEC 60811-506)					
	test temperature	°C	−15	−15	−15
	tolerance	K	±2	±2	±2
Requirement			no cracks	no cracks	no cracks
Heat shock test ~~(9.2 of IEC 60811-3-1)[a]~~ (IEC 60811-509)					
Treatment:	test temperature	°C	150	150	–
	tolerance	K	±3	±3	–
	test duration	h	1	1	–
Requirement			no cracks	no cracks	–

~~[a] All documents cited in this table refer to the dated editions that are listed in the normative references clause.~~

~~[b]~~[a] Due to climatic conditions, national standards ~~may~~ can require the use of a lower or higher test temperatures.

Table 10 – Test requirements for fire performance characteristics of cables with PVC and LSHF oversheaths

Designation of compound (see 4.4)		Unit	ST_1	ST_2	ST_{12}
Tests on ST_{12} (LSHF) oversheath material					
pH value and conductivity tests (12.5.14.2.1) (IEC 60754-2)					
	pH	–	–	–	≥ 4,3
	Conductivity	µS/mm	–	–	≤ 10
Halogen content of gases (12.5.14.2.2) (IEC 60754-3)					
Value for each of the 4 individual halogens (F, Cl, Br, I)	H_i	mg/g	–	–	≤ 2
Sum of values for the 4 individual halogens (F, Cl, Br, I)	$\sum H_i$	mg/g	–	–	≤ 5
Tests for cable					
Vertical flame propagation test for single cable (12.5.14.3.1) (IEC 60332-1-2)					
Distance between the lower edge of the top support and the onset of charring		mm	> 50	> 50	> 50
Lower extent of charring below the lower edge of the top support		mm	≤ 540	≤ 540	≤ 540
Test for vertical flame spread of vertically-mounted cables (12.5.14.3.2) (IEC 60332-3-24)					
Upper limit of char above bottom edge of burner		m	–	–	≤ 2,5
Smoke density test of cables (12.5.14.3.3) (IEC 61034-2)					
Normalized transmittance	$(I_t/I_0)_{norm}$	%	–	–	≥ 60
pH value and conductivity tests (12.5.14.3.4) (IEC 60754-2)					
Weighted value for the non-metallic materials in the cable	pH	–	–	–	≥ 4,3
	Conductivity	µS/mm	–	–	≤ 10
Halogen content of gases evolved during combustion (12.5.14.3.5) (IEC 60754-3)					
Weighted values for non-metallic materials in the cable	Value for each of the 4 individual halogens (F, Cl, Br, I) H'_i	mg/g	–	–	≤ 2
	Sum of the values for the 4 individual halogens (F, Cl, Br, I) $\sum H'_i$	mg/g	–	–	≤ 5

Table 11 – Cantilever operating load for insulators for outdoor terminations

Highest voltage for equipment U_m kV	Rated current A							
	≤ 800		1 000 to 1 600		2 000 to 2 500		≥ 3 150	
	Maximum cantilever operating load in service and for which the insulator is designed (= MML for composite insulators)							
	N							
	Termination installed < 30° from the vertical							
	I	II	I	II	I	II	I	II
> 170 to 245	625	2 000	800	2 000	1 250	2 500	2 000	2 500
≥ 300	1 250	2 000	1 250	2 000	1 575	2 500	2 500	2 500

Key

Level I = normal load, Level II = heavy load

For outdoor terminations operating at an angle > 30° to the vertical, the effect of termination self-load should be considered when selecting test load and procedure. The values given above correspond to vertical terminations that shall be tested in a vertical position. If a tilted or horizontal termination is to be tested vertically, then an equivalent force should be added to achieve the bending moment at the flange caused by the weight of the termination in its operating position. If a vertical termination is to be tested horizontally, then the test load can be reduced in the same manner.

NOTE This table is derived from IEC 60137.

Table 12 – Test voltages for AC voltage test after installation

1	2	3	4	5	6	7
Rated voltage	Highest voltage for equipment	Value of U_0 for determination of test voltages	Preferred test voltage		Test voltage for special conditions (when use of the preferred test voltage of column 4 is not possible, see 16.3.1)	
			Voltage test after installation of 16.3	Multiplier	Voltage test after installation of 16.3	Multiplier
U	U_m	U_0	-	-	-	-
kV	kV	kV	kV	x U_0	kV	x U_0
220 to 230	245	127	216	1,7	180	1,4
275 to 287	300	160	272	1,7	210	1,3
330 to 345	362	190	323	1,7	250	1,3
380 to 400	420	220	374	1,7	260	1,2
500	550	290	435	1,5	320	1,1
A threshold electrical stress of 27 kV/mm to 30 kV/mm should not be exceeded for some insulations (as specified by the manufacturer) in order to avoid a possible weakening of the insulation.						

Annex A
(informative)

Determination of the cable conductor temperature

A.1 Purpose

For some tests, it is necessary to raise the cable conductor to a given temperature, typically 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 temperature.

In addition, the conductor temperature should be maintained within a restricted range (5 K) ~~whereas~~ since the ambient temperature ~~may~~ can vary over a wider range.

Although preliminary calibration on the cable under test or calculations ~~may~~ can be satisfactory in the first place, the variation of ambient conditions throughout the duration of the test ~~may~~ can lead to deviations of the temperature of the conductor outside range.

Therefore, methods should be used in which the conductor temperature can be monitored and controlled throughout the duration of the test.

Guidance is given hereafter on commonly used methods.

A.2 Calibration of the temperature of the main test loop

A.2.1 General

The purpose of the calibration is to determine the conductor temperature by direct measurement for a given current, within the temperature range required for the test.

The cable used for calibration (hereafter called the reference cable) should be taken from the same length as the cable used for the main test loop.

A.2.2 Installation of cable and temperature sensors

The calibration should be performed on the reference cable which shall have a minimum ~~cable~~ length of 5 m ~~taken from the same cable as tested~~. The length should 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~~ Two temperature sensors should be attached to the middle of the reference cable: one on the conductor (TC_{1c}), and one on the external surface or directly under the external surface (TC_{1s}).

Two other temperature sensors, TC_{2c} and TC_{3c}, should be installed on the conductor of the reference cable (see Figure A.1), each one about 1 m from the middle.

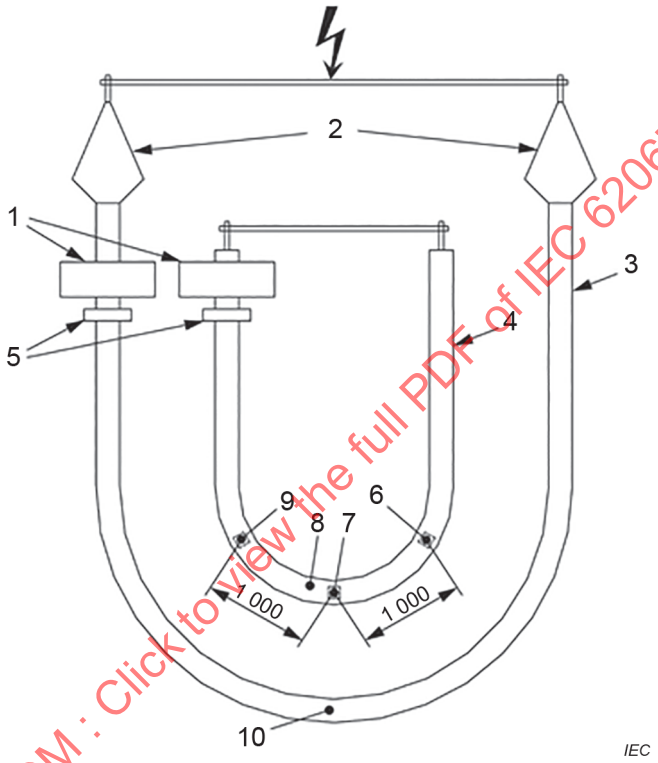
The temperature sensors should be attached to the conductor by mechanical means since they ~~may~~ can move due to vibrations of the cable during heating. Care should be taken to maintain good thermal contact during the tests and to prevent leakage of heat to the ambient. It is recommended to mount the temperature sensor(s), as shown in Figure A.2, between two strands of a stranded conductor or between the (solid) conductor and the conductor screen. To enable access to the conductor in the middle of the reference cable, a small hatch should be made by careful removal of the layers above the conductor. After installing the temperature

sensor(s), the layers that have been removed ~~may~~ can be put back. This ~~may~~ can restore the thermal behaviour of the reference cable.

~~NOTE~~ To prove a negligible heat transfer towards the cable ends, the difference between the readings of TC_{1C}, TC_{2C} and TC_{3C} should be less than 2 K.

If the actual main test loop includes several individual cable lengths installed close to each other, these lengths will be subjected to a thermal proximity effect. The calibration should therefore be carried out taking into account the actual test arrangement, measurements being performed on the hottest cable length (usually the middle length).

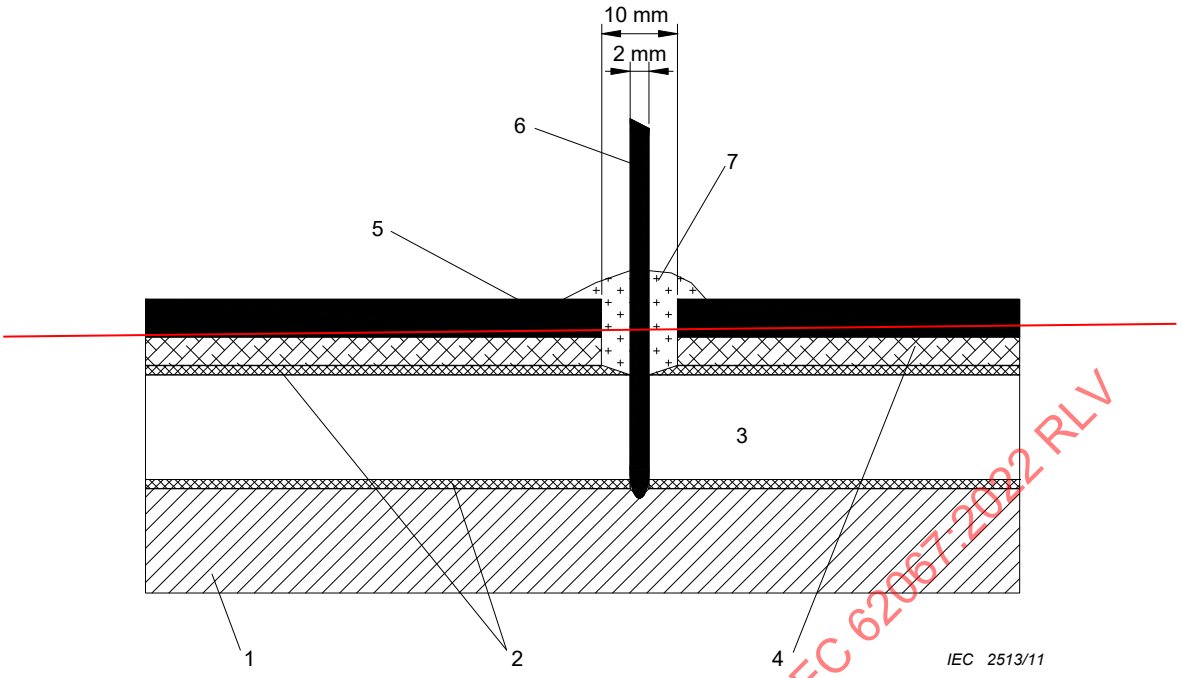
Dimensions in millimetres



Key

1	current inducing transformers	6	TC_{3c} (conductor)
2	terminations	7	TC_{1c} (conductor)
3	cable under test	8	TC_{1s} (sheath)
4	reference cable (≥ 5 m)	9	TC_{2c} (conductor)
5	current measuring transformers	10	TC_{s} (sheath)

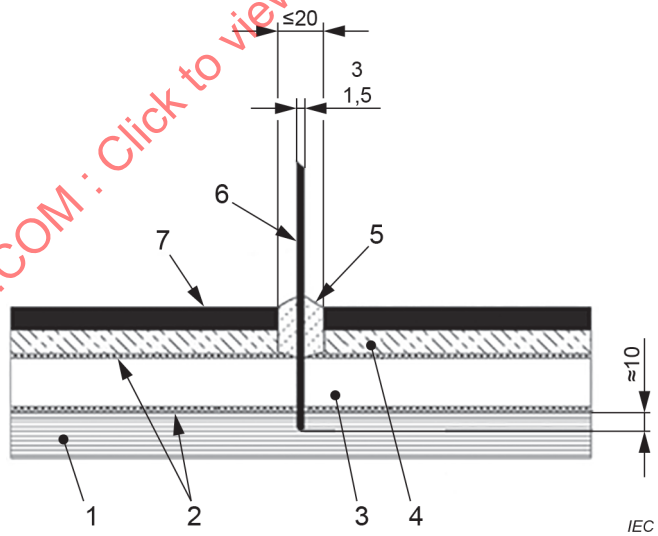
Figure A.1 – ~~Typical~~ Schematic diagram of test set-up for the reference loop and the main test loop



~~Key~~

~~1 conductor~~
~~2 semi-conducting screens~~
~~3 insulation~~
~~4 metal sheath~~
~~5 cable oversheath~~
~~6 temperature sensor~~
~~7 flexible thermal insulating compound~~

Dimensions in millimetres



Key

1 conductor
2 semi-conducting screens
3 insulation
4 metal sheath
5 flexible thermal insulating compound
6 temperature sensor
7 cable oversheath

Figure A.2 – Example of an arrangement of the temperature sensors on the conductor of the reference loop

A.2.3 Calibration method

The calibration should be carried out in a draught-free situation at a temperature of (20 ± 15) °C.

Temperature recorders should be used to measure the conductor, oversheath and ambient temperatures simultaneously.

The cable should be heated until the conductor temperature, indicated by temperature sensor TC_{1c} of Figure A.1, has stabilized and reached ~~the following temperatures:~~ a temperature between 5 K and 10 K above the maximum conductor temperature of the cable in normal operation, as given in Table 1.

When stabilization has been reached, the following should be noted:

– conductor temperature: average value at ~~positions 1, 2 and 3~~ sensors TC_{1c}, TC_{2c}, and TC_{3c};

– oversheath temperature at position TC_{1s};

– ambient temperature;

– heating current.

A.3 Heating for the test

A.3.1 Method 1 – Test using a reference cable

In this method, a reference cable identical to the cable used for the main test loop is heated with the same current value as the main test loop.

The installation of cable and temperature sensors for both loops should be as given in Clause A.2.

The test arrangement should be such that:

– the reference cable carries the same current as the main test loop at any time; small current changes are allowed in order to equalize the surface temperatures on the test cable and the reference cable;

– the reference cable is installed in such a way that mutual heating effects are taken into account throughout the test.

~~The heating current of both loops should be adjusted such that the conductor temperature is kept within the specified limits.~~

A temperature sensor (TC_s) should be mounted on or under the external surface of the main test loop at the hottest spot, usually in the middle of ~~it~~ the length, in the same way as temperature sensor TC_{1s} is mounted on the hottest spot of the reference cable to check that the oversheaths of both loops are at a similar temperature.

~~NOTE 1 The temperature measured with the temperature sensors on or under the oversheath of the main test loop (TC_s) and on the reference loop (TC_{1s}) are used to check whether the oversheath of both loops has the same temperature.~~

~~The temperature measured with temperature sensors TC_{1c} on the conductor of the reference loop may be considered as to be representative for the conductor temperature of the energized test loop.~~

~~NOTE 2 The temperature of the conductor of the main test loop may be slightly higher than that of the reference loop because of dielectric losses. If necessary, a correction should be made.~~

The temperature measured with temperature sensor TC_{1c} on the conductor of the reference loop can be considered to be representative for the conductor temperature of the energized test loop.

The heating current of both loops should be adjusted such that the conductor temperature is kept within the specified limits.

All temperature sensors should be connected to a recorder to enable temperature monitoring. The heating current of each loop should also be recorded to prove that the two currents are of the same value throughout the duration of the test. The difference between the heating currents should be kept within ±1 %.

The reference cable ~~may~~ can be connected in series with the test cable if the temperature is measured via an optical fibre link or equivalent.

A.3.2 Method 2 – Test using conductor temperature calculations and measurement of the surface temperature

A.3.2.1 Calibration of the test cable conductor temperature

The purpose of the calibration is to determine the conductor temperature by direct measurement for a given current, within the temperature range required for the test.

The cable used for calibration should be ~~identical to that to be~~ taken from the same length as the cable used for the main test loop and the way of heating should be identical.

The installation of cable and temperature sensors for the calibration should be as given in Clause A.2.

The calibration should be carried out in accordance with A.2.3 for the reference cable.

A.3.2.2 Test based on measurement of the external temperature

During calibration and during the test of the main loop, the cable conductor temperature of the main test loop should be calculated in accordance with IEC 60853-2 [10], based on the measured external temperature of the oversheath (TC_s). The measurement should be carried out with a temperature sensor at the hottest spot, attached to or under the external surface, in the same way as for the reference cable.

~~NOTE As an alternative, IEC 60287-1-1 may be used if demonstrated that asymptotic transient temperature is reached within the specified time.~~

IEC 60287-1-1 can be used to determine the asymptotic temperature.

The heating current should be adjusted to obtain the required value of the calculated conductor temperature, based on the measured external temperature of the oversheath.

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
(informative)

List of type, prequalification and extension of prequalification tests ~~of~~ for cable systems

Type tests ~~of~~ for cable systems are covered by Clause 12.

Table C.1 gives a summary and references for type testing of cable systems.

PQ tests of cable systems are covered by 13.1 and 13.2.

EQ tests for the extension of prequalification ~~tests of cable systems~~ are covered by 13.1 and 13.3.

Table C.2 gives a summary and references for prequalification testing of these cable systems.

Table C.3 gives a summary and references for the extension of prequalification testing of these cable systems.

Table C.1 – Type tests ~~on~~ for cable systems

Item	Test	Clauses
		~~Cable systems~~
a	General	12.1
b	Range of type approval	12.2
c	Electrical type tests	12.4
d	Test voltage values	12.4.1
e	Bending test	12.4.3
	Partial discharge test at ambient temperature	12.4.4
f	Tan δ measurement	12.4.5
g	Heating cycle voltage test	12.4.6
h	Partial discharge test at ambient and at high temperatures (after final cycle in item g above or after lightning impulse voltage test in item j below)	12.4.4
i	Switching impulse voltage test	12.4.7.1
j	Lightning impulse voltage test followed by power frequency voltage test	12.4.7.2
k	Partial discharge tests at ambient temperature and at high temperature (if not carried out after item ~~h~~ g above)	12.4.4
~~l~~	~~Tests of outer protection of joints~~	~~Annex G~~
l	Additional tests for accessories	Annex H
m	Examination	12.4.8
n	Resistivity of semi-conducting screens	12.4.9
o	Non-electrical type tests ~~on~~ for cable components and on completed cable	12.5

Table C.2 – PQ tests on cable systems

Item	Test	Clauses
		~~Cable systems~~
a	General and range of PQ test approval	13.1
b	PQ test on complete cable system	13.2
c	Summary of PQ tests	13.2.1
d	Test voltage values	13.2.2
e	Test arrangement	13.2.3
f	Heating cycle voltage test	13.2.4
g	Lightning impulse voltage test	13.2.5
h	Examination	13.2.6

Table C.3 – EQ tests on cable systems

Item	Test	Clauses
		~~Cable systems~~
a	General and range of prequalification test approval	13.1
b	Tests for the extension of the prequalification of a cable system	13.3
c	Electrical part of the extension of prequalification tests on complete cable system	13.3.2
d	Test voltage values	13.3.2.2
e	Bending test without partial discharge test	12.4.3
f	Partial discharge test at ambient temperature after installation of the accessories that are part of the test	12.4.4
g	Heating cycle ~~voltage~~ test without voltage	13.3.2.4
h	Tan δ measurement	12.4.5
i	Heating cycle voltage test	12.4.6
j	Partial discharge test at ambient and high temperatures (after final cycle in item i above or after lightning impulse voltage test in item l below)	12.4.4
k	Switching impulse voltage test	12.4.7.1
l	Lightning impulse voltage test followed by power frequency voltage test	12.4.7.2
m	Partial discharge test at high temperature (if not carried out after item i above)	12.4.4
~~n~~	~~Tests of outer protection of joints~~	~~Annex G~~
n	Additional tests for accessories	Annex H
o	Examination	12.4.8
p	Resistivity of semi-conducting screens	12.4.9
q	Non-electrical type tests on cable components and on completed cable	12.5

Annex D
(normative)

Measurement method for resistivity of semi-conducting screens

Each test piece shall be prepared from a 150 mm sample of ~~complete~~ 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 D.1a~~ Figure D.1). The insulation screen test piece shall be prepared by removing all the coverings from a sample of core (see ~~Figure D.1b~~ Figure D.2).

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 D.1a and D.1b~~ Figure D.1 and Figure D.2) 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 screen and the thicknesses 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 D.1b~~ Figure D.2.

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

a) conductor screen:

$$\rho_{\mathrm{c}} = \frac{R_{\mathrm{c}} \times \pi \times \left(D_{\mathrm{c}} - T_{\mathrm{c}}\right) \times T_{\mathrm{c}}}{2\, L_{\mathrm{c}}}$$

where:

ρ_{c} is the volume resistivity, in ohm metres (Ω · m);

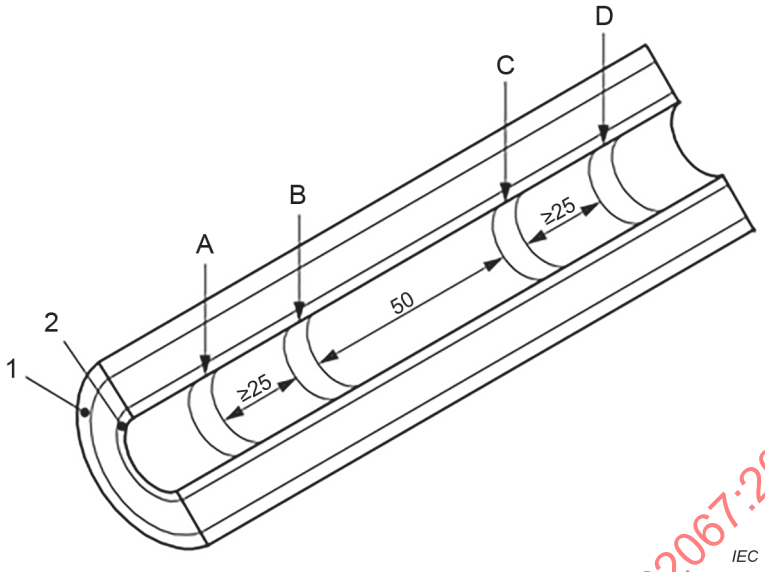
R_{c} is the measured resistance, in ohms (Ω);

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).

Dimensions in millimetres



Key

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

Figure D.1 – Dimensions for preparation of samples for measurement of resistivity of conductor screen

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 (Ω · m);

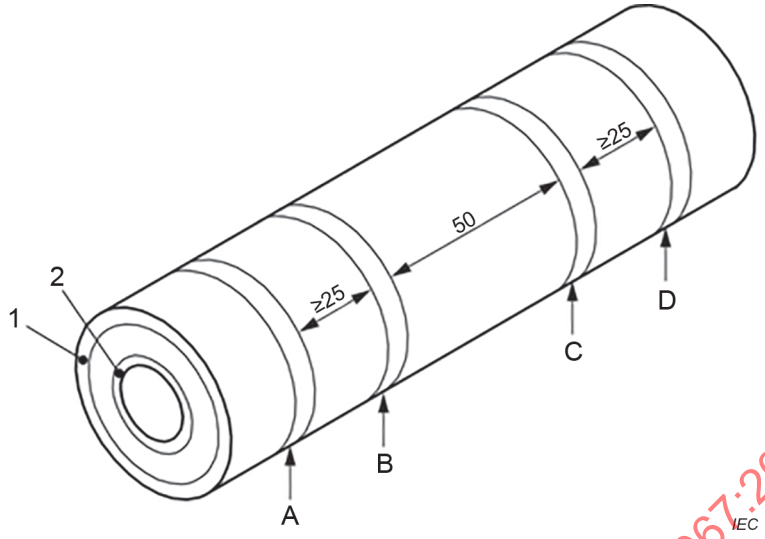
R_i is the measured resistance, in ohms (Ω);

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).

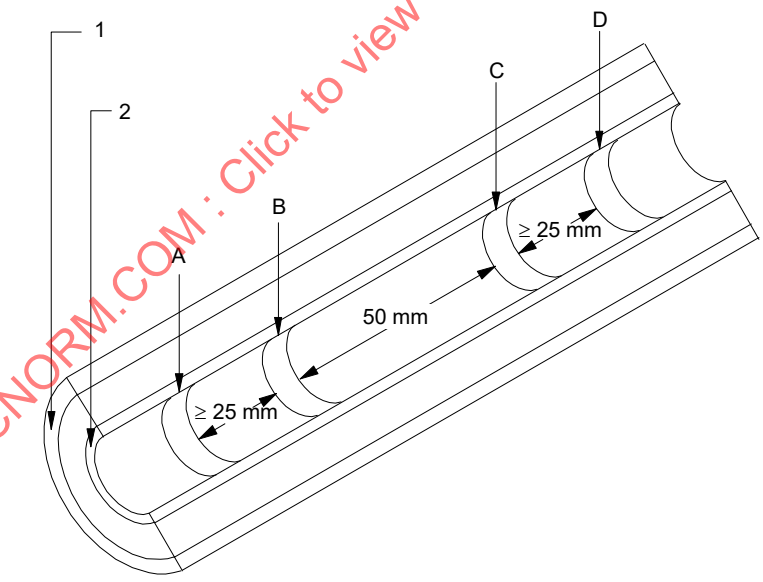
Dimensions in millimetres



Key

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

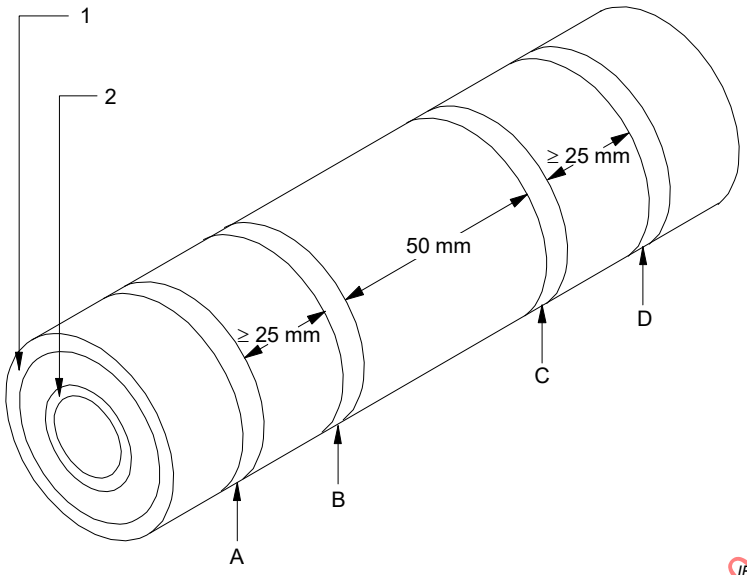
Figure D.2 – Dimensions for preparation of samples for measurement of resistivity of insulation screen



~~**Key**~~

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

~~**Figure D.1a – Measurement of the volume resistivity of the conductor screen**~~



Key

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

Figure D.1b – Measurement of the volume resistivity of the insulation screen

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

Annex E
(normative)

Water penetration test

E.1 Test piece

A sample of ~~complete~~ cable at least 8 m in length which has not been subjected to any of the tests described in 12.4 shall be subjected to the bending test described in 12.4.3.

An (8,0 ± 0,050) m length of cable shall be cut from the length which has been subjected to the bending test and placed horizontally. A ring approximately 50 mm wide shall be removed from the centre of the length. This ring shall comprise all the layers external to the insulation screen. Where the conductor is also claimed to contain a longitudinal water barrier, the ring shall comprise all layers external to the conductor.

If the cable contains intermittent barriers to longitudinal water penetration, then the sample shall contain at least two of these barriers, the ring being removed from between the barriers. In this case, the average distance between the barriers in such cables should be known.

The surfaces shall be cut so that the interfaces intended to be longitudinally watertight shall be readily exposed to water. The interfaces not intended to be longitudinally watertight shall be sealed with a suitable material or the outer coverings removed.

Examples of such interfaces include

– when the cable only has a conductor barrier;
– when the interface is positioned between the oversheath and the metal sheath.

Arrange a suitable device (see Figure E.1) to allow a tube having a diameter of at least 10 mm to be placed vertically over the exposed ring and sealed to the surface of the oversheath. The seals where the cable exits the apparatus shall not exert mechanical stress on the cable.

~~NOTE~~ The response of certain barriers to longitudinal penetration can be dependent on the composition of the water (e.g. pH, ion concentration). Normal tap water should be used for the test unless otherwise specified.

E.2 Test

The tube ~~is~~ shall be filled within 5 min with tap water at a temperature of (20 ± 10) °C so that the height of the water in the tube is (1,0 ± 0,050) m above the cable centre (see Figure E.1).

The sample shall be allowed to stand for 24 h.

The sample shall then be subjected to 10 heating cycles. The conductor shall be heated by a suitable method until it has reached a steady temperature 5 K to 10 K above the maximum conductor temperature in normal operation; it shall not, however, reach ~~100 °C~~ the boiling point of water.

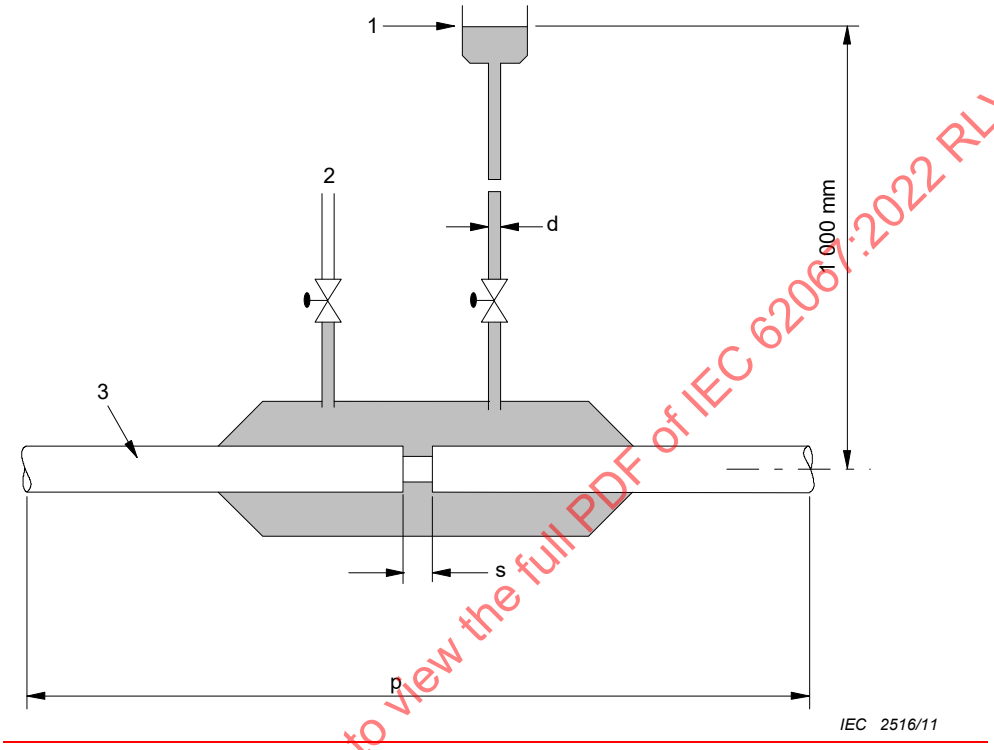
The heating shall be applied for at least 8 h. The conductor temperature shall be maintained within the stated temperature limits for at least 2 h of each heating period. This shall be followed by at least 16 h of natural cooling.

The water head shall be maintained at ~~1~~ (1,0 ± 0,050) m.

~~NOTE~~ No voltage being applied throughout the test, it is ~~advisable~~ recommended to connect a ~~dummy~~ reference cable in series with the cable to be tested, the temperature being measured directly on the conductor of this cable.

E.3 Requirements

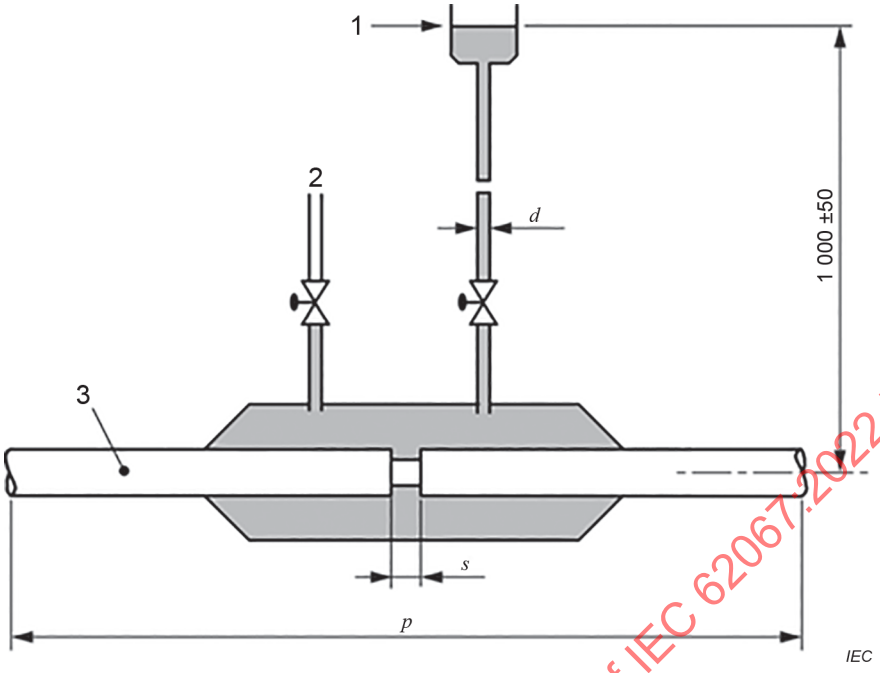
During the period of testing, no water shall emerge from the ends of the test piece.



~~Key~~

~~1~~	~~water header tank~~	~~d~~	~~Ø10 mm minimum (inner)~~
~~2~~	~~vent~~	~~s~~	~~50 mm approximately~~
~~3~~	~~cable~~	~~p~~	~~length = 8 000 mm~~

Dimensions in millimetres



Key

1	water header tank	*d*	Ø10 mm minimum (inner)
2	vent	*s*	50 mm approximately
3	cable	*p*	length = (8 000 ± 50) mm

Figure E.1 – Schematic diagram of apparatus for water penetration test

Annex F
(normative)

Test for water penetration in the conductor

F.1 Test piece

A (4,0 ± 0,050) m sample of cable which has been subjected to the bending test of 12.4.3 shall be placed horizontally.

All layers external to the insulation screen shall be removed from the sample and the full cross-section of the conductor shall be exposed at both ends of the test piece.

Arrange a suitable chamber to enclose one end of the test piece. The chamber shall be fitted with an air vent and a separate vertical tube, both of at least 10 mm internal diameter, with a header tank to allow the application of a (1,0 ± 0,050) m head of water (see Figure F.1). The chamber shall be sealed to the surface of the insulation screen. The seal where the cable exits the chamber shall not deform the insulation during the test.

The response of certain barriers to longitudinal penetration can be dependent on the composition of the water (e.g. pH, ion concentration). Normal tap water should be used for the test unless otherwise specified.

F.2 Test

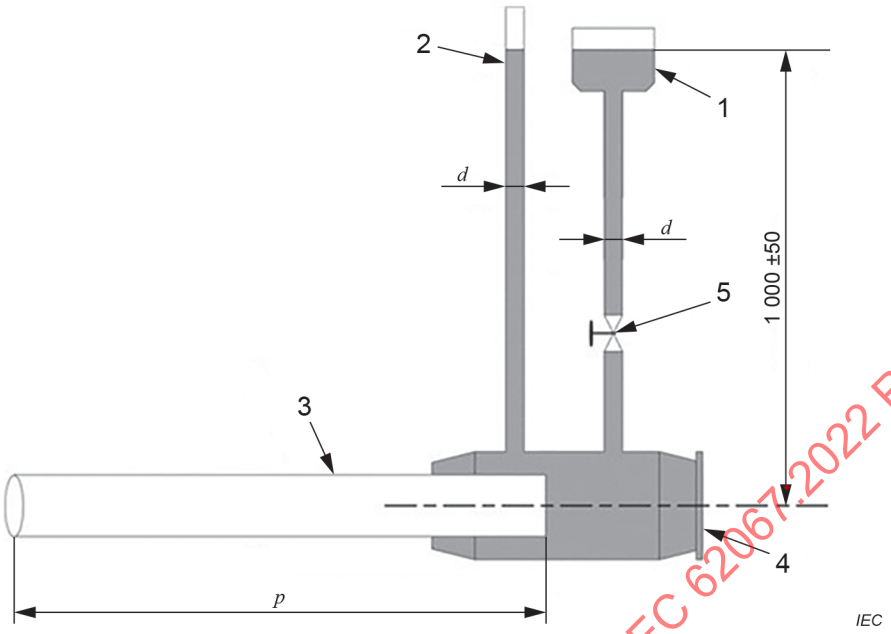
The tube shall be filled within 5 min with tap water at a temperature of (20 ± 10) °C so that the height of the water in the tube is (1,0 ± 0,050) m above the cable centre (see Figure F.1).

The sample shall be allowed to stand for 11 days at ambient temperature.

F.3 Requirements

During the period of testing, no water shall emerge from the end of the test piece.

Dimensions in millimetres



Key

1 water header tank
2 air vent
3 test piece
4 chamber
5 full bore valve (optional)
d internal diameter ≥ 10 mm
p length = (4 000 ± 50) mm

Figure F.1 – Schematic diagram of apparatus for water penetration test in the conductor

Annex G
(normative)

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

G.1 Visual ~~inspection~~ examination

The cable shall be dissected and visually examined. Examination of the samples with normal or corrected vision without magnification shall reveal no ~~cracks or separation of the metal foil of laminated protective coverings or damage to other parts of the cable~~ delamination, folding, cracking or tearing of the metal tape or foil, or buckling or crossing of the screen wires.

G.2 Adhesion and peel strength ~~of metal foil~~

G.2.1 General

Adhesion and peel strength are defined as

$$F / w$$

where:

F is the force (N);

w is the width of the 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, the adhesion strength and peel strength of the laminated covering shall be as high as possible.

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.

In the case of an SscD design (separate semi-conductive design – SscD design with separated electrical and radial watertightness properties with semi-conductive plastic-coated foil), the test cannot be performed because the metal foil is so thin that it breaks during the adhesion or peeling strength test.

NOTE Examples of the different designs as described above can be found in IEC TR 61901 [1].

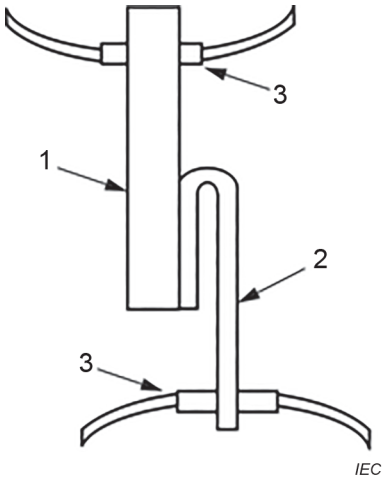
G.2.2 ~~Procedure~~ Test: Adhesion strength

The test specimens shall be taken from the cable covering where the metal tape or foil ~~is adhered~~ adheres to the oversheath.

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

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 ~~or the insulation screen~~ in one grip. The free end of the metal tape or foil shall be turned back and clamped in the other grip as shown in Figure G.1.



Key

1 oversheath

2 metal tape or foil ~~or laminated metal foil~~

3 grips

Figure G.1 – Adhesion of metal tape or foil

The specimen ~~shall~~ should be ~~maintained~~ held approximately vertically in the plane of the grips during the test ~~by holding the specimen~~.

After adjusting the continuous recording device, the metal tape or 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 ~~with~~ at a speed of approximately 50 mm/min.

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

~~**F.2.2 Requirements**~~

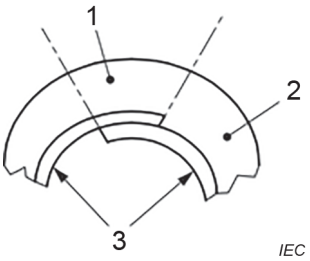
~~The adhesion strength shall then be calculated by dividing the peel force, in newtons, by the width of the specimen, in millimetres. At least five specimens shall be submitted to the test and the minimum value of the adhesion strength shall not be less than 0,5 N/mm.~~

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

G.2.3 Test: Peel strength of overlapped metal foil

~~**F.3.1 Procedure**~~

A sample specimen of approximately 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 G.2.



Key

1 specimen

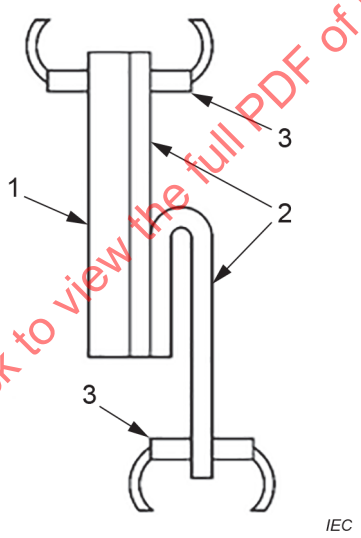
2 oversheath

3 metal foil or laminated metal foil

Figure G.2 – Example of overlapped metal foil

The test shall be conducted in the same manner as described ~~in Clause F.2~~ for the adhesion strength test. The arrangement of the test specimen is shown in Figure G.3.

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



Key

1 oversheath

2 metal foil or laminated metal foil

3 grips

Figure G.3 – Peel strength of overlapped metal foil

G.2.4 Requirements

~~The minimum value of the peel strength shall not be less than 0,5 N/mm.~~

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

The strength shall be recorded against the spacing of the grips. Typical recordings are shown in Figure G.4 and Figure G.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 steady state is achieved. The minimum strength F_{min} shall be determined for an increase in the spacing between the grips of at least

50 mm. A tensile testing machine with either a direct output for the minimum value or a graphical output can be used. Figure G.4 and Figure G.5 give typical curves from a graphical output machine and indicate how they shall be interpreted.

Minimum acceptable adhesion and peel strength forces are shown in Table G.1.

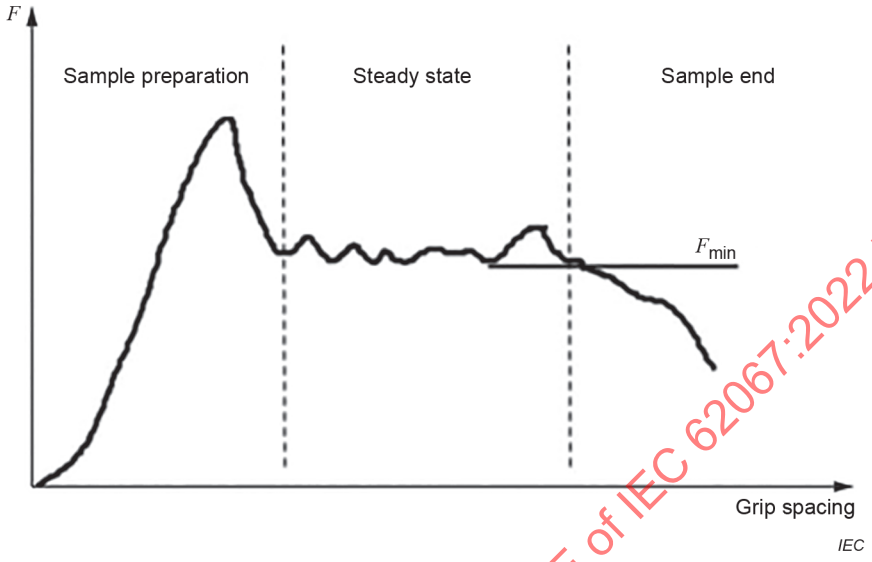


Figure G.4 – Typical strength versus grip spacing curve (1)

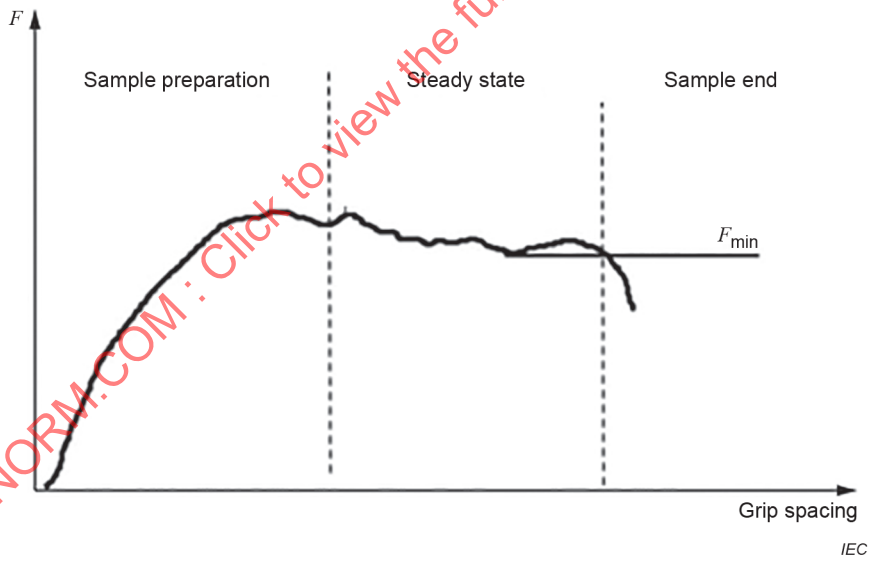


Figure G.5 – Typical strength versus grip spacing curve (2)

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

Adhesion or peel strength F_{min}	Type of screen					
	CD		SD		SscD	
N/mm	Copper	1,5	Copper	1,0	Lead	NA
N/mm	Aluminium	1,5	Aluminium	1,0	Aluminium	NA
N/mm	Overlap	1,5	Overlap	1,0	Overlap	NA
Key NA: The test cannot be performed.						

Annex G
(normative)

Tests of outer protection for joints

G.1 General

This annex specifies the procedure to be adopted for type approval testing of joint outer protection of all types, used in buried joints or sheath interrupters employed on insulated sheath power cable systems and, where employed, the associated sheath sectionalising insulation with screen interruption.

The manufacturer of the joint shall provide a drawing in which all water-protection barriers are clearly identified.

G.2 Range of approval

Where approval is required for joint outer protection embodying entries for items such as bonding leads, the outer protection tested shall include these design features.

A successful test on the joint outer protection for a sheath sectionalising insulation accessory for the diameters of complete cable for which approval is being sought in accordance with 12.2, will give approval to such protection for a similar accessory without sheath sectionalising insulation, but not the converse.

Where approval is granted for a design of joint outer protection, then all joint outer protections offered by the same manufacturer, embodying the same basic design principles, employing the same materials and within the diameter range tested, at equal or lower test voltages, shall be deemed to be approved.

The tests in Clauses G.3 and G.4 shall be applied successively to a joint which has passed the heating cycle voltage test (see 12.4.6) or to a separate joint which has undergone at least three thermal cycles without voltage, as specified in 12.4.2, item h), NOTE 2.

G.3 Water immersion and heat cycling

The test assembly shall be immersed in water to a depth of not less than 1 m at the highest point of the outer protection. Where desired, this may be achieved by using a header tank connected to a sealed-off vessel containing the test assembly. Water shall have access to the water barrier(s) declared by the manufacturer.

A total of 20 heating/cooling cycles shall be applied by raising the water temperature to within 15 K to 20 K below the maximum temperature of the cable conductor in normal operation. In each cycle the water shall be raised to the specified temperature, maintained at that level for at least 5 h and then be permitted to cool to within 10 K above ambient temperature. The test temperature may be achieved by mixing the water with water of higher or lower temperature. The minimum duration of each heating cycle shall be 12 h and the duration for raising the water temperature to the specified temperature shall be as much as possible the same as the duration for cooling the water equal to or less than 30 °C or 10 K above ambient temperature.

G.4 Voltage tests

G.4.1 General

On completion of the heating cycles, and with the test assembly still immersed, voltage tests shall be carried out as follows.

G.4.2 Assemblies embodying accessories without sheath sectionalising insulation

A test voltage of 25 kV d.c. shall be applied for 1 min between the metal screen/sheath of the power cable and the earthed exterior of the joint outer protection.

G.4.3 Assemblies embodying sheath sectionalising insulation

G.4.3.1 DC voltage tests

A test voltage of 25 kV d.c. shall be applied for 1 min between the metal screens/sheaths of the power cable, at either end of the accessory, and also between the metal screens/sheaths and the earthed exterior of the joint outer protection.

G.4.3.2 Impulse voltage tests

To test each part to earth, a test voltage in accordance with Table G.1 shall be applied between the metal screens/sheaths and the exterior of the assembly whilst immersed. If it is not practicable to carry out the impulse test on the assembly whilst immersed, it may be removed from the water and impulse tested with a minimum of delay or it may be maintained wet by wrapping with a wet fabric, or a conductive coating may be applied over the entire exterior surface of the test assembly.

For the test between the metal screens/sheaths, the assembly shall be removed from the water before the impulse test.

The testing procedure shall be performed in accordance with IEC 60230, the joint being at ambient temperature.

Table G.1 – Impulse voltage tests

Rated lightning impulse voltage for main insulation[a] kV	Impulse level			
	Between parts		Each part to earth	
	Bonding leads ≤ 3 m kV	Bonding leads > 3 m and ≤ 10 m[b] kV	Bonding leads ≤ 3 m kV	Bonding leads > 3 m and ≤ 10 m[b] kV
1 050	60	95	30	47,5
1 175 to 1 425	75	125	37,5	62,5
1 550	75	145	37,5	72,5

[a] See Table 4, column 8.

[b] If sheath voltage limiters are placed adjacent to the joint, the voltages for bonding leads ≤3 m are used.

No breakdown shall occur during any of the above tests.

NOTE It may be considered to perform the voltage tests of Clause G.4 (in reverse order) before starting the heat cycling in order to check the proper installation of the assembly.

~~**G.5 Examination of test assembly**~~

~~On completion of the tests described in Clause G.4, the test assembly shall be examined.~~

~~Joint outer protection boxes filled with removable compounds shall be regarded as satisfactory if there is no visible evidence of either internal voids or internal displacement of compound by water ingress, or of compound loss via the various seals or box walls.~~

~~For joint outer protections employing alternative designs and materials, there shall be no evidence of water ingress or internal corrosion.~~

Annex H
(normative)

Additional tests for accessories

H.1 General

Annex H specifies the procedure for additional tests, which are either type tests or extension of qualification tests for accessories for:

– joints with or without screen interruption;
– accessories for cable screen interruption and/or earth connection;
– terminations with an insulated screen;
– insulators for outdoor terminations;
– gas immersed terminations, when changing the insulating gas in the cable connection enclosure.

Accessories specified for installation in air only can be tested without the water immersion test, subject to agreement between purchaser and manufacturer. The risk of presence of water, for example in terms of tunnel installation or any other risk of temporary exposure of joints or accessories to water, should be considered in this case.

Accessories tested with the water immersion test are compliant when used for installation in air as well as in other situations. Accessories tested without the water immersion test are not compliant when used for buried installation or in an environment with the risk of exposure to water.

The manufacturer of the accessory shall provide a drawing in which all relevant features tested under this annex are clearly defined and identified.

Table H.1 lists the test procedures for different types of accessories.

Table H.1 – Test sequence

Test sequence	Joints without screen or metal sheath interruption and cable accessories without a screen or metal sheath/screen interruption (e.g. earth connection)	Joints with screen or metal sheath interruption and cable accessories with a screen or metal sheath/screen interruption (e.g. earth connection and/or cross bonding applications)	Terminations with an insulated screen	Insulators for outdoor terminations	Change of insulating gas for gas immersed termination
	Clause H.3	Clause H.3	Clause H.4	Clause H.4.4	Clause H.6
Subjected to 20 thermal cycles with or without voltage	X	X	X[b]	–	–
Water immersion conditioning (20 thermal cycles)	X[a]	X[a]	–	–	–
DC voltage withstand test screen to earth	X	X	X	–	–
DC voltage withstand test screen to screen	–	X	–	–	–
Lightning impulse voltage withstand test screen to earth	X	X	X	–	–
Lightning impulse voltage withstand test screen to screen	–	X	–	–	–
Internal pressure test	–	–	–	X	–
Cantilever load test	–	–	–	X	–
Examination	X	X	X	–	–
Electrical tests	–	–	–	–	X
Leak rate test	–	–	–	–	X

[a] Not applicable to accessories for installation in air, tested without water immersion.

[b] Not applicable if the sheath sectionalizing insulation is external to the main body of the accessory, see H.4.1.

H.2 Range of approval

H.2.1 Range of approval for joints without screen or metal sheath interruption

When the test sequence according to this annex has been successfully performed for a joint design without screen interruption, the type approval shall be considered as valid for all joints without screen interruption for the same conductor size or smaller, embodying the same basic design principles and the same materials tested at equal or lower test voltages.

Where approval is required for joint outer protection embodying entries for items such as bonding leads, the outer protection tested shall include these design features.

A successful test on the joint outer protection with embodying entries will give approval to such outer protection for a similar joint without embodying entries, but not the converse.

H.2.2 Range of approval for joints with screen or metal sheath interruption

When the test sequence according to this annex has been successfully performed for a joint design with screen interruption, the type approval shall be considered as valid for all joints with or without screen interruption for the same conductor size or smaller, embodying the same basic design principles and the same materials tested at an equal or lower voltage group.

Where approval is required for joint outer protection embodying entries for items such as bonding leads, the outer protection tested shall include these design features.

A successful test on the joint outer protection with embodying entries will give approval to such outer protection for a similar joint without embodying entries, but not the converse.

H.2.3 Range of approval for accessories for cable screen interruption and/or earth connection

When the test sequence according to this annex has been successfully performed on a cable with screen or metal sheath interruption, the type approval shall be considered as valid for all cables with screen or metal sheath interruption offered by the same manufacturer, embodying the same basic design principles, at an equal or lower voltage group.

H.2.4 Range of approval for terminations with an insulated screen

When the test sequence according to this annex has been successfully performed for terminations with an insulated screen, the type approval shall be considered as valid for all terminations without an insulated screen, offered by the same manufacturer, embodying the same basic design principles, at an equal or lower voltage group.

H.3 Tests of joints with or without screen or metal sheath interruption and accessories for cable screen interruption and/or earth connection

H.3.1 Conditioning of sample for test

The test of joints, cables with a metal sheath interruption and accessories for cable screen interruption and/or earth connection, shall be applied to an accessory which has passed the heating cycle voltage test (see 12.4.6) or to a separate accessory which has undergone at least 20 thermal cycles according to 12.4.6 but without voltage applied.

If the accessory is not to be subjected to wet conditions in service (i.e. not directly buried in earth or not intermittently or continuously immersed in water), the test in H.3.2 can be omitted.

H.3.2 Water immersion test

The assembly to be approved shall be immersed in water to a depth of not less than 1,0 m at the highest point of the outer protection. Where desired, this can be achieved by using a header tank connected to a sealed-off vessel containing the test assembly.

Additional voltage tests according to H.3.3 can be carried out before commencing the heating/cooling cycles, at the discretion of the manufacturer.

A total of 20 heating/cooling cycles shall be applied by raising the water temperature to within 15 K to 20 K below the maximum temperature of the cable conductor in normal operation. In each cycle, the water shall be raised to the specified temperature, maintained at that level for at least 5 h and then be permitted to cool to within 10 K above the ambient temperature. The test temperature can be achieved by mixing the water with water of higher or lower temperature. The minimum duration of each cycle of heating and cooling shall be 12 h and the duration for raising the water temperature to the specified temperature shall be as much as possible the same as the duration for cooling the water to within 30 °C or 10 K above the ambient temperature, whichever is the higher.

H.3.3 Electrical tests

H.3.3.1 General

For accessories subjected to the water immersion test, voltage tests shall be carried out on completion of the heating cycles in water, with the test assembly still immersed. If it is not practicable to carry out the electrical tests whilst the assembly is still immersed in water, the assembly can be removed from the water and the voltage tests carried out with a minimum of delay. In this case, earthing of the test object can be achieved by wrapping with a wet fabric, or by using a conductive coating applied over the entire exterior surface of the test assembly.

For accessories without a water immersion, test earthing of the test object can be achieved by wrapping with a conductive tape or mesh, or using a conductive coating applied over the entire exterior surface of the test assembly.

All accessories shall be subjected to the tests in H.3.3.2 and H.3.3.4. In addition, accessories with a screen or metal sheath interruption shall also be subjected to the tests in H.3.3.3 and H.3.3.5. In both cases the tests shall be carried out in the order given below. All tests in this annex shall be carried out at ambient temperature if not specified otherwise.

No breakdown of the test object shall occur during any of the electrical withstand tests. Failure or flashover of a termination of the cable shall not be considered a failure of the test object.

H.3.3.2 DC voltage withstand test between screen and earth

A test voltage of 25 kV DC shall be applied for 1 min between the metal screen or sheath and the earthed exterior of the test object.

H.3.3.3 DC voltage withstand test between screen and screen

A test voltage of 25 kV DC shall be applied for 1 min between both sides of the metal screen or sheath interruption of the test object.

H.3.3.4 Lightning impulse voltage withstand test between screen and earth

A test voltage in accordance with Table H.2 shall be applied between the metal screens/sheaths and the exterior of the assembly.

The testing procedure shall be performed in accordance with IEC 60230.

Table H.2 – Lightning impulse voltage withstand test between screen and earth of joints with or without screen or metal sheath interruption and accessories for cable screen interruption and/or earth connection

Rated lightning impulse voltage for main insulation[a] kV	Lightning impulse level – metal screen to earth kV
1 050	47,5
1 175 to 1 425	62,5
1 550	72,5
[a] See Table 4, column 8.	

H.3.3.5 Lightning impulse voltage withstand test between screen and screen

Before the lightning impulse test between the metal screens/sheaths, the assembly shall be removed from the water, if applicable.

To test between parts, a test voltage in accordance with Table H.3 shall be applied.

The testing procedure shall be performed in accordance with IEC 60230.

Table H.3 – Lightning impulse voltage withstand test between screen and screen of joints with screen or metal sheath interruption and accessories for cable screen interruption and/or earth connection

Rated lightning impulse voltage for main insulation[a] kV	Lightning impulse level – between parts kV
1 050	95
1 175 to 1 425	125
1 550	145
[a] See Table 4, column 8.	

H.3.4 Examination

The examination of the accessories shall be done as stated in 12.4.8.1 and in addition for accessories subjected to the water immersion test:

– the accessory shall be examined with respect to the defined and clearly identified water-protection barriers (see Clause H.1);

– outer protection boxes filled with removable compounds shall be regarded as satisfactory if there is no visible evidence of either internal voids or internal displacement of compound by water ingress, or of compound loss via the various seals or box walls;

– for outer protections employing alternative designs and materials, there shall be no evidence of water ingress or internal corrosion behind the defined water-protection barriers.

H.4 Tests of terminations with an insulated screen

H.4.1 Conditioning of sample for test

The test of terminations with an insulated screen shall be applied to an accessory which has passed the heating cycle voltage test (see 12.4.6) or to a separate accessory which has undergone at least 20 thermal cycles according to 12.4.6 but without voltage applied. This requirement can be omitted if the screen insulation is external to the main body of the accessory, for example in the case of support insulators.

H.4.2 DC voltage withstand test between screen and earth

A test voltage of 25 kV DC shall be applied for 1 min between the screen and earth.

H.4.3 Lightning impulse voltage withstand test between screen and earth

A test voltage in accordance with Table H.4 shall be applied between the screen and earth.

The testing procedure shall be performed in accordance with IEC 60230.

Table H.4 – Lightning impulse voltage withstand tests between screen and earth of terminations with an insulated screen

Rated lightning impulse voltage for main insulation[a] kV	Lightning impulse level – metal screen to earth kV
1 050	47,5
1 175 to 1 425	62,5
1 550	72,5

[a] See Table 4, column 8.

H.4.4 Examination

The examination of the accessories shall be done as stated in 12.4.8.1.

H.5 Tests for insulators for outdoor terminations

H.5.1 Tests for ceramic insulators

H.5.1.1 General

One insulator of each type shall be subjected to the tests given in H.5.1.2 and H.5.1.3. Alternatively, a certificate or test report can be provided, as acceptable evidence of testing as specified in 12.2.

H.5.1.2 Internal pressure test

For insulators which will be pressurized in service, the type test pressure test shall be carried out according to IEC 62155.

The requirements of IEC 62155 shall be met.

H.5.1.3 Cantilever load withstand test

The cantilever load withstand test shall be carried out according to IEC 60137. The test load for insulators designed for Level I and Level II cantilever loads shall be in accordance with Table 11. The test load for insulators designed for other cantilever loads shall be subject to agreement between the purchaser and the manufacturer.

There shall be no evidence of damage (deformation, rupture or leakage).

H.5.2 Tests for composite insulators

H.5.2.1 General

One insulator of each type shall be subjected to the tests according to IEC 61462 as given in H.5.2.2 and H.5.2.3. Alternatively, a certificate or test report can be provided, as acceptable evidence of testing as specified in 12.2.

H.5.2.2 Internal pressure test

For insulators which will be pressurized in service, the internal pressure test according to IEC 61462 shall be carried out. The requirements of IEC 61462 shall be met.

H.5.2.3 Bending test

The bending test according to IEC 61462 shall be carried out for the declared MML value for the insulator, see Clause 7. The requirements of IEC 61462 shall be met.

H.6 Tests for gas-immersed terminations in case of changing insulating gas

H.6.1 General

The tests in H.6.2 and H.6.3 shall be carried out in order to approve a design of gas immersed termination for use with an alternative gas, to that used during a type test, in the cable connection enclosure.

In addition, the type test for the pressure test on the insulator, according to IEC 62271-209, shall be carried out if the design pressure of the insulator required for the alternative gas is higher than the design pressure for which the insulator has previously been type tested.

The compatibility of new gases or gas mixture with the components, especially seals, of the cable termination shall be considered to avoid the possibility of leaks developing in service. Other technical aspects can require evaluation depending on the nature of the alternative gas.

H.6.2 Electrical tests

H.6.2.1 Test assembly

The gas immersed termination shall be installed in a cable connection enclosure in accordance with 8.6. There shall be at least 5 m of free cable between the gas immersed termination and any other accessory. The termination shall be heated by conductor current for the tests in H.6.2.3 and H.6.2.4.

H.6.2.2 Partial discharge test at ambient temperature

A partial discharge test shall be carried out at ambient temperature according to 12.4.4.

H.6.2.3 Impulse voltage tests

Impulse voltage tests shall be carried out according to 12.4.7.

H.6.2.4 Partial discharge test at high temperature

A partial discharge test at high temperature shall be carried out according to 12.4.4.

H.6.3 Leak rate test

The leak rate type test on the insulator of a cable termination according to IEC 62271-209 shall be carried out.

The requirements of IEC 62271-209 shall be met.

Annex I
(informative)

Guidance on examination of cable and accessories

It should be noted that it is not possible to specify objective acceptance criteria for all possible types of deterioration (such as deformation or changes) that can be encountered during a visual inspection.

The visual inspection will therefore always contain some degree of subjectivity. To reduce this problem a list of possible types of deterioration that can be encountered during a visual inspection is given in this annex.

When carrying out an examination, care should be taken to avoid contamination of samples, keeping in mind that the overall purpose is to check for signs of deterioration which could affect the operation of a cable system in service.

In some cases, it can be helpful to have an untreated sample of the cable or accessory (or components of an accessory) as a reference for the visual inspection.

Samples of cable, possibly taken from different positions in the tested length, and accessories, for example one of the joints and terminations, should be subjected to the visual inspection, as required by this document.

Examination of the samples with normal or corrected vision without magnification should not reveal any deterioration of the types listed below. The following list is not exhaustive, so any unexpected or unusual changes shall also be considered and their potential effects on operation of a cable system in service considered by the examining persons when making a decision as to their acceptability or otherwise.

– damage to the conductor which could have a detrimental effect on the cable performance;
– harmful indentations in the cable core(s), sharp indentations of the semi-conductive screen into the insulation;
– presence of corrosion on metallic parts, for example metallic screen and connections;
– indication of possible mechanical degradation in the dielectric parts;
– indication of possible electrical degradation in primary insulation of accessory and cable: shrinkage, deformation or other distortions that can affect compliance with the requirements of the relevant product specification, for example creepage distances should not fall below minimum acceptable values and there should not be any change that would make any hazardous part accessible;
– indication of thermal degradation (all components);
– cracking or damage to the insulation;
– damage on the cable sheath which could have a detrimental effect on the cable performance for example water ingress, possibly leading to corrosion in the long term;
– leak or emission of insulating fluid: any leakage of material involved in the insulation of an accessory should be reported;
– significant change in dimensions which could have a detrimental effect on the cable or accessory performance.

Annex J
(informative)

Guidance for type test on heating-cycle-voltage-test interruption and cycle validity

J.1 Interruption of cycles during a heating cycle voltage test

J.1.1 Scheduled interruption of test

During the interruption, no heating cycles are applied to the cable system. As the interruption of the test is scheduled, the interruption is made after ending of a complete heating cycle. After the interruption period, the test is restarted by applying the test voltage together with the start of a new heating cycle. Only complete applied heating cycles count towards the required number of heating cycles. Planning of interruptions to influence the outcome of the test is not allowed.

J.1.2 Non-scheduled interruption of test

a) If the cause of a non-scheduled interruption is detected and corrected within 15 min it can be treated as a controlled interruption of test, as detailed in J.1.1.

b) More often, the delay is more than 15 min and the non-scheduled interruption takes place somewhere during the heating cycle. In such a case, after clearing the cause of the interruption, the test should be restarted after the temperature of the conductor has reached a temperature less than or equal to 30 °C or within 15 K of ambient temperature, whichever is the higher, but with a maximum of 45 °C.

The interrupted heating cycle does not count towards the required number of heating cycles.

J.2 Valid heating cycles

Valid heating cycles are those for which:

- there are no interruptions other than as given in J.1.2, item a);
- test voltage, at the specified value, is applied continuously;
- the temperature of the cable conductor, at the start of the cycle and at the end of the cycle, is within the range given in J.1.2, item b) above;
- the temperature of the cable conductor at the hot part of the cycle is at or above the minimum value specified for at least the time specified;
- the ambient temperature is within the range specified;
- the length of the cycle is at least 24 h and the heating is applied for at least 8 h;
- there are records confirming the above points.

Annex K
(normative)

Methods for determining the weighted value of halogen content of the non-metallic materials in the cable

K.1 Calculating the weighted value for the cable when the halogen content of individual non-metallic material is tested

Measure the weight, w_i, of each non-metallic material, i, per unit length of cable.

The weighted value for the halogen content of non-metallic materials in the cable, H_i' for each halogen (i.e. F, Cl, Br, I), is calculated as follows:

$$H_i' = \frac{\Sigma(H_i \times w_i)}{\Sigma w_i}$$

Where H_i is the halogen content of the individual material of weight w_i.

The sum of the weighted values of the halogen content of non-metallic materials in the cable of the four individual halogens (F, Cl, Br, I), i.e. $\Sigma H_i'$, shall be calculated.

K.2 Preparation of the test sample for measurement of halogen content on a sample representative of the non-metallic materials in the cable

A sample of length 15 mm to 25 mm of the cable shall be cut into small pieces after all metal elements have been removed. The sample shall be of sufficient length to give the required weight of test specimen. The cable components shall be cut into small pieces no larger than 3 mm.

The pieces should be well mixed and the test sample shall be taken from the mixture.

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INTERNATIONAL STANDARD

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Power cables with extruded insulation and their accessories for rated voltages above 150 kV (U_m = 170 kV) up to 500 kV (U_m = 550 kV) – Test methods and requirements

Câbles d'énergie à isolation extrudée et leurs accessoires pour des tensions assignées supérieures à 150 kV (U_m = 170 kV) et jusqu'à 500 kV (U_m = 550 kV) – Méthodes et exigences d'essai

IEC 62067:2022-04(en-fr)

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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POWER CABLES WITH EXTRUDED INSULATION AND THEIR ACCESSORIES FOR RATED VOLTAGES ABOVE 150 kV (U_m = 170 kV) UP TO 500 kV (U_m = 550 kV) – TEST METHODS AND REQUIREMENTS

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IEC 62067 has been prepared by IEC technical committee 20: Electric cables. It is an International Standard.

This third edition cancels and replaces the second edition published in 2011. This edition constitutes a technical revision.

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

a) A new material class (ST_{12}) is introduced which has fire performance requirements.
b) A full range of fire performance tests is available which can be selected on the basis of claimed cable performance characteristics.

c) The range of cable metal screen designs and the bending test has been revised in line with IEC TR 61901 [1][1].

d) Requirements are introduced for outdoor termination insulators.

e) Design and testing requirements for gas immersed terminations (and their separating insulating barriers) are coordinated with IEC 62271-209. An additional type test is required where the separating insulating barrier is installed by the switchgear manufacturer.

f) A separate water penetration test for the cable conductor is required.

g) AC voltage testing of the insulation after installation has been revised in line with recently published CIGRE recommendations.

h) Tests have been added for a change in the type of insulating gas used in the cable connection enclosure of a gas immersed termination.

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

Draft	Report on voting
20/2017/FDIS	20/2020/RVD

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

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/standardsdev/publications.

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

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

[1] Numbers in square brackets refer to the bibliography.

INTRODUCTION

As a result of major developments in cable systems with extruded insulation for voltages above 150 kV, CIGRE Study Committee (SC) 21 set up Working Group (WG) 21.03 in 1990. The terms of reference of WG 21.03 were "*to prepare recommendations for electrical type tests, sample and routine tests, based on extending IEC 60840:1988 up to 400 kV and to make proposals for prequalification/development tests which, as a minimum, should be performed*".

WG 21.03 reported that the extension of IEC 60840 [2] to voltages above 150 kV needed extra consideration because of the following factors:

1) such cables form part of the backbone of the transmission system and, therefore, reliability considerations are of the highest priority;
2) these cables and their accessories operate with higher electrical stresses than cables up to 150 kV and, as a result, have a smaller safety margin with respect to the intrinsic performance boundaries of the cable system;
3) such cables and accessories have a thicker insulation wall than those up to 150 kV and, as a result, are subjected to greater thermo-mechanical effects;
4) the design and coordination of the cables and accessories become more difficult with increasing system voltage levels.

The recommendations of the WG 21.03 were published in Electra No. 151 [3] [4] in December 1993 and taken into account by IEC in 1995 in the preparation of this standard for cable systems with extruded insulation for voltages above 150 kV. IEC considered that the new standard should also cover the 500 kV level. Thus, at its meeting in September 1996, CIGRE SC 21 set up a task force 21.18 to study the extension of the initial recommendations to the 500 kV level. The resulting updated recommendations were taken into account by IEC Technical Committee (TC) 20 in the preparation of the first edition of this standard.

On the advice of CIGRE, a long term accelerated ageing test was introduced in the first edition, in order to gain some indication of the long term reliability of a cable system. This test, known as the "prequalification test", was to be performed on the complete system comprising the cable, joints and terminations in order to demonstrate the performance of the system.

In addition, CIGRE WG 21.09, published recommendations for "tests after installation on high-voltage extruded insulation cable systems" in Electra No. 173 [5] in August 1997. These recommendations (which state, amongst other things, that DC tests should be avoided on the main insulation, as they are both ineffective and potentially damaging) were also taken into account in the first edition of this standard.

At its meeting in November 2004, TC 20 concluded that the next revision of IEC 62067 should include the recommendation for testing of HV and EHV extruded cables that was under preparation by the CIGRE SC B1 (previously SC 21) WG B1.06. This was made available as a CIGRE Technical Brochure 303 [6] before the meeting of TC 20 in October 2006, which confirmed this view. Therefore, Technical Brochure 303 has been considered by TC 20 and major parts have been implemented in this standard. This has resulted in some modifications to the prequalification test requirements, a major change being the addition of the extension of the prequalification test. The latter test requires approximately one quarter of the time to complete when compared with the full prequalification test.

This third edition of IEC 62067 has been produced as part of the normal periodic review and updating procedures of IEC taking into account progress and developments within the energy industry.

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

POWER CABLES WITH EXTRUDED INSULATION AND THEIR ACCESSORIES FOR RATED VOLTAGES ABOVE 150 kV (U_m = 170 kV) UP TO 500 kV (U_m = 550 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 installations, for rated voltages above 150 kV (U_m = 170 kV) up to and including 500 kV (U_m = 550 kV).

The requirements apply to single-core cables and to their accessories for usual conditions of installation and operation, but not to special cables and their accessories, such as submarine cables, for which modifications to the standard tests can be necessary or special test conditions that may need to be devised.

This document does not cover transition joints between cables with extruded insulation and paper insulated cables.

2 Normative references

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

IEC 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 60137, *Insulated bushings for alternating voltages above 1000 V*

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

IEC 60332-1-2, *Tests on electric and optical fibre cables under fire conditions – Part 1-2: Test for vertical flame propagation for a single insulated wire or cable – Procedure for 1 kW pre-mixed flame*

IEC 60332-1-3, *Tests on electric and optical fibre cables under fire conditions – Part 1-3: Test for vertical flame propagation for a single insulated wire or cable – Procedure for determination of flaming droplets/particles*

IEC 60332-3-24, *Tests on electric and optical fibre cables under fire conditions – Part 3-24: Test for vertical flame spread of vertically-mounted bunched wires or cables – Category C*

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

IEC 60754-3, *Test on gases evolved during combustion of materials from cables – Part 3: Measurement of low level of halogen content by ion chromatography*

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

IEC 60811-202:2012, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 202: General tests – Measurement of thickness of non-metallic sheath*
IEC 60811-202:2012/AMD1:2017

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

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

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

IEC 60811-409, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 409: Miscellaneous tests – Loss of mass test for thermoplastic insulations and sheaths*

IEC 60811-501:2012, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 501: Mechanical tests – Tests for determining the mechanical properties of insulation and sheathing compounds*
IEC 60811-501:2012/AMD1:2018

IEC 60811-505, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 505: Mechanical tests – Elongation at low temperature for insulations and sheaths*

IEC 60811-506, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 506: Mechanical tests – Impact test at low temperature for insulations and sheaths*

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

IEC 60811-508:2012, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 508: Mechanical tests – Pressure test at high temperature for insulations and sheaths*
IEC 60811-508:2012/AMD1:2017

IEC 60811-509, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 509: Mechanical tests – Tests for resistance of insulations and sheaths to cracking (heat shock test)*

IEC 60811-605:2012, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 605: Physical tests – Measurement of carbon black and/or mineral filler in polyethylene compounds*

IEC 60811-606, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 606: Physical tests – Methods for determining the density*

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

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

IEC 61462, *Composite hollow insulators – Pressurized and unpressurized insulators for use in electrical equipment with rated voltage greater than 1 000 V – Definitions, test methods, acceptance criteria and design recommendations*

IEC 62155, *Hollow pressurized and unpressurized ceramic and glass insulators for use in electrical equipment with rated voltages greater than 1 000 V*

IEC 62271-209, *High-voltage switchgear and controlgear – Part 209: Cable connections for gas-insulated metal-enclosed switchgear for rated voltages above 52 kV – Fluid-filled and extruded insulation cables – Fluid-filled and dry-type cable-terminations*

3 Terms and definitions

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

IEC and ISO 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 relating to 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 this document, in order to demonstrate satisfactory performance characteristics to meet the intended application

Note 1 to entry: Type tests are of such a nature that, after they have been made, they need not be repeated unless changes are made in the materials, design or type of manufacturing process of cable or accessory which might change the performance characteristics.

3.2.4
prequalification test
PQ test
test made before supplying, on a general commercial basis, a type of cable system covered by this document, in order to demonstrate satisfactory long term performance of the complete cable system

3.2.5
extension of prequalification test
EQ test
test made before supplying, on a general commercial basis, a type of cable system covered by this document, in order to demonstrate satisfactory long term performance of the complete cable system, taking into account an already prequalified cable system

3.2.6
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 purchaser request. Tests to be defined on agreement between purchaser 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

Note 1 to entry: The equations for calculation of the stresses are given in Clause 6, item n).

Note 2 to entry: Electrical stress is expressed in kV/mm.

3.3.3
combined design
CD
metal screen design that combines radial watertightness and electrical properties

Note 1 to entry: Details of the construction are given in 4.3.

3.3.4
separate design
SD
metal screen design that uses different metal components for radial watertightness and electrical properties

Note 1 to entry: Details of the construction are given in 4.3.

3.3.5
separate semi-conductive design
SscD
metal screen design that has separated electrical and radial watertightness properties and uses semi-conductive plastic-coated foil

Note 1 to entry: Details of the construction are given in 4.3.

3.3.6
nominal conductor cross-sectional area
size of the cable conductor in accordance with IEC 60228

3.3.7
maximum mechanical load
MML
highest mechanical cantilever load which is expected to be applied to a composite outdoor termination insulator in service and for which it is designed

3.3.8
maximum service pressure
MSP
highest difference between the maximum absolute internal pressure, when the equipment (of which a composite hollow insulator is a part) is carrying its rated normal current at maximum operational temperature and the normal outside pressure

3.3.9
cable accessory with screen or metal sheath interruption
cable accessory where the metal screen/sheath and insulation screen of the cable are electrically interrupted

3.3.10
joint with screen or metal sheath interruption
joint where the metal screen/sheath and insulation screen of the cable are electrically interrupted

3.3.11
termination with an insulated screen
termination where the metal screen/sheath and insulation screen of the cable are electrically interrupted to the ground

4 Voltage designations, materials and rounding of numbers

4.1 Rated voltages

In this document, the symbols U_0, U and U_m are used to designate the rated voltages of cables and accessories where these symbols have the meanings given in IEC 60183 [7].

4.2 Cable insulating compounds

This document applies to cables insulated with one of the compounds listed in Table 1, which also specifies, for each type of insulating compound, the maximum operating conductor temperatures on which the specified test conditions are based.

It is recommended that cable cores with a cross-linked insulation system should have been degassed.

4.3 Cable metal screens/sheaths

This document applies to the various designs in use. It covers designs providing a radial watertightness and designs that do not provide radial watertightness.

In all cases the metal screen/sheath shall be able to meet the screen short circuit rating.

Designs that provide radial watertightness mainly consist of:

– seamless or longitudinally welded metal sheaths;
– longitudinally applied metal tapes or foils bonded to the oversheath:
  - CD: a metal screen design using a metal tape or foil, with either a welded or glued overlap, that carries part or all of the screen short circuit current with, if necessary, metal wires to carry part of the short circuit current;
  - SD: a metal screen design using a laminated metal foil (coated on one or both sides) for radial watertightness, and metal wires for carrying the full screen short circuit current;
  - SscD: a metal screen design using a thin lead or aluminium foil coated with glue on the outer side and semi-conductive plastic on the underside, over a layer of semi-conductive tape, which is in turn over a layer of round copper wires.

  NOTE Definitions of CD, SD, and SscD are given in 3.3.3, 3.3.4 and 3.3.5.
– composite screens, involving a layer of wires and either a metal sheath or a metal tape or foil bonded to the oversheath, acting as a radial water impermeable barrier (see Clause 5),

  During development of the cable and cable system, with a longitudinally applied metal tape or foil bonded to the oversheath, the tests as specified in IEC TR 61901 [1] are recommended.

Designs which do not provide radial watertightness include:

– metal tapes or foils not bonded to the oversheath,
– a layer of metal wires only.

4.4 Cable oversheathing compounds

Tests are specified for five types of oversheath, as follows:

– ST_1 and ST_2 based on polyvinyl chloride (PVC);
– ST_3 and ST_7 based on polyethylene (PE);
– ST_{12} based on low smoke halogen free material (LSHF).

The choice of the type of oversheath depends on the design of the cable and the mechanical, thermal and fire performance required during installation and operation.

The maximum conductor temperatures in normal operation for the different types of oversheathing compounds covered by this document are given in Table 2.

If there is concern that the oversheath will be deteriorated by UV radiation, the oversheath shall be protected against UV radiation, which will be mutually agreed with the purchaser. Black PE oversheaths containing the required amount of a suitable and well-dispersed grade of carbon black (see Table 5) are protected against UV radiation.

NOTE 1 For installation in air as for example in tunnels or buildings, it is preferable for the cable to have some fire performance and low smoke and halogen free properties. For such applications, an ST_{12} (LSHF) oversheath can be applied.

NOTE 2 For some applications the oversheath can be covered by a functional layer (e.g. semi-conductive).

4.5 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 Precautions against water penetration in cables

When cable systems are installed in the ground, in locations with a risk of water ingress or corrosion or in water, a radial water impermeable barrier is recommended.

Longitudinal water barriers can also be applied in order to avoid the need to replace long sections of cable in case of damage in the presence of water.

A test for longitudinal water penetration is given in 12.5.15.

NOTE No test for radial water penetration is currently available.

6 Cable characteristics

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

The following characteristics shall be declared by the manufacturer:

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) fire performance: if ST_1, ST_2 or ST_{12} oversheath material is used (see 4.4 and Table 2), then the subclauses of 12.5.14.3, if any, to which compliance is claimed, shall be declared;

NOTE Fire performance is dependent on the cable design as well as the oversheath material.

d) type of conductor, its material and nominal cross-sectional area, in square mm; conductor construction; presence, if any, and nature of measures taken to reduce skin effect; presence, if any, and nature of measures taken to achieve longitudinal watertightness; if the nominal cross-sectional area is not in accordance with IEC 60228, the maximum DC conductor resistance, corrected to 1 km length and to 20 °C;

e) compound (as defined in Table 1) and nominal thickness of insulation (t_n) (see 4.2);

f) type of manufacturing process for insulation system;

g) presence, if any, and nature of watertightness measures in the screening area;

h) metal screen/sheath:

- constructional details of metal screen/sheath, for example, material and construction of metal screen, number and diameter of wires; material, construction and nominal thickness of metal sheath, or longitudinally applied metal tape or foil bonded to the oversheath, if any. For cables with longitudinal applied metal tape or foil bonded to the oversheath whether the type is CD or SD or SscD;
- maximum DC resistance of the metal screen/sheath, corrected to 1 km length and to 20 °C;

i) compound (as defined in 4.4 and Table 2) and nominal thickness of oversheath, and if applicable, nature and material of semi-conductive covering;

j) nominal diameter of the conductor (d);

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

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

m) nominal capacitance, corrected to 1 km length, between conductor and metal screen/sheath;

n) calculated nominal electrical stress 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

U_0 is the value declared in item b) above in kV;

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;

o) the design of any integrated optical element(s), if applicable.

7 Accessories characteristics

7.1 Gas immersed cable terminations

Gas immersed cable terminations shall be designed in accordance with IEC 62271-209.

7.2 Insulators for outdoor cable terminations

Insulators for outdoor cable terminations shall comply with the requirements given in Table 11 for Level I or II maximum cantilever operating load in service (or MML in the case of composite insulators). Level I refers to a normal load and shall be generally applied, unless a purchaser specifies a heavy load of Level II. Alternatively, a different value of maximum cantilever operating load or MML can be agreed between the purchaser and manufacturer.

7.3 Accessory characteristics to be declared

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 declared by the manufacturer:

a) cables used for testing accessories shall be correctly identified as in Clause 6;

b) a drawing shall be provided in which all relevant features tested under Annex H are shown, see Clause H.1;

c) current carrying connections used within the accessories shall be correctly identified, for both the conductor and metal screen/sheath, with respect to:

- assembly technique,
- type, reference number and any other identification of the connector,
- details of the type test approval of the connector if applicable;

d) accessories to be tested shall be correctly identified with respect to

- name of manufacturer,
- type, designation and manufacturing date or date code,

- rated voltage (see Clause 6, item b)),
- material type of rubber mouldings forming the main insulation (e.g. silicone rubber or EPDM),
- material type of dielectric fluid filling, if any,
- type of outer protection,
- whether the design includes sheath sectionalizing insulation,
- installation instructions (reference and date);

e) additional requirements for gas immersed terminations:

- design pressure for the outside of the termination insulator, see IEC 62271-209,
- type of insulating gas to be used in the cable connection enclosure (SF_6 or details of alternative gas type),
- whether or not the termination insulator is suitable for supply to the switchgear manufacturer, in order to confirm compatibility and performance for the installation in the switchgear before delivery to site, see IEC 62271-209,
- if suitable, the measures which are required to allow the switchgear routine test to be carried out without the cable present;

f) additional requirements for composite outdoor termination insulators:

- the MML value for the composite insulator, see 7.2,
- for insulators which will be pressurized in service, the MSP value;

g) additional requirements for ceramic outdoor termination insulators:

- the maximum cantilever operating load in service,
- for insulators which will be pressurized in service, the design pressure.

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.

8.2 High voltage tests

Unless otherwise indicated in this document, high voltage tests shall be carried out in accordance with IEC 60060-1. All high voltage tests in this document are withstand voltage tests.

No "atmospheric correction in dry tests" (IEC 60060-1) shall be applied to the test voltage values specified in this document.

8.3 Waveform of impulse test voltages

The waveforms of lightning and switching impulse tests shall be as given in 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 the determination of test voltages can 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 associated test voltages shall be established by calculation using the multipliers given in Table 4 or interpolation where no multiplier is given.

The test voltages in this document are based on the assumption that the cables and accessories are used on a system of category A, as defined in IEC 60183 [7].

8.5 Determination of the cable conductor temperature

It is recommended that one of the test methods described in Annex A is used to determine the actual conductor temperature.

8.6 Tests on gas immersed terminations

Electrical tests on gas immersed terminations shall be carried out in a cable connection enclosure with the diameter specified in IEC 62271-209 for the relevant value of rated voltage. The gas pressure requirements for electrical type tests given in IEC 62271-209 shall also be complied with.

9 Routine tests on cables and accessories

9.1 General

The following tests shall be carried out on each manufactured length of cable:

a) partial discharge test (see 9.2);

b) voltage test (see 9.3);

c) electrical test on oversheath of the cable, if required (see 9.4).

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

The main insulation of prefabricated accessories shall undergo partial discharge (see 9.2) and voltage (see 9.3) routine tests according to either 1), 2) or 3) below:

1) on the main insulation of prefabricated accessories installed on the cable;

2) by using a host accessory into which a component of an accessory is substituted for the test;

3) by using a simulated accessory rig in which the electrical stress environment of a main insulation component is reproduced.

In cases 2) and 3), the test voltage shall be selected so as to obtain at least the same electrical stresses as those on the component in a complete accessory when subjected to the test voltages specified in 9.2 and 9.3.

The insulator of a gas immersed termination shall also be subjected to the routine tests given in IEC 62271-209.

Outdoor termination insulators, which will be subjected to internal gas pressure in service, shall be subjected to the routine pressure test according to IEC 61462 for composite insulators, or IEC 62155 for ceramic insulators. No failure shall occur.

Routine tests do not apply to accessories taped and/or moulded on-site.

NOTE The main insulation of prefabricated accessories consists of the components that come in direct contact with the cable insulation or are necessary to control the electric stress distribution in the accessory. Examples are pre-moulded or precast elastomer or filled epoxy resin insulating components that can be used singly or jointly to provide the necessary insulation or screening of accessories.

9.2 Partial discharge test

The partial discharge test shall be carried out in accordance with IEC 60885-3 for cables and the sensitivity as defined in IEC 60885-3 shall be 10 pC or better. Testing of accessories follows the same principles, but the sensitivity shall be 5 pC or better.

The test voltage shall be raised gradually to and held at 1,75 U_0 for 10 s and then slowly reduced to 1,5 U_0 (see Table 4, column 5).

There shall be no detectable discharge exceeding the declared sensitivity from the test object at 1,5 U_0.

9.3 Voltage test

The voltage test shall be made at ambient temperature using an alternating test voltage at power frequency.

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

No breakdown of the insulation shall occur.

9.4 Electrical test on oversheath of the cable

Subject to agreement between purchaser and manufacturer, the cable oversheath shall be subjected to the electrical test specified in Clause 3 of IEC 60229:2007.

10 Sample tests on cables

10.1 General

The following tests shall be carried out on samples which, for the tests in items b) and g) below, shall be complete drum lengths of cable, taken to represent batches:

a) conductor examination (see 10.4);
b) measurement of electrical resistance of conductor and of metal screen/sheath (see 10.5);
c) measurement of thickness of insulation and oversheath (see 10.6);
d) measurement of thickness of metal sheath (see 10.7);
e) measurement of diameters, if required (see 10.8);
f) hot set test for XLPE and EPR insulations (see 10.9);
g) measurement of capacitance (see 10.10);
h) measurement of density of HDPE insulation (see 10.11);
i) lightning impulse voltage test (see 10.12);
j) water penetration test, if applicable (see 10.13);
k) tests on components of cables with longitudinally applied metal tape or foil, bonded to the oversheath (see 10.14).

10.2 Frequency of tests

The sample tests in items a) to h) and k) of 10.1 shall be carried out on one length from each batch (manufacturing series) of the same type and cross-section of cable but shall be limited to not more than 10 % of the number of lengths in any contract, rounded to the nearest whole number.

The frequency of the tests in items i) and j) of 10.1 shall be in accordance with agreed quality control procedures. In the absence of such an agreement, one test shall be made for contracts with a cable length between 4 km and 20 km and two tests for contracts with longer cable lengths.

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/sheath

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/sheath 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 can be measured on a sample of conductor or metal screen/sheath, conditioned for at least 1 h in a temperature-controlled liquid bath.

The DC resistance of the conductor or metal screen/sheath shall be corrected to a temperature of 20 °C and a 1 km length in accordance with the formula given in IEC 60228:

– using the temperature coefficients given in IEC 60228 for a conductor or metal screen/sheath of copper or aluminium or
– for a metal screen/sheath other than copper or aluminium, using temperature coefficients given in IEC 60287-1-1.

The corrected DC resistance of the conductor at 20 °C shall not exceed either the appropriate maximum value specified in IEC 60228 or, when a value for maximum DC conductor resistance is declared in Clause 6, item d), then the corrected DC resistance of the conductor at 20 °C shall not exceed the declared value.

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

10.6 Measurement of thickness of insulation and oversheath

10.6.1 General

The test method shall be in accordance with IEC 60811-201 for the insulation. For the oversheath the test method in accordance with IEC 60811-202:2012 and IEC 60811-202:2012/AMD1:2017 shall be applied, except that for sheaths where the underlying surface is not irregular the measurement can be made with a micrometer having a ball nose radius of 2,5 mm to 3 mm. The accuracy of the micrometer shall be ±0,01 mm.

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 can have suffered damage.

In 10.6 the following symbols are used:

t_{max} is the maximum measured thickness, in mm;

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

t_n is the nominal thickness, in mm.

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:

$$\frac{t_{max} - t_{min}}{t_{max}} \leq 0{,}10$$

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.

10.6.3 Requirements for the cable oversheath

The minimum measured thickness shall not be less than 85 % of the nominal thickness minus 0,1 mm:

$$t_{min} \geq 0{,}85\ t_n - 0{,}1$$

In addition, for oversheaths applied onto a substantially smooth surface, the average of the measured values rounded to 0,1 mm shall not be less than the nominal thickness.

The latter requirement does not apply to oversheaths applied onto an irregular surface, such as one formed by metal screens of wires and/or tapes or corrugated metal sheath.

10.7 Measurement of thickness of metal sheath

10.7.1 General

The following tests apply if the cable has a metal sheath of lead, lead alloy, copper or aluminium. Foils which are applied for radial watertightness purposes only are excluded from these tests.

In 10.7 the following symbols are used:

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

t_n is the nominal thickness, in mm.

10.7.2 Lead or lead alloy sheath

10.7.2.1 General

The minimum measured thickness of the sheath shall not be less than 95 % of the nominal thickness minus 0,1 mm:

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

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

10.7.2.2 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. The piece shall be slit longitudinally and carefully flattened. After cleaning the test piece, a sufficient number of measurements shall be made along the circumference of the sheath and not less than 10 mm away from the edge of the flattened piece to ensure that the minimum thickness is measured.

10.7.2.3 Ring method

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

10.7.3 Copper or aluminium sheath

The minimum measured thickness of the sheath shall not be less than 90 % of the nominal thickness minus 0,1 mm for non-corrugated copper or aluminium sheath:

$$t_{min} \geq 0{,}9\ t_n - 0{,}1$$

and not less than 85 % of the nominal thickness minus 0,1 mm for corrugated copper or aluminium sheath:

$$t_{min} \geq 0{,}85\ t_n - 0{,}1$$

The measurements shall be made with a micrometer having ball noses of radii about 3 mm. The accuracy of the micrometer shall be ±0,01 mm.

The measurements shall be made on a ring of the sheath, about 50 mm wide, carefully removed from the cable. 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.

10.7.4 Metal tape for CD design

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

$$t_{min} \geq 0{,}9\ t_n$$

The measurements shall be made with a micrometer having ball noses of radii about 3 mm. The accuracy of the micrometer shall be ±0,01 mm.

The measurements shall be made on a ring of the tape and oversheath, about 50 mm wide, carefully removed from the cable. The thickness shall be determined at a number of points around the circumference and on the side ends of the ring to ensure that the minimum thickness is measured.

10.8 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.

10.9 Hot set test for XLPE and EPR insulations

10.9.1 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.

10.9.2 Requirements

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

10.10 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 %.

10.11 Measurement of density of HDPE insulation

10.11.1 Procedure

The density of HDPE shall be measured using the sampling and test procedure given in IEC 60811-606.

10.11.2 Requirements

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

10.12 Lightning impulse voltage test

The test shall be performed on a cable at least 10 m in length excluding test accessories, at a conductor temperature 5 K to 10 K above the maximum conductor temperature in normal operation.

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

If, for practical reasons, the test temperature cannot be reached, additional thermal insulation can be applied. The conductor temperature shall be maintained within the stated temperature limits for at least 2 h.

The lightning impulse voltage shall be applied, according to the procedure given in IEC 60230, after the completion of the above 2 h heating period and while the conductor temperature is within the limits stated above.

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

No breakdown of the insulation shall occur.

10.13 Water penetration test

If applicable, samples shall be taken from the cable, the test shall be applied and the requirements shall be met as described in 12.5.15.

10.14 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 cable and subjected to the tests and requirements in 12.5.16.

11 Sample tests on accessories

11.1 Tests on components of accessory

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

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 manufacturer to another, it is not possible to define common sample tests on components in this document.

11.2 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 a fully assembled accessory:

a) partial discharge test (see 9.2);

b) voltage test (see 9.3).

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

NOTE Examples of main insulations that are not routine tested are insulations taped and/or moulded on site.

These tests shall be performed on one accessory of each type per contract if the number of that type in the contract is above 50.

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 are intended to demonstrate the satisfactory performance of cable systems.

Once successfully completed, type 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.

The clause or subclause references to be considered during a type test on a cable system are given in Annex C.

Type tests on gas immersed cable terminations shall be carried out according to IEC 62271-209 in addition to the tests specified in this document.

Additional electrical type tests are required in IEC 62271-209, for the case where the gas immersed termination insulator is to be supplied to the switchgear manufacturer, to demonstrate that the termination can meet the switchgear routine and on-site tests.

NOTE Tests on terminations under environmental conditions such as precipitation and/or pollution are not specified in this document.

12.2 Range of type approval

When type tests have been successfully performed on one or more 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 following conditions of a) to h) are met.

Type tests which have been successfully performed according to previous editions of this standard are valid if the following conditions are met:

a) The voltage group is not higher than that of the tested cable system(s). Cable systems of the same 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 nominal conductor cross-sectional area 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).

   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 not necessary on account of the differences in the conductor or connector type or material or of the protective layers applied over the screened cores or over the main insulation part of the accessory, unless 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. bending test, 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 and the impulse voltage stress, calculated using nominal dimensions, at the cable insulation screen, 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 same type of gas or gas mixture and pressure is used in the cable connection enclosure of a gas immersed termination.

NOTE Clause H.6 gives requirements for approval of a gas immersed termination with an alternative type of gas.

h) A gas immersed termination has the same separating insulating barrier, stress cone assembly and cable as are used in the type test, taking into account the relevant allowances and requirements of a) to g) above.

The type tests on cable components (see 12.5) need not be carried out on samples from cables of different voltage ratings and/or nominal conductor cross-sectional areas unless 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 12.5.5) can be mutually agreed with the purchaser 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.

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 electrical tests on the complete cable system as specified in 12.4 and the appropriate non-electrical tests on cable components and completed cable specified in 12.5.

The non-electrical tests on cable components and cable are listed in Table 5 to Table 10, indicating which tests are applicable to each insulation and oversheath compound. The tests under fire conditions, as listed in Table 10, are only required if the manufacturer wishes to claim compliance with these tests as a special feature of the design of the cable.

The tests listed in 12.4.2 shall be performed on one or more samples of cable, depending on the number of accessories involved.

A sufficient length of cable shall be subjected to the bending test of 12.4.2 a) in order to allow construction of a test assembly for the tests of 12.4.2 c) to g) and the test of 12.4.2 b) where applicable.

The partial discharge test of 12.4.2 a) and the tests in 12.4.2 c) to g) shall be carried out on a test assembly comprising at least one sample of each accessory type to be tested. The accessories shall be installed on a cable such that there is a length of at least 5 m of free cable (i.e. excluding that contained within the length of any accessory) between adjacent accessories and at least 10 m of free cable in total.

The tan δ measurement of 12.4.2 b) can be carried out using the test assembly described above or on a separate cable sample taken from the same manufacturing batch. In the latter case, a bending test is not required on the cable and the test terminations can be different from those used for the other tests. There shall be at least 10 m of free cable in total. For the tests in 12.4.2 c) to g), accessories shall be installed after the bending test on the cable.

Cables 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.

The external surface of accessories shall be dry and clean, but 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.

If any joints are included in the cable system to be tested, during tests c) to g) of 12.4.2, it is necessary to test them with the outer protection fitted.

Measurement of resistivity of semi-conducting screens described in 12.4.9 shall be made on a separate sample.

12.4 Electrical type tests on complete cable systems

12.4.1 Test voltage values

Prior to the electrical type tests, the insulation thickness of the cable shall be measured by the method specified in IEC 60811-201 on a representative sample taken from the length to be used for the tests, to check that the average 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 determined according to 8.4 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 %.

12.4.2 Tests and sequence of tests

The tests in items a) to i) shall be made in the following sequence (see also 12.3):

a) bending test on the cable followed by visual examination, where applicable, (see 12.4.3). The installation of the accessories shall then be carried out by the manufacturer and a partial discharge test carried out at ambient temperature (see 12.4.4);

b) tan δ measurement (see 12.4.5 and 12.3);

c) heating cycle voltage test (see 12.4.6);

d) partial discharge tests (see 12.4.4):

- at ambient temperature, and
- at high temperature.

The tests shall be carried out after the final cycle of item c) above or, alternatively, after item f) below;

e) switching impulse voltage test (required for U_m ≥ 300 kV, see 12.4.7.1);

f) lightning impulse voltage test followed by a power frequency voltage test (see 12.4.7.2);

g) partial discharge tests, if not previously carried out in item d) above;

h) additional tests for accessories (see Annex H);

i) examination of the cable system with cable and accessories on completion of the above tests (see 12.4.8);

j) resistivity of the cable semi-conducting screens (see 12.4.9) that shall be measured on a separate sample. No bending test is required on the test sample.

Test voltages shall be determined in accordance with 8.4 and adjusted according to 12.4.1 if required.

12.4.3 Bending test

The cable sample shall be bent around a test cylinder (for example, the hub of a cable drum) at ambient temperature for at least one complete turn and unwound, without axial rotation. The sample shall then be rotated through 180° and the process repeated.

This cycle of operations shall be carried out three times in total.

The nominal diameter of the test cylinder shall be:

– for cables with non-corrugated copper or non-corrugated aluminium sheaths:
  - 36 (d + D);
– for cables with lead, lead-alloy or corrugated metal sheaths:
  - 25 (d + D);
– for cables with longitudinally applied metal tape or foils (overlapped or welded) bonded to the oversheath:
  - 20 (d + D) for CD,
  - 25 (d + D) for SD and CD + wires,
  - 10 D_s for SscD.
– for other cables:
  - 20 (d + D);

  where

  d is the nominal diameter of the conductor, in mm (see Clause 6, item j));

  D is the nominal overall diameter of the cable, in mm (see Clause 6, item k)).

  D_s is the nominal diameter of the metal screen layer, in mm.

The diameter of the test cylinder is the nominal diameter with a tolerance of 0 % to +5 %. Smaller bending diameters can be used at the discretion of the manufacturer.

In the case of cables with a laminated metal tape or foil, a visual examination according to Clause G.1 shall be carried out, after completion of the three bending cycles.

12.4.4 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 1,75 U_0 for 10 s and then slowly reduced to 1,5 U_0 (see Table 4, column 5).

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

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

There shall be no detectable discharge, exceeding the declared sensitivity, from the test object at 1,5 U_0.

12.4.5 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.

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

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

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 value given in Table 3.

12.4.6 Heating cycle voltage test

The cable shall have a U-bend with a diameter not greater than the test cylinder diameter for the bending test of 12.4.3. The diameter and allowed tolerances shall be as specified in 12.4.3.

The 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.

If, for practical reasons, the test temperature cannot be reached, additional thermal insulation can 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 15 K of ambient temperature, whichever is the higher, but with a maximum of 45 °C. The conductor current during the last 2 h of each heating period shall be recorded.

If the cable exhibits excessive dielectric loss at the test voltage, this can affect cooling. In extreme cases this could prevent cooling of the conductor to within the specified temperature range. This behaviour shall be considered a test failure.

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 assembly (see Table 4, column 7).

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

Interruption of the test is allowed, provided 20 complete heating cycles in total under voltage are completed. Guidance concerning interruption of the test and the determination of valid heating cycles is given in Annex J.

12.4.7 Impulse voltage tests

12.4.7.1 Switching impulse voltage test

A switching impulse voltage test shall be carried out on the assembly for systems, cables and accessories of voltage U_m ≥ 300 kV.

The 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.

The conductor temperature shall be maintained within the stated temperature limits for at least 2 h before the first switching impulse voltage is applied. The temperature shall be maintained within the above limits until the test is completed.

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

The switching impulse voltage shall be applied according to the procedure given in IEC 60230 with standard switching impulse withstand voltage levels according to Table 4, column 10.

The assembly shall withstand, without failure or flashover, 10 positive and 10 negative voltage impulses.

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

The 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.

The conductor temperature shall be maintained within the stated temperature limits for at least 2 h before the first lightning impulse voltage is applied. The temperature shall be maintained within the above limits until the test is completed.

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

The lightning impulse voltage shall be applied according to the procedure given in IEC 60230, while the conductor temperature is within the limits stated above.

The 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 assembly shall be subjected to a power frequency voltage test at 2 U_0 for 15 min (see Table 4, column 9). At the discretion of the manufacturer, this test can be carried out either during the cooling period or at ambient temperature.

No breakdown of the insulation or flashover shall occur.

12.4.8 Examination

12.4.8.1 Cable and accessories

Examination of the cable by dissection of a sample 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.

Additional guidance on the examination of cable and accessories is given in informative Annex I.

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

A 1 m sample shall be taken from the U-bend part of the cable length and subjected to the tests in 12.5.16.

12.4.9 Resistivity of semi-conducting screens

12.4.9.1 General

Measurement of resistivity of the cable semi-conducting screens shall be made on samples from the same manufacturing batch as the cable under test.

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 12.5.5.

12.4.9.2 Procedure

The test procedure shall be in accordance with Annex D.

The measurements shall be made at a temperature within ±2 K of the maximum conductor temperature in normal operation.

12.4.9.3 Requirements

The resistivity, both before and after ageing, shall not exceed the following values:

– conductor screen: 1 000 Ω · m;
– insulation screen: 500 Ω · m.

12.5 Non-electrical type tests on cable and on cable components

12.5.1 General

The tests are as follows:

a) check of cable construction (see 12.5.2);
b) tests for determining the mechanical properties of insulation before and after ageing (see 12.5.3);
c) tests for determining the mechanical properties of oversheaths before and after ageing (see 12.5.4);
d) ageing tests on pieces of cable to check compatibility of materials (see 12.5.5);
e) loss of mass test on PVC oversheaths of type ST_2 (see 12.5.6);
f) pressure test at high temperature for oversheaths (ST_1, ST_2, ST_7, and ST_{12}) (see 12.5.7);

g) tests for PVC and LSHF oversheaths (ST_1, ST_2, and ST_{12}) at low temperature (see 12.5.8);

h) heat shock test for PVC oversheaths (ST_1 and ST_2) (see 12.5.9);

i) ozone resistance test for EPR insulation (see 12.5.10);

j) hot set test for EPR and XLPE insulations (see 12.5.11);

k) measurement of density for HDPE insulation (see 12.5.12);

l) measurement of carbon black content for black PE oversheaths (ST_3 and ST_7) (see 12.5.13);

m) test under fire conditions (ST_1, ST_2 and ST_{12}) (see 12.5.14);

n) water penetration test (see 12.5.15);

o) tests for components of cables with a longitudinally applied metal tape or foil, bonded to the oversheath (see 12.5.16).

12.5.2 Check of cable construction

The examination of the conductor and measurements of insulation, oversheath and metal sheath thicknesses shall be carried out in accordance with, and shall comply with the requirements given in 10.4, 10.6 and 10.7.

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

12.5.3.1 Sampling

Sampling and preparation of test pieces shall be carried out in accordance with IEC 60811-501:2012 and IEC 60811-501:2012/AMD1:2018.

12.5.3.2 Ageing treatment

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

12.5.3.3 Conditioning and mechanical tests

Conditioning and measurement of mechanical properties shall be carried out in accordance with IEC 60811-501:2012 and IEC 60811-501:2012/AMD1:2018, except that:

a) it is not compulsory to carry out tensile tests on the aged and unaged test pieces in immediate succession, and

b) any suitable measuring instrument can be used, for example a micrometer.

12.5.3.4 Requirements

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

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

12.5.4.1 Sampling

Sampling and preparation of test pieces shall be carried out in accordance with IEC 60811-501:2012 and IEC 60811-501:2012/AMD1:2018.

12.5.4.2 Ageing treatment

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

12.5.4.3 Conditioning and mechanical tests

Conditioning and the measurement of mechanical properties shall be carried out in accordance with IEC 60811-501:2012 and IEC 60811-501:2012/AMD1:2018, except that:

a) it is not compulsory to carry out tensile tests on the aged and unaged test pieces in immediate succession, and

b) any suitable measuring instrument can be used, for example a micrometer.

12.5.4.4 Requirements

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

12.5.5 Ageing tests for pieces of cable to check compatibility of materials

12.5.5.1 General

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

The test is applicable to cables of all types.

12.5.5.2 Sampling

Samples for the test on insulation and oversheath shall be taken from the completed cable as described in IEC 60811-401.

12.5.5.3 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 1);

– duration: 7 × 24 h.

12.5.5.4 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 60811-401.

12.5.5.5 Requirements

The variations between the median values of tensile strength and elongation at break after ageing and the corresponding values obtained without ageing (see 12.5.3 and 12.5.4) shall not exceed the values applying to the test after ageing in an air oven given in Table 6 for insulations and in Table 7 for oversheaths.

12.5.6 Loss of mass test on PVC oversheaths of type ST_2

12.5.6.1 Procedure

The loss of mass test for ST_2 oversheaths shall be carried out as described in IEC 60811-409 under the conditions given in Table 9.

12.5.6.2 Requirements

The results shall comply with the requirements given in Table 9.

12.5.7 Pressure test at high temperature on oversheaths

12.5.7.1 Procedure

The pressure test at high temperature for ST_1, ST_2, ST_7 and ST_{12} oversheaths shall be carried out as described in IEC 60811-508:2012 and IEC 60811-508:2012/AMD1:2017, except that:

a) either an oven with natural air circulation or one with fan assisted circulation can be used. In the latter case better temperature control is possible, however the test sample shall not be subjected to vibration, and

b) if the oversheath is solidly bonded to a metal sheath then the oversheath shall not be removed from the metal sheath but shall be tested as if the metal sheath were the mandrel. The metal sheath shall be supported so that it is not deformed during the test.

The test conditions given in the test method and Table 7 shall be used.

12.5.7.2 Requirements

The results shall comply with the requirements given in Table 7.

12.5.8 Test for PVC oversheaths (ST_1 and ST_2) and LSHF oversheaths (ST_{12}) at low temperature

12.5.8.1 Procedure

The test at low temperature for ST_1, ST_2 and ST_{12} oversheaths shall be carried out as described in IEC 60811-505 and IEC 60811-506, employing the test temperature given in Table 9.

12.5.8.2 Requirements

The results of the test shall comply with the requirements given in Table 9.

12.5.9 Heat shock test for PVC oversheaths (ST_1 and ST_2)

12.5.9.1 Procedure

The heat shock test on ST_1 and ST_2 oversheaths shall be carried out as described in IEC 60811-509, the test temperature and duration being in accordance with Table 9.

12.5.9.2 Requirements

The results of the test shall comply with the requirements given in Table 9.

12.5.10 Ozone resistance test for EPR insulation

12.5.10.1 Procedure

EPR 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.

12.5.10.2 Requirements

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

12.5.11 Hot set test for EPR and XLPE insulations

EPR and XLPE insulations shall be subjected to the hot set test described in 10.9 and shall comply with its requirements.

12.5.12 Measurement of density for HDPE insulation

The density of HDPE insulation shall be measured in accordance with 10.11 and shall comply with its requirements.

12.5.13 Measurement of carbon black content for black PE oversheaths (ST_3 and ST_7)

12.5.13.1 Procedure

The carbon black content of ST_3 and ST_7 black oversheaths shall be measured using the sampling and test procedure described in IEC 60811-605:2012, except that after the final heating stage (in which the remaining carbon is burnt), the sample shall not be allowed to cool in the test assembly but shall be cooled in a desiccator, using the same procedure as used for the previous cooling stage (but with air or oxygen instead of nitrogen gas flow).

If there is an extruded semi-conductive layer applied to the oversheath, this shall not be included in the test sample.

12.5.13.2 Requirements

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

By agreement between manufacturer and purchaser lower values are allowed for special applications not exposed to UV radiation in service.

12.5.14 Test under fire conditions

12.5.14.1 General

The tests in 12.5.14.2 shall be carried out on ST_{12} (LSHF) oversheath material.

The tests in 12.5.14.3 shall be carried out in accordance with the fire performance claimed for the cable, see Clause 6, item c).

12.5.14.2 Tests on gases evolved during combustion of ST_{12} (LSHF) oversheath material

12.5.14.2.1 Determination of acidity (by pH measurement) and conductivity of gases evolved during combustion

The test according to IEC 60754-2 shall be carried out on the oversheath of the cable.

The results shall comply with the requirements given in Table 10.

12.5.14.2.2 Measurement of halogen content of gases evolved during combustion

The value for the oversheath, H_i, of the individual halogen content for each of the four halogens F, Cl, Br, and I, shall be determined by carrying out the test according to IEC 60754-3.

The values for each of the four individual halogens, H_i, and the sum of the values for the oversheath for the four halogens, i.e. $\sum H_i$, shall comply with the requirements given in Table 10.

12.5.14.3 Fire performance tests for the cable

12.5.14.3.1 Vertical flame propagation test for single cable

The test under fire conditions in accordance with IEC 60332-1-2 shall be carried out on a sample of completed cable. During the test, the determination of flaming droplets and particles shall be carried out in accordance with IEC 60332-1-3.

The results for IEC 60332-1-2 shall comply with the requirements given in Table 10 and the filter paper (IEC 60332-1-3) shall not ignite during the test duration.

If a failure to meet the requirements of either standard is recorded, two more tests shall be carried out. If both tests result in passes, the cable shall be deemed to have passed the test.

12.5.14.3.2 Test for vertical flame spread of vertically-mounted cables

The test for vertical flame spread of vertically-mounted cables shall be carried out in accordance with IEC 60332-3-24, on samples of completed cable.

NOTE Higher performance to meet the requirements of IEC 60332-3-22 [8] or IEC 60332-3-23 [9] can be agreed between the purchaser and manufacturer. The fire performance level achieved depends on cable design as well as material performance.

The results shall comply with the requirements given in Table 10.

12.5.14.3.3 Measurement of smoke density of cables burning under defined conditions

The test for measurement of smoke density of cables burning under defined conditions shall be carried out in accordance with IEC 61034-2 on a sample of completed cable.

The results shall comply with the requirements given in Table 10.

12.5.14.3.4 Determination of acidity (by pH measurement) and conductivity of gases evolved during combustion of the non-metallic materials in the cable

The test according to IEC 60754-2 shall be carried out on the non-metallic components of the cable. Non-metallic components with a mass less than or equal to 1 % of the total non-metallic mass need not be tested.

The weighted values of pH and conductivity of the non-metallic components of the cable shall be calculated according to IEC 60754-2 and shall comply with the requirements given in Table 10.

12.5.14.3.5 Measurement of halogen content of gases evolved during combustion of the non-metallic materials in the cable

The weighted value for the cable, H_i', for the four halogens F, Cl, Br, and I, shall be determined by carrying out the test according to IEC 60754-3 either:

– individually on each non-metallic component of the cable, and calculating the weighted value for the cable, for each halogen, as described in Annex K, or

– on a sample representative of the cable construction prepared as described in Annex K, in which case the result for each halogen shall be taken as the weighted value for the cable.

Non-metallic components with a mass less than or equal to 1 % of the total non-metallic mass need not be tested.

The weighted value for the cable, H_i', for each of the four individual halogens and the sum of the weighted values for the non-metallic components of the cable for the four halogens, i.e. $\sum H_i'$ shall comply with the requirements given in Table 10.

12.5.15 Water penetration test

The water penetration test shall be applied to those designs of cable where barriers to longitudinal water penetration have been included as declared in Clause 6, item d) and Clause 6, item g). The test is designed to meet the requirements for buried cables and is not intended to apply to cables which are constructed for use as submarine cables.

The test consists of two parts, one for the complete cable and all its design elements and one for the water penetration in the conductor. The apparatus, sampling, test procedure and requirements shall be in accordance with Annex E and Annex F.

12.5.16 Tests for 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 G.1);

b) adhesion strength of the laminated metal tape or foil (see Clause G.2);

c) peel strength of the laminated metal tape or foil (see Clause G.2).

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

13 Prequalification test of the cable system

13.1 General and range of prequalification test approval

When a PQ test has been successfully performed on a cable system, it qualifies the manufacturer as a supplier of cable systems of the same family with the same or lower voltage ratings, as long as the calculated nominal electrical stresses at the cable insulation screen are equal to or lower than for the tested cable system.

The PQ test shall be performed except:

– if cable systems with the same construction and accessories of the same family have been prequalified for an equal or higher rated voltage, or

– if the manufacturer can demonstrate good service experience with cable systems with equal or higher calculated electrical stresses on the conductor and insulation screens, in the main insulation part(s) and in boundaries of the accessories and of accessories of the same family, or

– if the manufacturer has fulfilled the requirements of an equivalent long-term test, on a cable system at an equal or higher voltage rating with the same construction and accessories of the same family, following a national or purchaser specification.

When a prequalified cable system is changed by exchanging a cable and/or accessory with another one that is already prequalified in another cable system with the same or higher calculated nominal electrical stresses at the insulation screen of the subjected system, the current prequalification shall be extended with this cable and/or accessory when the requirements of 13.3 are all met.

When a prequalified cable system is changed by using another cable and/or accessory that is not part of a prequalified cable system or is already prequalified in another cable system with lower calculated nominal electrical stresses at the insulation screen of the subjected system, the PQ test on this new complete cable system shall be performed by meeting all requirements of 13.2.

The PQ test need only be carried out once unless there is a substantial change in the cable system with respect to material, manufacturing process, design or design electrical stress levels. A substantial change is defined as that which might adversely affect the performance of the cable system. The manufacturer should provide a detailed case, including test evidence, if modifications are introduced which are claimed not to constitute a substantial change.

It is recommended that a PQ test should use a cable with a large conductor cross-section in order to cover thermo-mechanical aspects.

Prequalification tests which have been successfully performed according to the previous edition of this standard are valid.

A list of PQ tests and EQ tests is given in Annex C.

A PQ or EQ 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 PQ or EQ test certificate issued by an independent test laboratory shall be acceptable as evidence of PQ or EQ testing. Such a certificate or report shall include details of the indoor test arrangement or outdoor installation and shall specify details of laying conditions and how the cable system was installed.

For a more detailed understanding of the need for a PQ or EQ tests, reference should be made to CIGRE TB 303 [6].

13.2 Prequalification test on complete cable system

13.2.1 Summary of prequalification tests

The PQ test shall comprise the electrical tests on the complete cable system with approximately 100 m of full-sized cable, including at least one of each type of accessory. The minimum length of free cable between accessories shall be 10 m. The sequence of tests shall be as follows:

a) heating cycle voltage test (see 13.2.4);

b) lightning impulse voltage test (see 13.2.5);

c) examination of the cable system after completion of the tests above (see 13.2.6).

It could be the case that one or more of the accessories do not fulfil all the requirements of the PQ tests in 13.2. After repair of the test assembly the PQ tests can be continued on the remaining cable system (cable with the remaining accessories). If all the requirements of the tests in 13.2 are met by this remaining cable system, this remaining system is prequalified. The accessory or accessories that did not fulfil the requirements are excluded from this prequalification.

The test can be continued for prequalification of the cable with the replaced accessory until all requirements of 13.2 are met. If the manufacturer decides to include the repaired accessory in the cable system prequalification, the beginning of the PQ test of the complete system is considered to start after the repair.

13.2.2 Test voltage values

Prior to the PQ test of the cable system, the insulation thickness of the cable shall be measured and the test voltage values determined, as stated in 8.4 and 12.4.1.

13.2.3 Test arrangement

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.

The test arrangement shall be representative of the installation design conditions, for example rigidly fixed, flexible and transition arrangements, underground and in air. In particular, special attention shall be paid to thermo-mechanical aspects of accessories.

Ambient conditions can vary between installations and during the test and are not considered to have any major influence. The temperature limits of 8.1 do not apply.

If the cable system includes sections installed under different conditions (e.g. directly buried and in an air-filled chamber) then the manufacturer shall select one part of the cable system to be used for determination of cable conductor temperature. Temperatures shall be determined at this fixed position for the duration of the test. If a reference cable is used for determination of conductor temperature (see Annex A) then the reference cable shall be installed in conditions representative of the cable system under test.

13.2.4 Heating cycle voltage test

The assembly shall be heated by conductor current only, until the cable conductor reaches a temperature 0 K to 5 K above the maximum conductor temperature in normal operation. Variable ambient conditions can require adjustment of the conductor current during the test.

The heating arrangements shall be selected so that the cable conductor attains the temperature specified above, remote from the accessories. The surface temperature of the cable shall be recorded for information.

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.

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

A voltage of 1,7 U_0 and heating cycles shall be applied to the assembly during the whole of the test period of at least 8 760 h. The cycles of heating and cooling shall be carried out at least 180 times. Heating cycles with a conductor temperature higher than 5 K above the maximum conductor temperature in normal operation are considered valid. Up to a maximum of 10 cycles, in which the period at high temperature is between 1 h and 2 h can also be counted as valid cycles. At least 180 valid heating cycles, with applied voltage, shall be completed.

As an example, in order to comply with the above requirements, if the heating cycles are of 24 h duration then 365 cycles (8 760/24) would be necessary. If cycles are of a longer duration then a reduced number is permissible.

Interruption of the heating cycles or the test voltage is allowed during the test, however the required minimum number of cycles shall be carried out irrespective of interruptions.

No breakdown shall occur.

Partial discharge measurements are recommended, to provide an early warning of possible degradation and to enable the possibility of a repair before failure.

13.2.5 Lightning impulse voltage test

The test shall be performed on the complete assembly or one or more cable samples, with a minimum total active length of 30 m, cut from the assembly. The cable conductor temperature shall be 0 K to 5 K above the maximum conductor temperature in normal operation and shall be maintained within the stated temperature limits for at least 2 h before the first lightning impulse voltage is applied. The temperature shall be maintained within the above limits while the lightning impulse voltages are applied.

The lightning impulse voltage shall be applied according to the procedure given in IEC 60230, except that the maximum front time is increased to 8 µs.

The test assembly or cable samples shall withstand without failure 10 positive and 10 negative voltage impulses of the appropriate value given in 13.2.2.

13.2.6 Examination

The examination of the cable system (cable and accessories) and the requirements shall be as stated in 12.4.8.

13.3 Tests for the extension of the prequalification of a cable system

13.3.1 Summary of the extension of prequalification test

The EQ tests shall comprise the electrical part of the tests on the complete cable system as specified in 13.3.2 and the non-electrical tests on the cable as specified in 12.5.

For a more detailed understanding of the need for a PQ or EQ tests, reference should be made to CIGRE TB 303 [6].

13.3.2 Electrical part of the extension of prequalification tests on complete cable system

13.3.2.1 General

The tests listed in 13.3.2.3 shall be performed on one or more samples of cable, of the already prequalified cable system or having minor changes from an already prequalified design, depending on the number of accessories involved. The test shall include at least one accessory of each type that needs the extension of the prequalification. The accessories, if any, shall already have been prequalified on a different cable system (with an insulation screen stress at least as high as the value for the EQ test) or had minor changes from the prequalified design. The test can be performed in a laboratory and not necessarily in a situation simulating the real installation conditions.

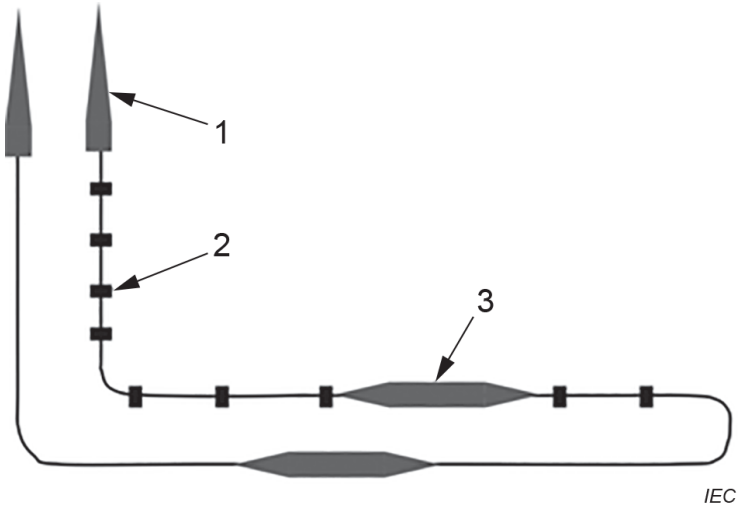
The minimum total cable length shall be 20 m, not including that inside accessories. The minimum length of cable between accessories shall be 5 m.

A bending test shall be carried out on the cable, according to 12.4.3, before the installation of the accessories. The same diameter tolerances given in 12.4.3 shall apply.

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.

The cable shall have a U-bend with a diameter not greater than the test cylinder diameter, including the +5 % tolerance, as specified in 12.4.3.

If the prequalification of a joint is to be extended for use both in flexible and in rigid installations, one joint shall be installed in a flexible configuration and the other one in a rigid configuration, see Figure 1.



Key

1 termination

2 cleat

3 joint

Figure 1 – Example of EQ test arrangement for the prequalification of a system with another joint, designed for rigid as well as for flexible installation

With the exception of the provisions of 13.3.2.2 all the tests listed in 13.3.2.3 shall be applied successively to the same sample.

The measurement of the resistivity of semi-conducting screens, described in 12.4.9, shall be made on a separate sample from the same manufacturing batch of cable.

13.3.2.2 Test voltage values

Prior to the electrical EQ tests, the insulation thickness of the cable shall be measured, and the test voltage values determined as stated in 8.4 and 12.4.1.

13.3.2.3 Sequence of the electrical part of the extension of prequalification tests

The sequence of the electrical part of the EQ tests shall be as follows:

a) installation of the accessories that shall be carried out by the manufacturer;

b) partial discharge test at ambient temperature (see 12.4.4), to check the installation and the quality of the installed accessories;

c) heating cycle test without voltage (see 13.3.2.4);

d) tan δ measurement, if the extension to prequalification is for the cable (see 12.4.5). This test can be carried out on a different cable sample from that used for the remainder of the sequence of tests, taken from the same manufacturing batch, with special test terminations;

e) heating cycle voltage test (see 12.4.6);

f) partial discharge tests (see 12.4.4) at ambient temperature and at high temperature. These tests shall be carried out after the final cycle of item e) above or, alternatively, after the lightning impulse voltage test in item h) below;

g) switching impulse test (required for U_m ≥ 300 kV, see 12.4.7.1);

h) lightning impulse voltage test followed by a power frequency voltage test (see 12.4.7.2);

i) partial discharge tests, if not previously carried out in item f) above;

j) additional tests for accessories (see Annex H);

k) examination of the cable and/or accessories, as applicable, shall be carried out after completion of the tests above (see 12.4.8).

13.3.2.4 Heating cycle test without voltage

The assembly shall be heated by conductor current only, until the cable conductor reaches a temperature 0 K to 5 K above the maximum conductor temperature in normal operation.

If, for practical reasons, the test temperature cannot be reached, additional thermal insulation can 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 15 K of ambient temperature, whichever is the higher, but with a maximum of 45 °C. The conductor current during the last 2 h of each heating period shall be recorded.

Heating cycles with a conductor temperature higher than 5 K above the maximum conductor temperature in normal operation are considered valid.

The cycle of heating and cooling shall be carried out 60 times.

Interruption of the test is allowed, provided 60 complete heating cycles in total are completed. Guidance concerning interruption of the test and the determination of valid heating cycles is given in Annex J.

14 Type test on cables

Cables will be type tested as part of a cable system.

15 Type test on accessories

Accessories will be type tested as part of a cable system.

16 Electrical test after installation (on-site tests)

16.1 General

Tests on new installations (on-site tests) are carried out when the installation of the cable system has been completed. The tests carried out shall be in accordance with IEC 60060-3.

A DC oversheath test according to 16.2 and/or an AC insulation test according to 16.3 are recommended.

For installations where only the oversheath test according to 16.2 is carried out, quality assurance procedures during installation of accessories can, by agreement between the purchaser and manufacturer, replace the insulation test according to 16.3.

The use of very low frequency (VLF) and damped AC (DAC) waveforms for on-site tests are not recommended, as further studies of these test methods are required.

16.2 DC voltage test of the oversheath

The electrical test after installation shall be carried out on the oversheath according to IEC 60229:2007.

For the test to be effective, it is necessary that the ground makes good contact with all of the outer surface of the oversheath. The test cannot be carried out unless the oversheath has an outer electrode, for example moist backfill or a conductive layer.

16.3 Tests using AC voltage

16.3.1 AC voltage test of the insulation

The AC test voltage to be applied shall be subject to agreement between the purchaser and the manufacturer.

The waveform shall be substantially sinusoidal and the frequency shall be between 20 Hz and 300 Hz. In particular cases, the minimum frequency can be reduced to 10 Hz subject to agreement between the purchaser and the manufacturer.

A voltage according to Table 12, column 4 shall be applied for 1 h, except in cases where this is not practicable, for example, for very long circuit lengths. In such cases the alternative lower voltage according to Table 12, column 6 shall be applied for 1 h.

Alternatively, a voltage of U_0 can be applied for 24 h.

For installations which have been in use, lower voltages than given in Table 12 and/or shorter durations can be used. Values should be negotiated, taking into account the age, environment, history of breakdowns and the purpose of carrying out the test.

16.3.2 Partial discharge test

A partial discharge (PD) test under AC voltage is recommended and can be carried out by agreement between the purchaser and the manufacturer. Distributed PD measurements can be carried out along the cable route. Typical pass criteria for such measurements are no detectable PD from the cable system at 1,5 U_0, or at the test voltage, if lower. When applicable, the test procedure and pass criteria should be agreed. The PD test can be carried out during the AC voltage test of the insulation (at the voltage used for that test) or as a separate test. PD tests shall not be considered to replace the AC voltage test of the insulation.

Table 1 – Insulating compounds for cables

Insulating compound		Maximum conductor temperature °C	
		Normal operation	Short-circuit (maximum duration 5 s)
Low density thermoplastic polyethylene	(PE)	70	130[a]
High density thermoplastic polyethylene	(HDPE)	80	160[a]
Cross-linked polyethylene	(XLPE)	90	250
Ethylene-propylene rubber[b]	(EPR)	90	250

[a] For PE and HDPE, a short-circuit temperature rise up to 20 K in excess of those shown can be acceptable with suitable semi-conducting layers over the conductor and the insulation and by agreement between purchaser and manufacturer.

[b] Only for cables with rated voltage $U_m \leq 245$ kV.

Table 2 – Oversheathing compounds for cables

Oversheathing compound	Abbreviated designation	Maximum conductor temperature in normal operation °C
Polyvinyl chloride (PVC)	ST_1	80
	ST_2	90
Polyethylene (PE)	ST_3	80
	ST_7	90
Low smoke halogen free (LSHF)	ST_{12}	90

Table 3 – Tan δ requirements for insulating compounds for cables

Designation of compound (see 4.2)		PE	HDPE	EPR	XLPE
Maximum tan δ	10^{-4}	10	10	30	10

Table 4 – Test voltages

1[c]	2	3	4[a]		5[a]	6[a]	7[a]	8[a]	9[a]	10[a]
Rated voltage U	**Highest voltage for equipment** U_m	**Value of U_0 for determination of test voltages** U_0	**Voltage test of 9.3** Voltage[b]	Duration[b]	**Partial discharge test of 9.2 and 12.4.4** 1,5 U_0	**Tan δ measurement of 12.4.5** U_0	**Heating cycle voltage test of 12.4.6** 2 U_0	**Lightning impulse voltage test of 10.12, 12.4.7.2 and 13.2.5**	**Voltage test after impulse voltage test of 12.4.7.2** 2 U_0	**Switching impulse voltage test of 12.4.7.1**
kV	kV	kV	kV	min	kV	kV	kV	kV	kV	kV
220 to 230	245	127	318	30	190	127	254	1 050	254	–
275 to 287	300	160	400	30	240	160	320	1 050	320	850
330 to 345	362	190	420	60	285	190	380	1 175	380	950
380 to 400	420	220	440	60	330	220	440	1 425	440	1 050
500	550	290	580	60	435	290	580	1 550	580	1 175

Subject to agreement between purchaser and manufacturer, the voltage test of 9.3 can be replaced by a test at lower voltage and longer duration, even if the maximum stress in the insulation is lower than 30 kV/mm. However, the voltage level shall not be below 1,5 U_0 and the duration not longer than 10 h.

Test voltages for the voltage test after installation of 16.3 are given in Table 12.

[a] If necessary, these test voltages shall be adjusted as stated in 12.4.1.

[b] A threshold limit of 27 kV/mm to 30 kV/mm should not be exceeded for some insulations (as specified by the manufacturer), in order to avoid any possible weakening of the insulation prior to delivery which might later cause a failure in service. At the voltage test of 9.3, for example for a rated voltage 330 kV to 500 kV, the voltage is lowered, combined with a longer testing time in order to avoid too high stresses. For insulations where a threshold limit is not a problem, the manufacturer can increase the test voltage and reduce the testing time. However, the duration should be at least 30 min.

[c] For rated voltages not listed in column 1, see 8.4.

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

Designation of compound (see 4.2 and 4.4)	Insulation				Oversheath				
	PE	HDPE	EPR	XLPE	ST_1	ST_2	ST_3	ST_7	ST_{12}
Check of cable construction Water penetration test[a]	Applicable irrespective of insulation and oversheathing compounds								
Mechanical properties (Tensile strength and elongation at break)									
a) without ageing	x	x	x	x	x	x	x	x	x
b) after ageing in air oven	x	x	x	x	x	x	x	x	x
c) after ageing of the complete cable (compatibility test)	x	x	x	x	x	x	x	x	x
Pressure test at high temperature	–	–	–	–	x	x	–	x	x
Behaviour at low temperature									
a) cold elongation test	–	–	–	–	x	x	–	–	x
b) cold impact test	–	–	–	–	x	x	–	–	x
Loss of mass in air oven	–	–	–	–	–	x	–	–	–
Heat shock test	–	–	–	–	x	x	–	–	–
Ozone resistance test	–	–	x	–	–	–	–	–	–
Hot set test	–	–	x	x	–	–	–	–	–
Measurement of density	–	x	–	–	–	–	–	–	–
Carbon black content[b]	–	–	–	–	–	–	x	x	–
pH value (12.5.14.2.1)	–	–	–	–	–	–	–	–	x
Conductivity test (12.5.14.2.1)	–	–	–	–	–	–	–	–	x
Halogen content (12.5.14.2.2)	–	–	–	–	–	–	–	–	x

Key

x: the test shall be applied

–: the test shall not be applied

[a] Shall be applied to those designs of cable where the manufacturer claims that barriers to longitudinal water penetration have been included.

[b] For black oversheaths only.

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

Designation of compound (see Table 1)		Unit	PE	HDPE	XLPE	EPR
Maximum conductor temperature in normal operation		°C	70	80	90	90
Without ageing (IEC 60811-501:2012 and IEC 60811-501:2012/AMD1:2018)						
Minimum tensile strength		N/mm^2	10,0	12,5	12,5	4,2
Minimum elongation at break		%	300	350	200	200
After ageing in air oven (IEC 60811-401)						
Treatment:	temperature	°C	100	110	135	135
	tolerance	K	±2	±2	±3	±3
	duration	h	240	240	168	168
Tensile strength						
a) minimum value after ageing		N/mm^2	–	–	–	–
b) maximum variation[a]		%	–	–	±25	±30
Elongation at break						
a) minimum value after ageing		%	300	350	–	–
b) maximum variation[a]		%	–	–	±25	±30

[a] 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 4.4)	Unit	ST_1	ST_2	ST_3	ST_7	ST_{12}
Without ageing (IEC 60811-501:2012 and IEC 60811-501:2012/AMD1:2018)						
Minimum tensile strength	N/mm^2	12,5	12,5	10,0	12,5	12,5
Minimum elongation at break	%	150	150	300	300	300
After ageing in air oven (IEC 60811-401)						
Treatment: temperature	°C	100	100	100	110	110
tolerance	K	±2	±2	±2	±2	±2
duration	h	168	168	240	240	240
Tensile strength:						
a) minimum value after ageing	N/mm^2	12,5	12,5	–	–	10,0
b) maximum variation[a]	%	±25	±25	–	–	±30
Elongation at break:						
a) minimum value after ageing	%	150	150	300	300	300
b) maximum variation[a]	%	±25	±25	–	–	–
Pressure test at high temperature (IEC 60811-508:2012 and IEC 60811-508:2012/AMD1:2017)						
Test temperature	°C	80	90	–	110	110
Tolerance	K	±2	±2	–	±2	±2
Maximum indentation	%	50	50	–	50	50

[a] Variation: difference between the median value obtained after ageing and the median value obtained without ageing, expressed as a percentage of the latter.

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

Designation of compound (see 4.2)	Unit	PE	HDPE	XLPE	EPR
Ozone resistance test (IEC 60811-403)					
Ozone concentration (by volume)	%	–	–	–	0,025 to 0,030
Test duration without cracks	h	–	–	–	24
Hot set test (IEC 60811-507)					
Treatment: air temperature	°C	–	–	200	250
tolerance	K	–	–	±3	±3
tensile stress	N/cm^2	–	–	20	20
Maximum elongation under load	%	–	–	175	175
Maximum permanent elongation after cooling	%	–	–	15	15
Density (IEC 60811-606)					
Minimum density	g/cm^3	–	0,940	–	–

Table 9 – Test requirements for particular characteristics of PVC and LSHF oversheathing for cables

Designation of compound (see 4.4)	Unit	ST_1	ST_2	ST_{12}
Loss of mass in air oven (IEC 60811-409)				
Treatment: temperature	°C	–	100	–
tolerance	K	–	±2	–
duration	h	–	168	–
Maximum permissible loss of mass	mg/cm^2	–	1,5	–
Behaviour at low temperature[a]				
Tests to be carried out without previous ageing:				
a) Cold elongation test on dumb-bells (IEC 60811-505)				
test temperature	°C	−15	−15	−15
tolerance	K	±2	±2	±2
Requirement	%	≥ 20	≥ 20	≥ 20
b) Cold impact test (IEC 60811-506)				
test temperature	°C	−15	−15	−15
tolerance	K	±2	±2	±2
Requirement	–	no cracks	no cracks	no cracks
Heat shock test (IEC 60811-509)				
Treatment: test temperature	°C	150	150	–
tolerance	K	±3	±3	–
test duration	h	1	1	–
Requirement		no cracks	no cracks	–

[a] Due to climatic conditions, national standards can require the use of a lower or higher test temperatures.

Table 10 – Test requirements for fire performance characteristics of cables with PVC and LSHF oversheaths

Designation of compound (see 4.4)		Unit	ST_1	ST_2	ST_{12}
Tests on ST_{12} (LSHF) oversheath material					
pH value and conductivity tests (12.5.14.2.1) (IEC 60754-2)					
	pH	–	–	–	≥ 4,3
	Conductivity	µS/mm	–	–	≤ 10
Halogen content of gases (12.5.14.2.2) (IEC 60754-3)					
Value for each of the 4 individual halogens (F, Cl, Br, I)	H_i	mg/g	–	–	≤ 2
Sum of values for the 4 individual halogens (F, Cl, Br, I)	$\sum H_i$	mg/g	–	–	≤ 5
Tests for cable					
Vertical flame propagation test for single cable (12.5.14.3.1) (IEC 60332-1-2)					
Distance between the lower edge of the top support and the onset of charring		mm	> 50	> 50	> 50
Lower extent of charring below the lower edge of the top support		mm	≤ 540	≤ 540	≤ 540
Test for vertical flame spread of vertically-mounted cables (12.5.14.3.2) (IEC 60332-3-24)					
Upper limit of char above bottom edge of burner		m	–	–	≤ 2,5
Smoke density test of cables (12.5.14.3.3) (IEC 61034-2)					
Normalized transmittance	$(I_t/I_0)_{norm}$	%	–	–	≥ 60
pH value and conductivity tests (12.5.14.3.4) (IEC 60754-2)					
Weighted value for the non-metallic materials in the cable	pH	–	–	–	≥ 4,3
	Conductivity	µS/mm	–	–	≤ 10
Halogen content of gases evolved during combustion (12.5.14.3.5) (IEC 60754-3)					
Weighted values for non-metallic materials in the cable	Value for each of the 4 individual halogens (F, Cl, Br, I) H'_i	mg/g	–	–	≤ 2
	Sum of the values for the 4 individual halogens (F, Cl, Br, I) $\sum H'_i$	mg/g	–	–	≤ 5

Table 11 – Cantilever operating load for insulators for outdoor terminations

Highest voltage for equipment U_m kV	Rated current A							
	≤ 800		1 000 to 1 600		2 000 to 2 500		≥ 3 150	
	Maximum cantilever operating load in service and for which the insulator is designed (= MML for composite insulators)							
	N							
	Termination installed < 30° from the vertical							
	I	II	I	II	I	II	I	II
> 170 to 245	625	2 000	800	2 000	1 250	2 500	2 000	2 500
≥ 300	1 250	2 000	1 250	2 000	1 575	2 500	2 500	2 500

Key

Level I = normal load, Level II = heavy load

For outdoor terminations operating at an angle > 30° to the vertical, the effect of termination self-load should be considered when selecting test load and procedure. The values given above correspond to vertical terminations that shall be tested in a vertical position. If a tilted or horizontal termination is to be tested vertically, then an equivalent force should be added to achieve the bending moment at the flange caused by the weight of the termination in its operating position. If a vertical termination is to be tested horizontally, then the test load can be reduced in the same manner.

NOTE This table is derived from IEC 60137.

Table 12 – Test voltages for AC voltage test after installation

1	2	3	4	5	6	7
Rated voltage	**Highest voltage for equipment**	**Value of U_0 for determination of test voltages**	**Preferred test voltage**		**Test voltage for special conditions** (when use of the preferred test voltage of column 4 is not possible, see 16.3.1)	
			Voltage test after installation of 16.3	**Multiplier**	**Voltage test after installation of 16.3**	**Multiplier**
U	U_m	U_0	-	-	-	-
kV	kV	kV	kV	x U_0	kV	x U_0
220 to 230	245	127	216	1,7	180	1,4
275 to 287	300	160	272	1,7	210	1,3
330 to 345	362	190	323	1,7	250	1,3
380 to 400	420	220	374	1,7	260	1,2
500	550	290	435	1,5	320	1,1
A threshold electrical stress of 27 kV/mm to 30 kV/mm should not be exceeded for some insulations (as specified by the manufacturer) in order to avoid a possible weakening of the insulation.						

Annex A
(informative)

Determination of the cable conductor temperature

A.1 Purpose

For some tests, it is necessary to raise the cable conductor to a given temperature, typically 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 temperature.

In addition, the conductor temperature should be maintained within a restricted range (5 K) since the ambient temperature can vary over a wider range.

Although preliminary calibration on the cable under test or calculations can be satisfactory in the first place, the variation of ambient conditions throughout the duration of the test can lead to deviations of the temperature of the conductor outside range.

Therefore, methods should be used in which the conductor temperature can be monitored and controlled throughout the duration of the test.

Guidance is given hereafter on commonly used methods.

A.2 Calibration of the temperature of the main test loop

A.2.1 General

The purpose of the calibration is to determine the conductor temperature by direct measurement for a given current, within the temperature range required for the test.

The cable used for calibration (hereafter called the reference cable) should be taken from the same length as the cable used for the main test loop.

A.2.2 Installation of cable and temperature sensors

The calibration should be performed on the reference cable which shall have a minimum length of 5 m. The length should 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.

Two temperature sensors should be attached to the middle of the reference cable: one on the conductor (TC_{1c}), and one on the external surface or directly under the external surface (TC_{1s}).

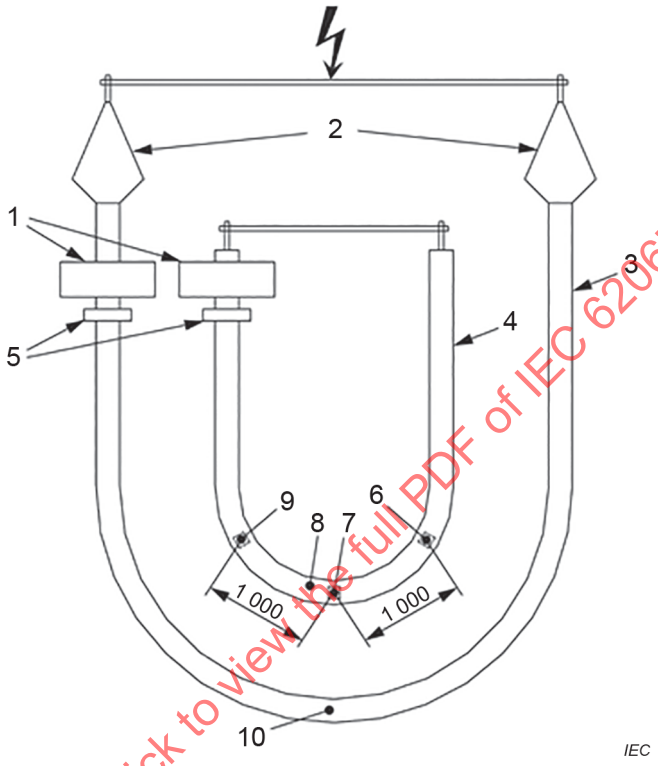
Two other temperature sensors, TC_{2c} and TC_{3c}, should be installed on the conductor of the reference cable (see Figure A.1), each one about 1 m from the middle.

The temperature sensors should be attached to the conductor by mechanical means since they can move due to vibrations of the cable during heating. Care should be taken to maintain good thermal contact during the tests and to prevent leakage of heat to the ambient. It is recommended to mount the temperature sensor(s), as shown in Figure A.2, between two strands of a stranded conductor or between the (solid) conductor and the conductor screen. To enable access to the conductor in the middle of the reference cable, a small hatch should be made by careful removal of the layers above the conductor. After installing the temperature sensor(s), the layers that have been removed can be put back. This can 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_{1C}, TC_{2C} and TC_{3C} should be less than 2 K.

If the actual main test loop includes several individual cable lengths installed close to each other, these lengths will be subjected to a thermal proximity effect. The calibration should therefore be carried out taking into account the actual test arrangement, measurements being performed on the hottest cable length (usually the middle length).

Dimensions in millimetres

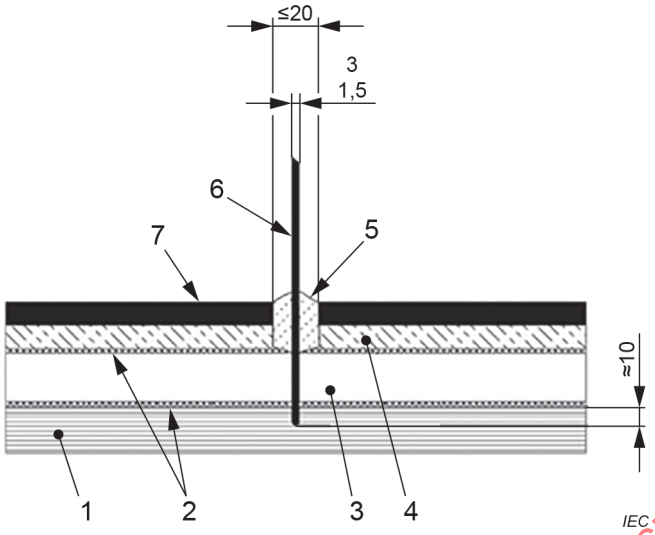


Key

1	current inducing transformers	6	TC_{3c} (conductor)
2	terminations	7	TC_{1c} (conductor)
3	cable under test	8	TC_{1s} (sheath)
4	reference cable (≥ 5 m)	9	TC_{2c} (conductor)
5	current measuring transformers	10	TC_{s} (sheath)

Figure A.1 – Schematic diagram of test set-up for the reference loop and the main test loop

Dimensions in millimetres



Key

1	conductor	5	flexible thermal insulating compound
2	semi-conducting screens	6	temperature sensor
3	insulation	7	cable oversheath
4	metal sheath		

Figure A.2 – Example of an arrangement of the temperature sensors on the conductor of the reference loop

A.2.3 Calibration method

The calibration should be carried out in a draught-free situation at a temperature of (20 ± 15) °C.

Temperature recorders should be used to measure the conductor, oversheath and ambient temperatures simultaneously.

The cable should be heated until the conductor temperature, indicated by temperature sensor TC_{1c} of Figure A.1, has stabilized and reached a temperature between 5 K and 10 K above the maximum conductor temperature of the cable in normal operation, as given in Table 1.

When stabilization has been reached, the following should be noted:

– conductor temperature: average value at sensors TC_{1c}, TC_{2c}, and TC_{3c};

– oversheath temperature at position TC_{1s};

– ambient temperature;

– heating current.

A.3 Heating for the test

A.3.1 Method 1 – Test using a reference cable

In this method, a reference cable identical to the cable used for the main test loop is heated with the same current value as the main test loop.

The installation of cable and temperature sensors for both loops should be as given in Clause A.2.

The test arrangement should be such that:

– the reference cable carries the same current as the main test loop at any time; small current changes are allowed in order to equalize the surface temperatures on the test cable and the reference cable;
– the reference cable is installed in such a way that mutual heating effects are taken into account throughout the test.

A temperature sensor (TC_s) should be mounted on or under the external surface of the main test loop at the hottest spot, usually in the middle of the length, in the same way as temperature sensor TC_{1s} is mounted on the hottest spot of the reference cable to check that the oversheaths of both loops are at a similar temperature.

The temperature measured with temperature sensor TC_{1c} on the conductor of the reference loop can be considered to be representative for the conductor temperature of the energized test loop.

The heating current of both loops should be adjusted such that the conductor temperature is kept within the specified limits.

All temperature sensors should be connected to a recorder to enable temperature monitoring. The heating current of each loop should also be recorded to prove that the two currents are of the same value throughout the duration of the test. The difference between the heating currents should be kept within ±1 %.

The reference cable can be connected in series with the test cable if the temperature is measured via an optical fibre link or equivalent.

A.3.2 Method 2 – Test using conductor temperature calculations and measurement of the surface temperature

A.3.2.1 Calibration of the test cable conductor temperature

The purpose of the calibration is to determine the conductor temperature by direct measurement for a given current, within the temperature range required for the test.

The cable used for calibration should be taken from the same length as the cable used for the main test loop and the way of heating should be identical.

The installation of cable and temperature sensors for the calibration should be as given in Clause A.2.

The calibration should be carried out in accordance with A.2.3 for the reference cable.

A.3.2.2 Test based on measurement of the external temperature

During calibration and during the test of the main loop, the cable conductor temperature of the main test loop should be calculated in accordance with IEC 60853-2 [10], based on the measured external temperature of the oversheath (TC_s). The measurement should be carried out with a temperature sensor at the hottest spot, attached to or under the external surface, in the same way as for the reference cable.

IEC 60287-1-1 can be used to determine the asymptotic temperature.

The heating current should be adjusted to obtain the required value of the calculated conductor temperature, based on the measured external temperature of the oversheath.

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
(informative)

List of type, prequalification and extension of prequalification tests for cable systems

Type tests for cable systems are covered by Clause 12.

Table C.1 gives a summary and references for type testing of cable systems.

PQ tests of cable systems are covered by 13.1 and 13.2.

EQ tests for the extension of prequalification are covered by 13.1 and 13.3.

Table C.2 gives a summary and references for prequalification testing of these cable systems.

Table C.3 gives a summary and references for the extension of prequalification testing of these cable systems.

Table C.1 – Type tests for cable systems

Item	Test	Clauses
a	General	12.1
b	Range of type approval	12.2
c	Electrical type tests	12.4
d	Test voltage values	12.4.1
e	Bending test	12.4.3
	Partial discharge test at ambient temperature	12.4.4
f	Tan δ measurement	12.4.5
g	Heating cycle voltage test	12.4.6
h	Partial discharge test at ambient and at high temperatures (after final cycle in item g above or after lightning impulse voltage test in item j below)	12.4.4
i	Switching impulse voltage test	12.4.7.1
j	Lightning impulse voltage test followed by power frequency voltage test	12.4.7.2
k	Partial discharge tests at ambient temperature and at high temperature (if not carried out after item g above)	12.4.4
l	Additional tests for accessories	Annex H
m	Examination	12.4.8
n	Resistivity of semi-conducting screens	12.4.9
o	Non-electrical type tests for cable components and on completed cable	12.5

Table C.2 – PQ tests on cable systems

Item	Test	Clauses
a	General and range of PQ test approval	13.1
b	PQ test on complete cable system	13.2
c	Summary of PQ tests	13.2.1
d	Test voltage values	13.2.2
e	Test arrangement	13.2.3
f	Heating cycle voltage test	13.2.4
g	Lightning impulse voltage test	13.2.5
h	Examination	13.2.6

Table C.3 – EQ tests on cable systems

Item	Test	Clauses
a	General and range of prequalification test approval	13.1
b	Tests for the extension of the prequalification of a cable system	13.3
c	Electrical part of the extension of prequalification tests on complete cable system	13.3.2
d	Test voltage values	13.3.2.2
e	Bending test without partial discharge test	12.4.3
f	Partial discharge test at ambient temperature after installation of the accessories that are part of the test	12.4.4
g	Heating cycle test without voltage	13.3.2.4
h	Tan δ measurement	12.4.5
i	Heating cycle voltage test	12.4.6
j	Partial discharge test at ambient and high temperatures (after final cycle in item i above or after lightning impulse voltage test in item l below)	12.4.4
k	Switching impulse voltage test	12.4.7.1
l	Lightning impulse voltage test followed by power frequency voltage test	12.4.7.2
m	Partial discharge test at high temperature (if not carried out after item i above)	12.4.4
n	Additional tests for accessories	Annex H
o	Examination	12.4.8
p	Resistivity of semi-conducting screens	12.4.9
q	Non-electrical type tests on cable components and on completed cable	12.5

Annex D
(normative)

Measurement method for resistivity of semi-conducting screens

Each test piece shall be prepared from a 150 mm sample of 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 D.1). The insulation screen test piece shall be prepared by removing all the coverings from a sample of core (see Figure D.2).

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

Four silver-painted electrodes A, B, C and D (see Figure D.1 and Figure D.2) 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 screen and the thicknesses 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 D.2.

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

a) conductor screen:

$$\rho_{\mathrm{c}} = \frac{R_{\mathrm{c}} \times \pi \times \left(D_{\mathrm{c}} - T_{\mathrm{c}}\right) \times T_{\mathrm{c}}}{2\, L_{\mathrm{c}}}$$

where:

ρ_{c} is the volume resistivity, in ohm metres (Ω · m);

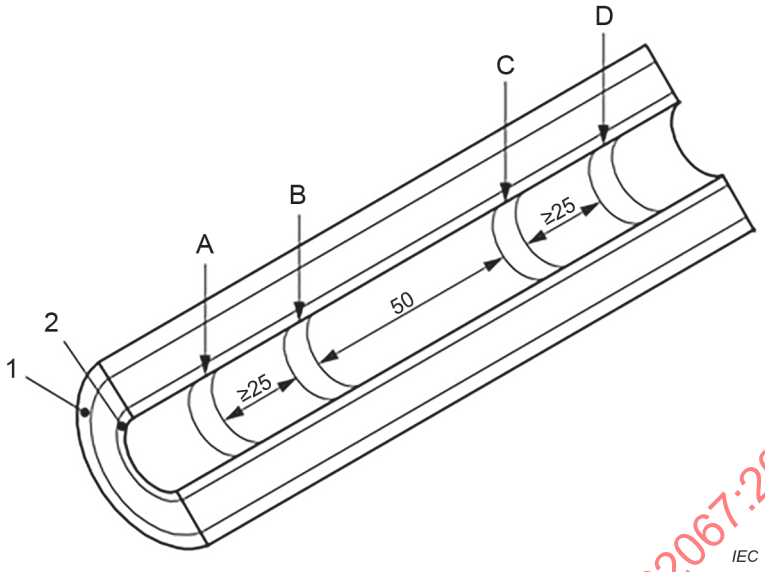
R_{c} is the measured resistance, in ohms (Ω);

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).

Dimensions in millimetres



Key

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

Figure D.1 – Dimensions for preparation of samples for measurement of resistivity of conductor screen

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 (Ω · m);

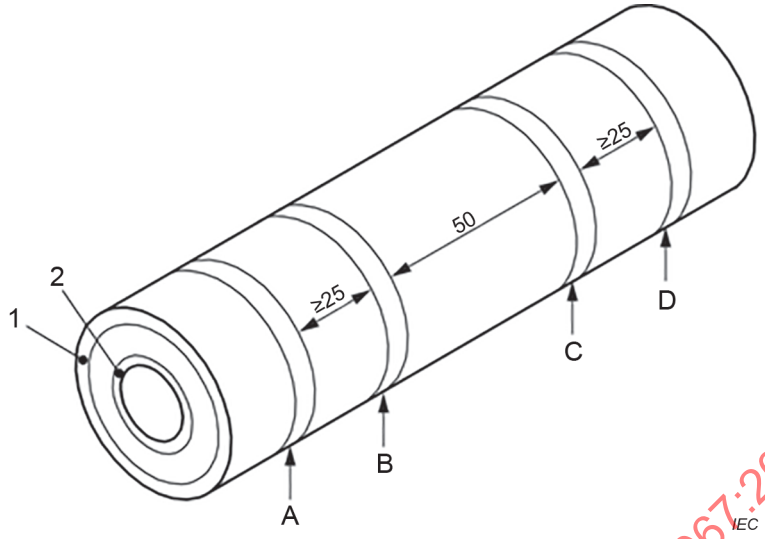
R_i is the measured resistance, in ohms (Ω);

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



Key

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

Figure D.2 – Dimensions for preparation of samples for measurement of resistivity of insulation screen

Annex E
(normative)

Water penetration test

E.1 Test piece

A sample of cable at least 8 m in length which has not been subjected to any of the tests described in 12.4 shall be subjected to the bending test described in 12.4.3.

An (8,0 ± 0,050) m length of cable shall be cut from the length which has been subjected to the bending test and placed horizontally. A ring approximately 50 mm wide shall be removed from the centre of the length. This ring shall comprise all the layers external to the insulation screen. Where the conductor is also claimed to contain a longitudinal water barrier, the ring shall comprise all layers external to the conductor.

If the cable contains intermittent barriers to longitudinal water penetration, then the sample shall contain at least two of these barriers, the ring being removed from between the barriers. In this case, the average distance between the barriers in such cables should be known.

The surfaces shall be cut so that the interfaces intended to be longitudinally watertight shall be readily exposed to water. The interfaces not intended to be longitudinally watertight shall be sealed with a suitable material or the outer coverings removed.

Examples of such interfaces include

– when the cable only has a conductor barrier;
– when the interface is positioned between the oversheath and the metal sheath.

Arrange a suitable device (see Figure E.1) to allow a tube having a diameter of at least 10 mm to be placed vertically over the exposed ring and sealed to the surface of the oversheath. The seals where the cable exits the apparatus shall not exert mechanical stress on the cable.

The response of certain barriers to longitudinal penetration can be dependent on the composition of the water (e.g. pH, ion concentration). Normal tap water should be used for the test unless otherwise specified.

E.2 Test

The tube shall be filled within 5 min with tap water at a temperature of (20 ± 10) °C so that the height of the water in the tube is (1,0 ± 0,050) m above the cable centre (see Figure E.1).

The sample shall be allowed to stand for 24 h.

The sample shall then be subjected to 10 heating cycles. The conductor shall be heated by a suitable method until it has reached a steady temperature 5 K to 10 K above the maximum conductor temperature in normal operation; it shall not, however, reach the boiling point of water.

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.

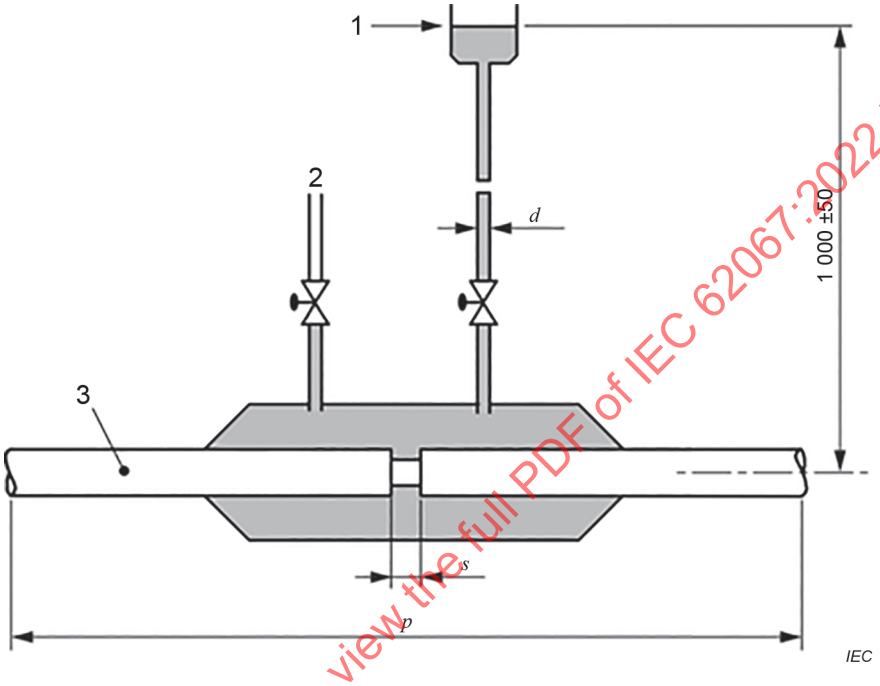
The water head shall be maintained at (1,0 ± 0,050) m.

No voltage being applied throughout the test, it is recommended to connect a reference cable in series with the cable to be tested, the temperature being measured directly on the conductor of this cable.

E.3 Requirements

During the period of testing, no water shall emerge from the ends of the test piece.

Dimensions in millimetres



Key

1	water header tank	*d*	Ø10 mm minimum (inner)
2	vent	*s*	50 mm approximately
3	cable	*p*	length = (8 000 ± 50) mm

Figure E.1 – Schematic diagram of apparatus for water penetration test

Annex F
(normative)

Test for water penetration in the conductor

F.1 Test piece

A (4,0 ± 0,050) m sample of cable which has been subjected to the bending test of 12.4.3 shall be placed horizontally.

All layers external to the insulation screen shall be removed from the sample and the full cross-section of the conductor shall be exposed at both ends of the test piece.

Arrange a suitable chamber to enclose one end of the test piece. The chamber shall be fitted with an air vent and a separate vertical tube, both of at least 10 mm internal diameter, with a header tank to allow the application of a (1,0 ± 0,050) m head of water (see Figure F.1). The chamber shall be sealed to the surface of the insulation screen. The seal where the cable exits the chamber shall not deform the insulation during the test.

The response of certain barriers to longitudinal penetration can be dependent on the composition of the water (e.g. pH, ion concentration). Normal tap water should be used for the test unless otherwise specified.

F.2 Test

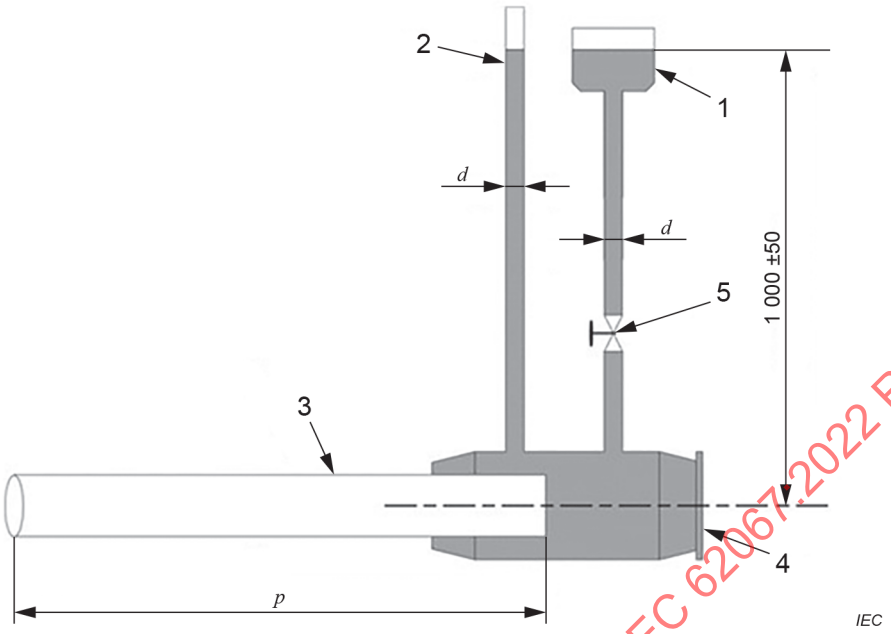
The tube shall be filled within 5 min with tap water at a temperature of (20 ± 10) °C so that the height of the water in the tube is (1,0 ± 0,050) m above the cable centre (see Figure F.1).

The sample shall be allowed to stand for 11 days at ambient temperature.

F.3 Requirements

During the period of testing, no water shall emerge from the end of the test piece.

Dimensions in millimetres



Key

1 water header tank
2 air vent
3 test piece
4 chamber
5 full bore valve (optional)
d internal diameter ≥ 10 mm
p length = (4 000 ± 50) mm

Figure F.1 – Schematic diagram of apparatus for water penetration test in the conductor

Annex G
(normative)

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

G.1 Visual examination

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 tape or foil, or buckling or crossing of the screen wires.

G.2 Adhesion and peel strength

G.2.1 General

Adhesion and peel strength are defined as

$$F / w$$

where:

F is the force (N);

w is the width of the 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, the adhesion strength and peel strength of the laminated covering shall be as high as possible.

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.

In the case of an SscD design (separate semi-conductive design – SscD design with separated electrical and radial watertightness properties with semi-conductive plastic-coated foil), the test cannot be performed because the metal foil is so thin that it breaks during the adhesion or peeling strength test.

NOTE Examples of the different designs as described above can be found in IEC TR 61901 [1].

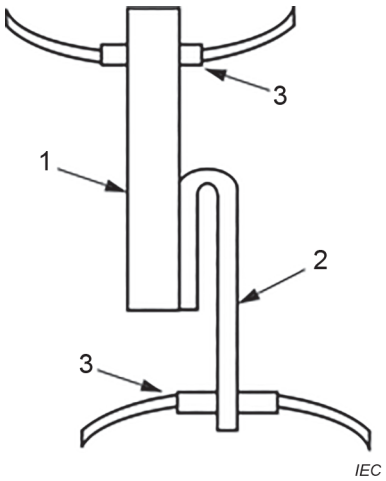
G.2.2 Test: Adhesion strength

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

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

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 tape or foil shall be turned back and clamped in the other grip as shown in Figure G.1.



Key

1 oversheath

2 metal tape or foil

3 grips

Figure G.1 – Adhesion of metal tape or foil

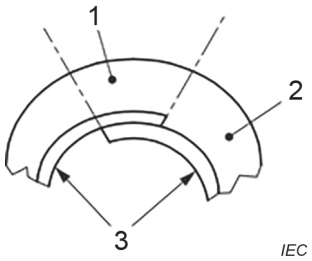
The specimen should be held approximately vertically in the plane of the grips during the test.

After adjusting the continuous recording device, the metal tape or 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 tape or foil so that the latter breaks before peeling, the test shall be terminated and the break point shall be recorded.

G.2.3 Test: Peel strength of overlapped metal foil

A sample specimen of approximately 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 G.2.



Key

1 specimen

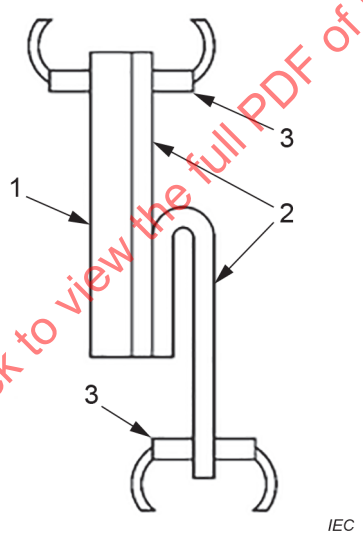
2 oversheath

3 metal foil or laminated metal foil

Figure G.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 G.3.

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



Key

1 oversheath

2 metal foil or laminated metal foil

3 grips

Figure G.3 – Peel strength of overlapped metal foil

G.2.4 Requirements

The strength shall be recorded against the spacing of the grips. Typical recordings are shown in Figure G.4 and Figure G.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 steady state is achieved. The minimum strength F_{min} shall be determined for an increase in the spacing between the grips of at least 50 mm. A tensile testing machine with either a direct output for the minimum value or a graphical output can be used. Figure G.4 and Figure G.5 give typical curves from a graphical output machine and indicate how they shall be interpreted.

Minimum acceptable adhesion and peel strength forces are shown in Table G.1.

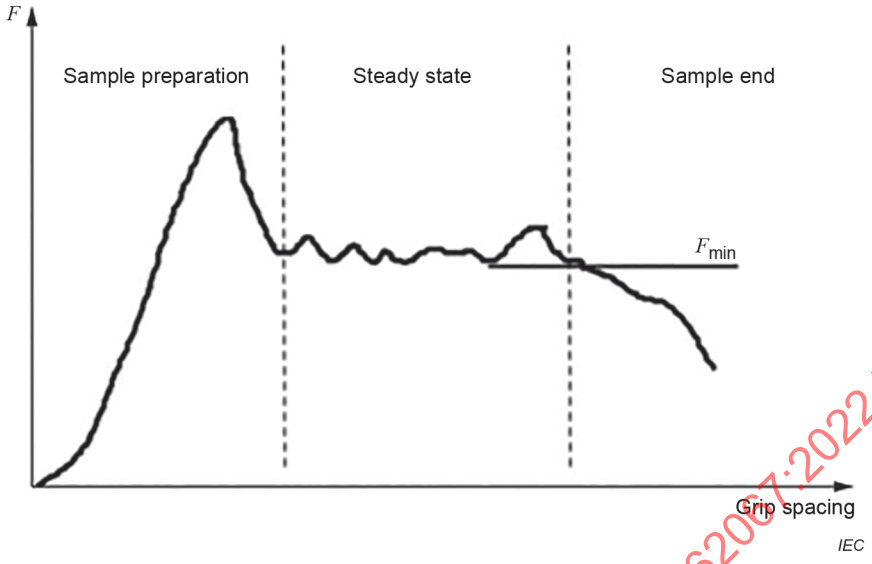


Figure G.4 – Typical strength versus grip spacing curve (1)

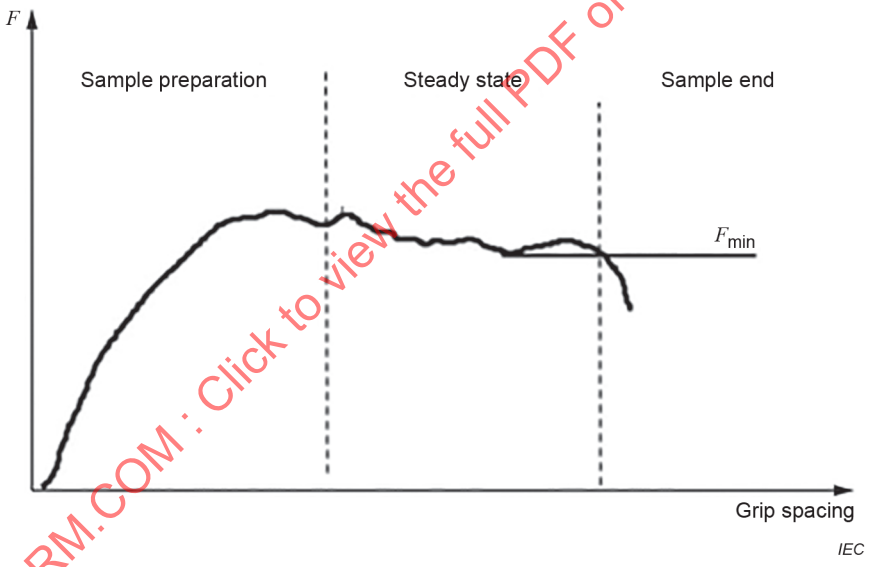


Figure G.5 – Typical strength versus grip spacing curve (2)

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

Adhesion or peel strength F_{min}	**Type of screen**					
	CD		SD		SscD	
N/mm	Copper	1,5	Copper	1,0	Lead	NA
N/mm	Aluminium	1,5	Aluminium	1,0	Aluminium	NA
N/mm	Overlap	1,5	Overlap	1,0	Overlap	NA
Key NA: The test cannot be performed.						

Annex H
(normative)

Additional tests for accessories

H.1 General

Annex H specifies the procedure for additional tests, which are either type tests or extension of qualification tests for accessories for:

– joints with or without screen interruption;
– accessories for cable screen interruption and/or earth connection;
– terminations with an insulated screen;
– insulators for outdoor terminations;
– gas immersed terminations, when changing the insulating gas in the cable connection enclosure.

Accessories specified for installation in air only can be tested without the water immersion test, subject to agreement between purchaser and manufacturer. The risk of presence of water, for example in terms of tunnel installation or any other risk of temporary exposure of joints or accessories to water, should be considered in this case.

Accessories tested with the water immersion test are compliant when used for installation in air as well as in other situations. Accessories tested without the water immersion test are not compliant when used for buried installation or in an environment with the risk of exposure to water.

The manufacturer of the accessory shall provide a drawing in which all relevant features tested under this annex are clearly defined and identified.

Table H.1 lists the test procedures for different types of accessories.

Table H.1 – Test sequence

Test sequence	Joints without screen or metal sheath interruption and cable accessories without a screen or metal sheath/screen interruption (e.g. earth connection)	Joints with screen or metal sheath interruption and cable accessories with a screen or metal sheath/screen interruption (e.g. earth connection and/or cross bonding applications)	Terminations with an insulated screen	Insulators for outdoor terminations	Change of insulating gas for gas immersed termination
	Clause H.3	Clause H.3	Clause H.4	Clause H.4.4	Clause H.6
Subjected to 20 thermal cycles with or without voltage	X	X	X[b]	–	–
Water immersion conditioning (20 thermal cycles)	X[a]	X[a]	–	–	–
DC voltage withstand test screen to earth	X	X	X	–	–
DC voltage withstand test screen to screen	–	X	–	–	–
Lightning impulse voltage withstand test screen to earth	X	X	X	–	–
Lightning impulse voltage withstand test screen to screen	–	X	–	–	–
Internal pressure test	–	–	–	X	–
Cantilever load test	–	–	–	X	–
Examination	X	X	X	–	–
Electrical tests	–	–	–	–	X
Leak rate test	–	–	–	–	X

[a] Not applicable to accessories for installation in air, tested without water immersion.

[b] Not applicable if the sheath sectionalizing insulation is external to the main body of the accessory, see H.4.1.

H.2 Range of approval

H.2.1 Range of approval for joints without screen or metal sheath interruption

When the test sequence according to this annex has been successfully performed for a joint design without screen interruption, the type approval shall be considered as valid for all joints without screen interruption for the same conductor size or smaller, embodying the same basic design principles and the same materials tested at equal or lower test voltages.

Where approval is required for joint outer protection embodying entries for items such as bonding leads, the outer protection tested shall include these design features.

A successful test on the joint outer protection with embodying entries will give approval to such outer protection for a similar joint without embodying entries, but not the converse.

H.2.2 Range of approval for joints with screen or metal sheath interruption

When the test sequence according to this annex has been successfully performed for a joint design with screen interruption, the type approval shall be considered as valid for all joints with or without screen interruption for the same conductor size or smaller, embodying the same basic design principles and the same materials tested at an equal or lower voltage group.

Where approval is required for joint outer protection embodying entries for items such as bonding leads, the outer protection tested shall include these design features.

A successful test on the joint outer protection with embodying entries will give approval to such outer protection for a similar joint without embodying entries, but not the converse.

H.2.3 Range of approval for accessories for cable screen interruption and/or earth connection

When the test sequence according to this annex has been successfully performed on a cable with screen or metal sheath interruption, the type approval shall be considered as valid for all cables with screen or metal sheath interruption offered by the same manufacturer, embodying the same basic design principles, at an equal or lower voltage group.

H.2.4 Range of approval for terminations with an insulated screen

When the test sequence according to this annex has been successfully performed for terminations with an insulated screen, the type approval shall be considered as valid for all terminations without an insulated screen, offered by the same manufacturer, embodying the same basic design principles, at an equal or lower voltage group.

H.3 Tests of joints with or without screen or metal sheath interruption and accessories for cable screen interruption and/or earth connection

H.3.1 Conditioning of sample for test

The test of joints, cables with a metal sheath interruption and accessories for cable screen interruption and/or earth connection, shall be applied to an accessory which has passed the heating cycle voltage test (see 12.4.6) or to a separate accessory which has undergone at least 20 thermal cycles according to 12.4.6 but without voltage applied.

If the accessory is not to be subjected to wet conditions in service (i.e. not directly buried in earth or not intermittently or continuously immersed in water), the test in H.3.2 can be omitted.

H.3.2 Water immersion test

The assembly to be approved shall be immersed in water to a depth of not less than 1,0 m at the highest point of the outer protection. Where desired, this can be achieved by using a header tank connected to a sealed-off vessel containing the test assembly.

Additional voltage tests according to H.3.3 can be carried out before commencing the heating/cooling cycles, at the discretion of the manufacturer.

A total of 20 heating/cooling cycles shall be applied by raising the water temperature to within 15 K to 20 K below the maximum temperature of the cable conductor in normal operation. In each cycle, the water shall be raised to the specified temperature, maintained at that level for at least 5 h and then be permitted to cool to within 10 K above the ambient temperature. The test temperature can be achieved by mixing the water with water of higher or lower temperature. The minimum duration of each cycle of heating and cooling shall be 12 h and the duration for raising the water temperature to the specified temperature shall be as much as possible the same as the duration for cooling the water to within 30 °C or 10 K above the ambient temperature, whichever is the higher.

H.3.3 Electrical tests

H.3.3.1 General

For accessories subjected to the water immersion test, voltage tests shall be carried out on completion of the heating cycles in water, with the test assembly still immersed. If it is not practicable to carry out the electrical tests whilst the assembly is still immersed in water, the assembly can be removed from the water and the voltage tests carried out with a minimum of delay. In this case, earthing of the test object can be achieved by wrapping with a wet fabric, or by using a conductive coating applied over the entire exterior surface of the test assembly.

For accessories without a water immersion, test earthing of the test object can be achieved by wrapping with a conductive tape or mesh, or using a conductive coating applied over the entire exterior surface of the test assembly.

All accessories shall be subjected to the tests in H.3.3.2 and H.3.3.4. In addition, accessories with a screen or metal sheath interruption shall also be subjected to the tests in H.3.3.3 and H.3.3.5. In both cases the tests shall be carried out in the order given below. All tests in this annex shall be carried out at ambient temperature if not specified otherwise.

No breakdown of the test object shall occur during any of the electrical withstand tests. Failure or flashover of a termination of the cable shall not be considered a failure of the test object.

H.3.3.2 DC voltage withstand test between screen and earth

A test voltage of 25 kV DC shall be applied for 1 min between the metal screen or sheath and the earthed exterior of the test object.

H.3.3.3 DC voltage withstand test between screen and screen

A test voltage of 25 kV DC shall be applied for 1 min between both sides of the metal screen or sheath interruption of the test object.

H.3.3.4 Lightning impulse voltage withstand test between screen and earth

A test voltage in accordance with Table H.2 shall be applied between the metal screens/sheaths and the exterior of the assembly.

The testing procedure shall be performed in accordance with IEC 60230.

Table H.2 – Lightning impulse voltage withstand test between screen and earth of joints with or without screen or metal sheath interruption and accessories for cable screen interruption and/or earth connection

Rated lightning impulse voltage for main insulation[a] kV	Lightning impulse level – metal screen to earth kV
1 050	47,5
1 175 to 1 425	62,5
1 550	72,5
[a] See Table 4, column 8.	

H.3.3.5 Lightning impulse voltage withstand test between screen and screen

Before the lightning impulse test between the metal screens/sheaths, the assembly shall be removed from the water, if applicable.

To test between parts, a test voltage in accordance with Table H.3 shall be applied.

The testing procedure shall be performed in accordance with IEC 60230.

Table H.3 – Lightning impulse voltage withstand test between screen and screen of joints with screen or metal sheath interruption and accessories for cable screen interruption and/or earth connection

Rated lightning impulse voltage for main insulation[a] kV	Lightning impulse level – between parts kV
1 050	95
1 175 to 1 425	125
1 550	145
[a] See Table 4, column 8.	

H.3.4 Examination

The examination of the accessories shall be done as stated in 12.4.8.1 and in addition for accessories subjected to the water immersion test:

– the accessory shall be examined with respect to the defined and clearly identified water-protection barriers (see Clause H.1);

– outer protection boxes filled with removable compounds shall be regarded as satisfactory if there is no visible evidence of either internal voids or internal displacement of compound by water ingress, or of compound loss via the various seals or box walls;

– for outer protections employing alternative designs and materials, there shall be no evidence of water ingress or internal corrosion behind the defined water-protection barriers.

H.4 Tests of terminations with an insulated screen

H.4.1 Conditioning of sample for test

The test of terminations with an insulated screen shall be applied to an accessory which has passed the heating cycle voltage test (see 12.4.6) or to a separate accessory which has undergone at least 20 thermal cycles according to 12.4.6 but without voltage applied. This requirement can be omitted if the screen insulation is external to the main body of the accessory, for example in the case of support insulators.

H.4.2 DC voltage withstand test between screen and earth

A test voltage of 25 kV DC shall be applied for 1 min between the screen and earth.

H.4.3 Lightning impulse voltage withstand test between screen and earth

A test voltage in accordance with Table H.4 shall be applied between the screen and earth.

The testing procedure shall be performed in accordance with IEC 60230.

Table H.4 – Lightning impulse voltage withstand tests between screen and earth of terminations with an insulated screen

Rated lightning impulse voltage for main insulation[a] kV	Lightning impulse level – metal screen to earth kV
1 050	47,5
1 175 to 1 425	62,5
1 550	72,5
[a] See Table 4, column 8.	

H.4.4 Examination

The examination of the accessories shall be done as stated in 12.4.8.1.

H.5 Tests for insulators for outdoor terminations

H.5.1 Tests for ceramic insulators

H.5.1.1 General

One insulator of each type shall be subjected to the tests given in H.5.1.2 and H.5.1.3. Alternatively, a certificate or test report can be provided, as acceptable evidence of testing as specified in 12.2.

H.5.1.2 Internal pressure test

For insulators which will be pressurized in service, the type test pressure test shall be carried out according to IEC 62155.

The requirements of IEC 62155 shall be met.

H.5.1.3 Cantilever load withstand test

The cantilever load withstand test shall be carried out according to IEC 60137. The test load for insulators designed for Level I and Level II cantilever loads shall be in accordance with Table 11. The test load for insulators designed for other cantilever loads shall be subject to agreement between the purchaser and the manufacturer.

There shall be no evidence of damage (deformation, rupture or leakage).

H.5.2 Tests for composite insulators

H.5.2.1 General

One insulator of each type shall be subjected to the tests according to IEC 61462 as given in H.5.2.2 and H.5.2.3. Alternatively, a certificate or test report can be provided, as acceptable evidence of testing as specified in 12.2.

H.5.2.2 Internal pressure test

For insulators which will be pressurized in service, the internal pressure test according to IEC 61462 shall be carried out. The requirements of IEC 61462 shall be met.

H.5.2.3 Bending test

The bending test according to IEC 61462 shall be carried out for the declared MML value for the insulator, see Clause 7. The requirements of IEC 61462 shall be met.

H.6 Tests for gas-immersed terminations in case of changing insulating gas

H.6.1 General

The tests in H.6.2 and H.6.3 shall be carried out in order to approve a design of gas immersed termination for use with an alternative gas, to that used during a type test, in the cable connection enclosure.

In addition, the type test for the pressure test on the insulator, according to IEC 62271-209, shall be carried out if the design pressure of the insulator required for the alternative gas is higher than the design pressure for which the insulator has previously been type tested.

The compatibility of new gases or gas mixture with the components, especially seals, of the cable termination shall be considered to avoid the possibility of leaks developing in service. Other technical aspects can require evaluation depending on the nature of the alternative gas.

H.6.2 Electrical tests

H.6.2.1 Test assembly

The gas immersed termination shall be installed in a cable connection enclosure in accordance with 8.6. There shall be at least 5 m of free cable between the gas immersed termination and any other accessory. The termination shall be heated by conductor current for the tests in H.6.2.3 and H.6.2.4.

H.6.2.2 Partial discharge test at ambient temperature

A partial discharge test shall be carried out at ambient temperature according to 12.4.4.

H.6.2.3 Impulse voltage tests

Impulse voltage tests shall be carried out according to 12.4.7.

H.6.2.4 Partial discharge test at high temperature

A partial discharge test at high temperature shall be carried out according to 12.4.4.

H.6.3 Leak rate test

The leak rate type test on the insulator of a cable termination according to IEC 62271-209 shall be carried out.

The requirements of IEC 62271-209 shall be met.

Annex I
(informative)

Guidance on examination of cable and accessories

It should be noted that it is not possible to specify objective acceptance criteria for all possible types of deterioration (such as deformation or changes) that can be encountered during a visual inspection.

The visual inspection will therefore always contain some degree of subjectivity. To reduce this problem a list of possible types of deterioration that can be encountered during a visual inspection is given in this annex.

When carrying out an examination, care should be taken to avoid contamination of samples, keeping in mind that the overall purpose is to check for signs of deterioration which could affect the operation of a cable system in service.

In some cases, it can be helpful to have an untreated sample of the cable or accessory (or components of an accessory) as a reference for the visual inspection.

Samples of cable, possibly taken from different positions in the tested length, and accessories, for example one of the joints and terminations, should be subjected to the visual inspection, as required by this document.

Examination of the samples with normal or corrected vision without magnification should not reveal any deterioration of the types listed below. The following list is not exhaustive, so any unexpected or unusual changes shall also be considered and their potential effects on operation of a cable system in service considered by the examining persons when making a decision as to their acceptability or otherwise.

– damage to the conductor which could have a detrimental effect on the cable performance;
– harmful indentations in the cable core(s), sharp indentations of the semi-conductive screen into the insulation;
– presence of corrosion on metallic parts, for example metallic screen and connections;
– indication of possible mechanical degradation in the dielectric parts;
– indication of possible electrical degradation in primary insulation of accessory and cable: shrinkage, deformation or other distortions that can affect compliance with the requirements of the relevant product specification, for example creepage distances should not fall below minimum acceptable values and there should not be any change that would make any hazardous part accessible;
– indication of thermal degradation (all components);
– cracking or damage to the insulation;
– damage on the cable sheath which could have a detrimental effect on the cable performance for example water ingress, possibly leading to corrosion in the long term;
– leak or emission of insulating fluid: any leakage of material involved in the insulation of an accessory should be reported;
– significant change in dimensions which could have a detrimental effect on the cable or accessory performance.

Annex J
(informative)

Guidance for type test on heating-cycle-voltage-test interruption and cycle validity

J.1 Interruption of cycles during a heating cycle voltage test

J.1.1 Scheduled interruption of test

During the interruption, no heating cycles are applied to the cable system. As the interruption of the test is scheduled, the interruption is made after ending of a complete heating cycle. After the interruption period, the test is restarted by applying the test voltage together with the start of a new heating cycle. Only complete applied heating cycles count towards the required number of heating cycles. Planning of interruptions to influence the outcome of the test is not allowed.

J.1.2 Non-scheduled interruption of test

a) If the cause of a non-scheduled interruption is detected and corrected within 15 min it can be treated as a controlled interruption of test, as detailed in J.1.1.

b) More often, the delay is more than 15 min and the non-scheduled interruption takes place somewhere during the heating cycle. In such a case, after clearing the cause of the interruption, the test should be restarted after the temperature of the conductor has reached a temperature less than or equal to 30 °C or within 15 K of ambient temperature, whichever is the higher, but with a maximum of 45 °C.

The interrupted heating cycle does not count towards the required number of heating cycles.

J.2 Valid heating cycles

Valid heating cycles are those for which:

- there are no interruptions other than as given in J.1.2, item a);
- test voltage, at the specified value, is applied continuously;
- the temperature of the cable conductor, at the start of the cycle and at the end of the cycle, is within the range given in J.1.2, item b) above;
- the temperature of the cable conductor at the hot part of the cycle is at or above the minimum value specified for at least the time specified;
- the ambient temperature is within the range specified;
- the length of the cycle is at least 24 h and the heating is applied for at least 8 h;
- there are records confirming the above points.

Annex K
(normative)

Methods for determining the weighted value of halogen content of the non-metallic materials in the cable

K.1 Calculating the weighted value for the cable when the halogen content of individual non-metallic material is tested

Measure the weight, w_i, of each non-metallic material, i, per unit length of cable.

The weighted value for the halogen content of non-metallic materials in the cable, H_i' for each halogen (i.e. F, Cl, Br, I), is calculated as follows:

$$H_i' = \frac{\sum(H_i \times w_i)}{\sum w_i}$$

Where H_i is the halogen content of the individual material of weight w_i.

The sum of the weighted values of the halogen content of non-metallic materials in the cable of the four individual halogens (F, Cl, Br, I), i.e. $\sum H_i'$, shall be calculated.

K.2 Preparation of the test sample for measurement of halogen content on a sample representative of the non-metallic materials in the cable

A sample of length 15 mm to 25 mm of the cable shall be cut into small pieces after all metal elements have been removed. The sample shall be of sufficient length to give the required weight of test specimen. The cable components shall be cut into small pieces no larger than 3 mm.

The pieces should be well mixed and the test sample shall be taken from the mixture.

Bibliography

[1] IEC TR 61901, *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)*

[2] 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*

[3] Electra No. 151, *Recommendations for electrical tests, prequalification and development, on extruded cables and accessories at voltages > 150 (170) kV and ≤ 400 (420) kV,* December 1993, pp 14-19

[4] Electra No. 151, *Recommendations for electrical tests, type, sample and routine, on extruded cables and accessories at voltages > 150 (170) kV and ≤ 400 (420) kV,* December 1993, pp 20-28

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

[6] CIGRE Technical Brochure 303: *Revision of qualification procedures for HV and EHV AC extruded underground cable systems*, August 2006

[7] IEC 60183, *Guidance for the selection of high-voltage A.C. cable systems*

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

[9] IEC 60332-3-23, *Tests on electric and optical fibre cables under fire conditions – Part 3-23: Test for vertical flame spread of vertically-mounted bunched wires or cables – Category B*

[10] IEC 60853-2, *Calculation of the cyclic and emergency current rating of cables – Part 2: Cyclic rating of cables greater than 18/30 (36) kV and emergency ratings for cables of all voltages*

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

[12] IEC 60811-100, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 100: General*

[13] IEC 60811-405, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 405: Miscellaneous tests – Thermal stability test for PVC insulations and PVC sheaths*

[14] IEC TS 60815-1, *Selection and dimensioning of high-voltage insulators intended for use in polluted conditions – Part 1: Definitions, information and general principles*

[15] IEC TS 60815-3, *Selection and dimensioning of high-voltage insulators intended for use in polluted conditions – Part 3: Polymer insulators for a.c. systems*

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

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

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

[19] Electra No. 205-3, *Experiences with AC tests after installation on the main insulation of polymeric (E)HV cable systems*, December 2002, pp 26-36

[20] Electra No. 227, *Revision of qualification procedures for extruded high voltage AC underground cable systems*, August 2006, pp 31-37

[21] CIGRE Technical Brochure 728, *On-site partial discharge assessment of HV and EHV cable systems*, May 2018

[22] CIGRE Technical Brochure 841, *After laying tests on AC and DC cable systems with new technologies*, September 2021

SOMMAIRE

COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

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CÂBLES D'ÉNERGIE À ISOLATION EXTRUDÉE ET LEURS ACCESSOIRES POUR DES TENSIONS ASSIGNÉES SUPÉRIEURES À 150 kV (U_m = 170 kV) ET JUSQU'À 500 kV (U_m = 550 kV) – MÉTHODES ET EXIGENCES D'ESSAI

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8) L'attention est attirée sur les références normatives citées dans cette publication. L'utilisation de publications référencées est obligatoire pour une application correcte de la présente publication.
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L'IEC 62067 a été établie par le comité d'études 20 de l'IEC: Câbles électriques. Il s'agit d'une Norme internationale.

Cette troisième édition annule et remplace la deuxième édition parue en 2011. Cette édition constitue une révision technique.

Cette édition inclut les modifications techniques majeures suivantes par rapport à l'édition précédente:

a) une nouvelle classe de matériaux (ST_{12}) soumise à des exigences de tenue au feu a été ajoutée;
b) la liste des essais de tenue au feu a été élargie; les essais peuvent être choisis en fonction des caractéristiques de performance revendiquées pour le câble;

c) la gamme des conceptions d'écrans métalliques pour câbles et l'essai d'enroulement ont été revus conformément à l'IEC TR 61901 [1][1];

d) des exigences ont été ajoutées pour les isolateurs pour extrémités extérieures;

e) les exigences de conception et d'essai pour les extrémités immergées dans du gaz (et leurs séparations isolantes) ont été alignées sur l'IEC 62271-209; un essai de type supplémentaire est exigé lorsque la séparation isolante est installée par le fabricant de l'appareillage;

f) un essai de pénétration d'eau distinct est exigé pour l'âme du câble;

g) les essais sous tension alternative de l'enveloppe isolante après installation ont été revus conformément aux recommandations récemment publiées CIGRE;

h) des essais ont été ajoutés en cas de changement du type de gaz isolant utilisé dans l'enveloppe du raccordement de câble d'une extrémité immergée dans du gaz.

Le texte de cette Norme internationale est issu des documents suivants:

Projet	Rapport de vote
20/2017/FDIS	20/2020/RVD

Le rapport de vote indiqué dans le tableau ci-dessus donne toute information sur le vote ayant abouti à son approbation.

La langue employée pour l'élaboration de cette Norme internationale est l'anglais.

Le présent document a été rédigé selon les Directives ISO/IEC, Partie 2, il a été développé selon les Directives ISO/IEC, Partie 1 et les Directives ISO/IEC, Supplément IEC, disponibles sous www.iec.ch/members_experts/refdocs. Les principaux types de documents développés par l'IEC sont décrits plus en détail sous www.iec.ch/standardsdev/publications.

Le comité a décidé que le contenu du présent document ne sera pas modifié avant la date de stabilité indiquée sur le site web de l'IEC sous webstore.iec.ch dans les données relatives au document recherché. A cette date, le document sera

- reconduit,
- supprimé,
- remplacé par une édition révisée, ou
- amendé.

[1] Les chiffres entre crochets renvoient à la bibliographie.

INTRODUCTION

Face aux développements majeurs dont ont fait l'objet les systèmes de câbles à isolation extrudée destinés à des tensions supérieures à 150 kV, le Comité d'études (SC) 21 du CIGRE a créé le Groupe de travail (WG) 21.03 en 1990. Les termes de référence du WG 21.03 étaient "*d'établir des recommandations pour les essais de type, les essais individuels de série et les essais sur prélèvements électriques, en étendant les tensions de l'IEC 60840:1988 à 400 kV et de formuler des propositions pour les essais de préqualification/développement qu'il convient d'effectuer au minimum*".

Le WG 21.03 a indiqué que l'extension de l'IEC 60840 [2] aux tensions supérieures à 150 kV nécessitait une considération particulière en raison des facteurs suivants:

1) ces câbles constituent l'un des éléments essentiels des réseaux de transport et, par conséquent, les considérations de fiabilité sont de la plus haute importance;
2) ces câbles et leurs accessoires fonctionnent sous des contraintes électriques supérieures à celles des câbles de tensions jusqu'à 150 kV et, de ce fait, ont une marge de sécurité plus restreinte par rapport à la performance intrinsèque des liaisons par câbles;
3) ces câbles et leurs accessoires ont une épaisseur d'isolation plus forte que celle des matériels jusqu'à 150 kV et sont donc soumis à des contraintes thermomécaniques plus fortes;
4) la conception et la coordination des câbles et de leurs accessoires deviennent plus difficiles avec l'accroissement des niveaux de tension des réseaux.

Les recommandations du WG 21.03 ont été publiées dans la brochure Electra n° 151 [3] [4] en décembre 1993 et prises en compte par l'IEC en 1995 lors de la préparation de la présente norme relative aux systèmes de câbles à isolation extrudée de tensions supérieures à 150 kV. Néanmoins, l'IEC a estimé qu'il convenait de couvrir également le niveau 500 kV dans la nouvelle norme. Lors de sa réunion de septembre 1996, le SC 21 du CIGRE a donc créé le groupe ad hoc 21.18 afin d'étudier l'extension des recommandations initiales à la tension de 500 kV. Le comité d'études (CE) 20 de l'IEC a pris en compte les recommandations mises à jour lors de la préparation de la première édition de la présente norme.

Sur avis du CIGRE, un essai de vieillissement accéléré de longue durée a été introduit dans la première édition afin de recueillir des indications sur la fiabilité à long terme d'un système de câble. Cet essai, appelé "essai de préqualification", devait être effectué sur le système complet équipé du câble, des jonctions et des extrémités afin de démontrer la performance du système.

En outre, en août 1997, le WG 21.09 du CIGRE a publié ses recommandations pour les "essais après installation des systèmes de câbles haute tension à isolation extrudée" dans la brochure Electra n° 173 [5]. Ces recommandations avaient également été prises en compte dans la première édition de la présente norme; celles-ci indiquaient notamment qu'il convenait d'éviter de réaliser les essais sous tension continue sur l'isolation principale, car ces essais étaient inefficaces et dangereux.

Lors de sa réunion en novembre 2004, le CE 20 a décidé qu'il convenait d'inclure dans la prochaine révision de l'IEC 62067 les recommandations d'essai pour les câbles extrudés HT et THT, qui étaient en cours de préparation par le WG B1.06 du SC B1 (antérieurement appelé SC 21). Ces recommandations ont été publiées dans le cadre de la Brochure thématique 303 [6] avant la réunion d'octobre 2006 du CE 20 qui a réaffirmé sa position. Le CE 20 a pris en compte la Brochure thématique 303 dont elle a repris une grande partie du contenu dans la présente norme. Les exigences d'essai de préqualification ont ainsi fait l'objet de quelques modifications mineures, et la modification majeure concernait l'ajout de l'essai d'extension de préqualification. Cet essai prend environ 25 % du temps nécessaire à l'essai de préqualification complet.

La présente troisième édition de l'IEC 62067 a été élaborée dans le cadre des procédures de revue et de mise à jour périodiques de l'IEC en tenant compte des progrès et développements observés dans le secteur de l'énergie.

Une liste des références CIGRE applicables est fournie dans la bibliographie.

CÂBLES D'ÉNERGIE À ISOLATION EXTRUDÉE ET LEURS ACCESSOIRES POUR DES TENSIONS ASSIGNÉES SUPÉRIEURES À 150 kV (U_m = 170 kV) ET JUSQU'À 500 kV (U_m = 550 kV) – MÉTHODES ET EXIGENCES D'ESSAI

1 Domaine d'application

Le présent document spécifie les méthodes et exigences d'essai relatives aux systèmes de câbles d'énergie, aux câbles à isolation extrudée et à leurs accessoires destinés aux installations fixes, pour des tensions assignées supérieures à 150 kV (U_m = 170 kV) et jusqu'à 500 kV (U_m = 550 kV) compris.

Les exigences sont applicables aux câbles unipolaires et à leurs accessoires dans des conditions d'installation et de fonctionnement courantes, mais ne sont pas applicables aux câbles spéciaux et à leurs accessoires, tels que les câbles sous-marins, pour lesquels il peut être nécessaire de modifier les essais normalisés ou d'établir des conditions d'essai particulières.

Les jonctions qui assurent le raccordement des câbles à isolant extrudé aux câbles isolés au papier ne sont pas couvertes par le présent document.

2 Références normatives

Les documents suivants sont cités dans le texte de sorte qu'ils constituent, pour tout ou partie de leur contenu, des exigences du présent document. Pour les références datées, seule l'édition citée s'applique. Pour les références non datées, la dernière édition du document de référence s'applique (y compris les éventuels amendements).

IEC 60060-1, *Techniques des essais à haute tension – Partie 1: Définitions et exigences générales*

IEC 60060-3, *High-voltage test techniques – Part 3: Definitions and requirements for on-site testing* (disponible en anglais seulement)

IEC 60137, *Traversées isolées pour tensions alternatives supérieures à 1 000 V*

IEC 60228, *Ames des câbles isolés*

IEC 60229:2007, *Câbles électriques – Essais sur les gaines extérieures extrudées avec fonction spéciale de protection*

IEC 60230, *Essais de choc des câbles et de leurs accessoires*

IEC 60287-1-1, *Câbles électriques – Calcul du courant admissible – Partie 1-1: Equations de l'intensité du courant admissible (facteur de charge 100 %) et calcul des pertes – Généralités*

IEC 60332-1-2, *Essais des câbles électriques et à fibres optiques soumis au feu – Partie 1-2: Essai de propagation verticale de la flamme sur conducteur ou câble isolé – Procédure pour flamme à prémélange de 1 kW*

IEC 60332-1-3, *Essais des câbles électriques et à fibres optiques soumis au feu – Partie 1-3: Essai de propagation verticale de la flamme sur conducteur ou câble isolé – Procédure pour la détermination des particules/gouttelettes enflammées*

IEC 60332-3-24, *Essais des câbles électriques et à fibres optiques soumis au feu – Partie 3- 24 : Essai de propagation verticale de la flamme des fils ou câbles montés en nappes en position verticale – Catégorie C*

IEC 60754-2, *Essai sur les gaz émis lors de la combustion des matériaux prélevés sur câbles – Partie 2: Détermination de la conductivité et de l'acidité (par mesure du pH)*

IEC 60754- 3, *Essai sur les gaz émis lors de la combustion des matériaux prélevés sur câbles – Partie 3: Mesure d'une faible teneur en halogène par chromatographie ionique*

IEC 60811-201, *Câbles électriques et à fibres optiques – Méthodes d'essai pour les matériaux non métalliques – Partie 201: Essais généraux – Mesure de l'épaisseur des enveloppes isolantes*

IEC 60811-202:2012, *Câbles électriques et à fibres optiques – Méthodes d'essai pour les matériaux non métalliques – Partie 202: Essais généraux – Mesure de l'épaisseur des gaines non métalliques*
IEC 60811-202:2012/AMD1:2017

IEC 60811-203, *Câbles électriques et à fibres optiques – Méthodes d'essai pour les matériaux non métalliques – Partie 203: Essais généraux – Mesure des dimensions extérieures*

IEC 60811-401, *Câbles électriques et à fibres optiques – Méthodes d'essai pour les matériaux non métalliques – Partie 401: Essais divers – Méthodes de vieillissement thermique – Vieillissement en étuve à air*

IEC 60811-403, *Câbles électriques et à fibres optiques – Méthodes d'essai pour les matériaux non métalliques – Partie 403: Essais divers – Essai de résistance à l'ozone sur les mélanges réticulés*

IEC 60811-409, *Câbles électriques et à fibres optiques – Méthodes d'essai pour les matériaux non métalliques – Partie 409: Essais divers – Essai de perte de masse des enveloppes isolantes et gaines thermoplastiques*

IEC 60811-501:2012, *Câbles électriques et à fibres optiques – Méthodes d'essai pour les matériaux non métalliques – Partie 501: Essais mécaniques – Détermination des propriétés mécaniques des mélanges pour les enveloppes isolantes et les gaines*
IEC 60811-501:2012/AMD1:2018

IEC 60811-505, *Câbles électriques et à fibres optiques – Méthodes d'essai pour les matériaux non métalliques – Partie 505: Essais mécaniques – Essai d'allongement à basse température pour les enveloppes isolantes et les gaines*

IEC 60811-506, *Câbles électriques et à fibres optiques – Méthodes d'essai pour les matériaux non métalliques – Partie 506: Essais mécaniques – Essai de choc à basse température pour les enveloppes isolantes et les gaines*

IEC 60811-507, *Câbles électriques et à fibres optiques – Méthodes d'essai pour les matériaux non métalliques – Partie 507: Essais mécaniques – Essai d'allongement à chaud pour les matériaux réticulés*

IEC 60811-508:2012, *Câbles électriques et à fibres optiques – Méthodes d'essai pour les matériaux non métalliques – Partie 508: Essais mécaniques – Essai de pression à température élevée pour les enveloppes isolantes et les gaines*
IEC 60811-508:2012/AMD1:2017

IEC 60811-509, *Câbles électriques et à fibres optiques – Méthodes d'essai pour les matériaux non métalliques – Partie 509: Essais mécaniques – Essai de résistance à la fissuration des enveloppes isolantes et des gaines (essai de choc thermique)*

IEC 60811-605:2012, *Câbles électriques et à fibres optiques – Méthodes d'essai pour les matériaux non métalliques – Partie 605: Essais physiques – Mesure du taux de noir de carbone et/ou des charges minérales dans les mélanges en polyéthylène*

IEC 60811-606, *Câbles électriques et à fibres optiques – Méthodes d'essai pour les matériaux non métalliques – Partie 606: Essais physiques – Méthodes de détermination de la masse volumique*

IEC 60885-3, *Méthodes d'essais électriques pour les câbles électriques – Partie 3: Méthodes d'essais pour la mesure des décharges partielles sur des longueurs de câbles de puissance extrudés*

IEC 61034-2, *Mesure de la densité de fumées dégagées par des câbles brûlant dans des conditions définies – Partie 2: Procédure d'essai et exigences*

IEC 61462, *Isolateurs composites creux – Isolateurs avec ou sans pression interne pour utilisation dans des appareillages électriques de tensions nominales supérieures à 1 000 V – Définitions, méthodes d'essais, critères d'acceptation et recommandations de conception*

IEC 62155, *Isolateurs creux avec ou sans pression interne, en matière céramique ou en verre, pour utilisation dans des appareillages prévus pour des tensions nominales supérieures à 1 000 V*

IEC 62271-209, *Appareillage à haute tension – Partie 209: Raccordement de câbles pour appareillage sous enveloppe métallique à isolation gazeuse de tension assignée supérieure à 52 kV – Câbles remplis d'un fluide ou à isolation extrudée – Extrémité de câble de type sec ou remplie d'un fluide*

3 Termes et définitions

Pour les besoins du présent document, les termes et définitions suivants s'appliquent.

L'ISO et l'IEC tiennent à jour des bases de données terminologiques destinées à être utilisées en normalisation, consultables aux adresses suivantes:

- IEC Electropedia: disponible à l'adresse http://www.electropedia.org
- ISO Online browsing platform: disponible à l'adresse http://www.iso.org/obp

3.1 Définitions de valeurs dimensionnelles (épaisseurs, sections, etc.)

3.1.1
valeur nominale
valeur utilisée pour dénommer une grandeur et qui est souvent indiquée dans les tableaux

Note 1 à l'article: Généralement, dans le présent document, les valeurs nominales correspondent aux valeurs à vérifier par mesurage, en tenant compte des tolérances spécifiées.

3.1.2
valeur médiane
lorsque plusieurs résultats d'essai ont été obtenus et classés dans l'ordre croissant (ou décroissant), valeur centrale de la série si le nombre de valeurs disponibles est impair et moyenne arithmétique des deux valeurs centrales de la série si le nombre est pair

3.2 Définitions relatives aux essais

3.2.1
essai individuel de série
essai effectué par le fabricant sur chacun des composants fabriqués (longueur de câble ou accessoire) afin de vérifier que le composant satisfait aux exigences spécifiées

3.2.2
essai sur prélèvements
essai effectué par le fabricant sur des échantillons de câble complet ou sur des composants prélevés sur un câble ou accessoire complet, à la fréquence spécifiée, afin de vérifier que le produit fini satisfait aux exigences spécifiées

3.2.3
essai de type
essai effectué avant la livraison, sur une base commerciale générale, d'un type de système de câble couvert par le présent document afin de démontrer que ses caractéristiques de performance répondent à l'application prévue

Note 1 à l'article: Les essais de type sont de telle nature qu'après avoir été effectués, il n'est pas nécessaire de les répéter, sous réserve que les matériaux, la conception ou le procédé de fabrication du câble ou des accessoires n'aient subi aucune modification susceptible de modifier leurs caractéristiques de performance.

3.2.4
essai de préqualification
essai PQ
essai effectué avant la livraison, sur une base commerciale générale, d'un type de système de câble couvert par le présent document afin de démontrer que ses performances à long terme sont satisfaisantes

3.2.5
essai d'extension de préqualification
essai EQ
essai effectué avant la livraison, sur une base commerciale générale, d'un type de système de câble couvert par le présent document afin de démontrer que ses performances à long terme sont satisfaisantes en s'appuyant sur un système de câble déjà préqualifié

3.2.6
essai électrique après installation
essai effectué pour démontrer l'intégrité du système de câble après installation

Note 1 à l'article: Les éléments optiques intégrés, le cas échéant, sont soumis à l'essai sur demande de l'acheteur. Les essais doivent être définis par accord entre l'acheteur et le fabricant.

3.3 Autres définitions

3.3.1
système de câble
câble équipé de ses accessoires, y compris les composants utilisés pour la gestion des contraintes thermomécaniques du système, mais limités à ceux utilisés pour les extrémités et les jonctions

3.3.2
gradient électrique nominal
gradient électrique calculé à U_0 en utilisant les dimensions nominales

Note 1 à l'article: Les équations pour le calcul des gradients sont données à l'Article 6, point n).

Note 2 à l'article: Le gradient électrique est exprimé en kV/mm.

3.3.3
conception combinée
CD
conception d'écran métallique qui combine des propriétés d'étanchéité radiale à l'eau et des propriétés électriques

Note 1 à l'article: Les détails de la constitution sont donnés en 4.3.

Note 2 à l'article: L'abréviation "CD" est dérivée du terme anglais développé correspondant "combined design".

3.3.4
conception séparée
SD
conception d'écran métallique qui utilise des composants métalliques différents pour assurer les propriétés d'étanchéité radiale à l'eau et les propriétés électriques

Note 1 à l'article: Les détails de la constitution sont donnés en 4.3.

Note 2 à l'article: L'abréviation "SD" est dérivée du terme anglais développé correspondant "separate design".

3.3.5
conception séparée semiconductrice
SscD
conception d'écran métallique qui possède des propriétés d'étanchéité radiale à l'eau et des propriétés électriques distinctes, et qui emploie une feuille à revêtement plastique semiconducteur

Note 1 à l'article: Les détails de la constitution sont donnés en 4.3.

Note 2 à l'article L'abréviation "SscD" est dérivée du terme anglais développé correspondant "separate semi-conductive design".

3.3.6
section nominale de l'âme
section de l'âme du câble conformément à l'IEC 60228

3.3.7
charge mécanique maximale
MML
charge de flexion mécanique la plus élevée qui peut être appliquée à un isolateur composite pour extrémités extérieures dans les conditions de service et pour laquelle l'isolateur est conçu

Note 1 à l'article: L'abréviation "MML" est dérivée du terme anglais développé correspondant "maximum mechanical load".

3.3.8
pression de service maximale
MSP
différence la plus élevée entre la pression interne absolue maximale et la pression extérieure lorsque l'équipement (dont fait partie un isolateur composite creux) est soumis au courant normal assigné à la température de fonctionnement maximale et à la pression ambiante normale

Note 1 à l'article: L'abréviation "MSP" est dérivée du terme anglais développé correspondant "maximum service pressure".

3.3.9
accessoire de câble avec interruption d'écran ou de gaine métallique
accessoire de câble où l'écran/la gaine métallique et l'écran sur enveloppe isolante du câble sont interrompus électriquement

3.3.10
jonction avec interruption d'écran ou de gaine métallique
jonction où l'écran/la gaine métallique et l'écran sur enveloppe isolante du câble sont interrompus électriquement

3.3.11
extrémité avec écran isolé
extrémité où l'écran/la gaine métallique et l'écran sur enveloppe isolante du câble sont isolés par rapport à la terre

4 Désignations des tensions, matériaux et arrondissement des nombres

4.1 Tensions assignées

Dans le présent document, les symboles U_0, U et U_m sont utilisés pour désigner les tensions assignées des câbles et accessoires. Ces symboles sont définis dans l'IEC 60183 [7].

4.2 Matériaux pour enveloppes isolantes de câbles

Le présent document s'applique aux câbles isolés au moyen d'un des mélanges énumérés dans le Tableau 1. Ce tableau spécifie également, pour chaque type de matériau pour enveloppe isolante, les températures maximales de service de l'âme, sur lesquelles reposent les conditions d'essai spécifiées.

Il est recommandé de dégazer les conducteurs du câble qui sont isolés par un système d'isolation réticulé.

4.3 Ecrans/gaines métalliques pour câbles

Le présent document s'applique aux différentes conceptions en usage. Il traite des conceptions qui procurent une étanchéité radiale à l'eau, ainsi que d'autres constructions.

Dans tous les cas, l'écran/la gaine métallique doit être capable de satisfaire aux caractéristiques de court-circuit assignées de l'écran.

Les conceptions qui procurent une étanchéité radiale à l'eau comprennent principalement:

– les gaines métalliques massives ou soudées en longueur;
– les feuilles ou rubans métalliques appliqués en longueur et contrecollés à la gaine extérieure:
  - CD: conception d'écran métallique qui comporte une feuille ou un ruban métallique avec recouvrement soudé ou collé, qui transporte une partie ou la totalité du courant de court-circuit de l'écran avec, si nécessaire, des fils métalliques qui transportent une partie du courant de court-circuit;
  - SD: conception d'écran métallique qui comporte une feuille métallique laminée (avec revêtement sur l'une ou les deux faces) pour assurer l'étanchéité radiale à l'eau, et des fils métalliques pour transporter la totalité du courant de court-circuit de l'écran;
  - SscD: conception d'écran métallique qui comporte une fine feuille de plomb ou d'aluminium, dont la face extérieure est revêtue de colle et la face intérieure de plastique semiconducteur, superposée sur une couche de ruban semiconducteur, qui repose à son tour sur une couche de fils de cuivre ronds;

NOTE Les définitions des conceptions CD, SD et SscD sont données en 3.3.3, en 3.3.4 et en 3.3.5.

– les écrans composites, qui comportent une couche de fils et soit une gaine, soit une feuille ou un ruban métallique contrecollé à la gaine extérieure qui sert de barrière d'étanchéité radiale à l'eau (voir Article 5).

  Lors du développement des câbles et systèmes de câbles qui comportent une feuille ou un ruban métallique appliqué en longueur et contrecollé à la gaine extérieure, les essais spécifiés dans l'IEC TR 61901 [1] sont recommandés.

Les conceptions qui ne procurent pas d'étanchéité radiale à l'eau comprennent:

– les feuilles ou rubans métalliques non contrecollés à la gaine extérieure;
– une couche de fils métalliques uniquement.

4.4 Matériaux pour gaines extérieures de câbles

Les essais sont spécifiés pour les cinq types suivants de gaines extérieures:

– ST_1 et ST_2 à base de polychlorure de vinyle (PVC);
– ST_3 et ST_7 à base de polyéthylène (PE);
– ST_{12} à base de matériau sans halogène à faible dégagement de fumée (LSHF, *Low Smoke Halogen Free*).

Le choix du type de gaine extérieure dépend de la conception du câble en fonction des performances mécaniques, thermiques et de tenue au feu exigées pour son installation et son fonctionnement.

Le Tableau 2 indique les températures maximales de l'âme en service normal pour les différents types de matériaux pour gaines extérieures couverts par le présent document.

S'il existe un risque que la gaine extérieure se détériore sous l'effet des rayonnements UV, celle-ci doit être protégée contre les rayonnements UV, selon un commun accord avec l'acheteur. Les gaines extérieures en PE de couleur noire qui contiennent le taux de noir de carbone exigé, de qualité adéquate et bien dispersé (voir Tableau 5), sont protégées contre les rayonnements UV.

NOTE 1 Pour une installation à l'air libre, par exemple dans des tunnels ou bâtiments, il est préférable que le câble présente une tenue au feu et qu'il soit construit avec des matériaux sans halogène à faible dégagement de fumée. Pour ces applications, une gaine extérieure de type ST_{12} (LSHF) peut être appliquée.

NOTE 2 Pour certaines applications, la gaine extérieure peut être recouverte d'une couche fonctionnelle (par exemple, semiconductrice).

4.5 Arrondissement des nombres

La procédure donnée à l'Annexe B doit être appliquée à l'ensemble des nombres et valeurs employés ou déterminés dans le cadre du présent document.

5 Précautions contre la pénétration d'eau dans les câbles

Lorsque les systèmes de câbles sont installés dans le sol, dans des zones qui sont situées dans l'eau ou qui présentent un risque de pénétration d'eau ou de corrosion, une barrière d'étanchéité radiale à l'eau est recommandée.

Des barrières d'étanchéité longitudinales peuvent également être appliquées afin d'éviter le remplacement de grandes sections de câble en cas de détérioration due à la présence d'eau.

Un essai de pénétration d'eau longitudinale est décrit en 12.5.15.

NOTE A ce jour, aucun essai n'est disponible pour la pénétration d'eau radiale.

6 Caractéristiques du câble

Pour les essais du câble ou système de câble décrits dans le présent document et l'enregistrement des résultats, le câble doit être identifié.

Le fabricant doit déclarer les caractéristiques suivantes:

a) le nom du fabricant, le type, la désignation et la date de fabrication (date de la dernière phase de production) ou le code de date;

b) la tension assignée: les valeurs de U_0, U, U_m doivent être indiquées (voir 4.1 et 8.4);

c) la tenue au feu: si le matériau de gaine extérieure utilisé est de type ST_1, ST_2 ou ST_{12} (voir 4.4 et Tableau 2), les paragraphes du 12.5.14.3, le cas échéant, auxquels la conformité est revendiquée doivent être indiqués;

NOTE La tenue au feu dépend de la conception du câble, ainsi que du matériau de la gaine extérieure.

d) le type d'âme, son matériau constitutif et sa section nominale, exprimée en millimètres carrés; la constitution de l'âme; la présence éventuelle et la nature des dispositions prises pour réduire l'effet de peau; la présence éventuelle et la nature des dispositions prises pour assurer une étanchéité longitudinale; si la section nominale n'est pas conforme à l'IEC 60228, la résistance maximale en courant continu de l'âme, rapportée à une longueur de 1 km et à 20 °C;

e) le mélange isolant (défini dans le Tableau 1) et l'épaisseur nominale de l'isolation (t_n) (voir 4.2);

f) le type de procédé de fabrication du système d'isolation;

g) la présence éventuelle et la nature des dispositions prises pour assurer l'étanchéité au niveau de l'écran;

h) pour l'écran/la gaine métallique:

- les détails constitutifs de l'écran/la gaine métallique, par exemple matériau et constitution de l'écran métallique, nombre et diamètre des fils; le matériau, la constitution et l'épaisseur nominale de la gaine métallique, de la feuille ou du ruban métallique appliqué en longueur et contrecollé à la gaine extérieure, le cas échéant. Pour les câbles qui comportent une feuille ou un ruban métallique appliqué en longueur et contrecollé à la gaine extérieure, le type de construction CD, SD ou SscD;
- la résistance maximale en courant continu de l'écran/la gaine métallique, rapportée à une longueur de 1 km et à 20 °C;

i) le matériau (défini en 4.4 et dans le Tableau 2) et l'épaisseur nominale de la gaine extérieure et, le cas échéant, la nature et le matériau de la couche fonctionnelle semiconductrice;

j) le diamètre nominal sur âme (d);

k) le diamètre extérieur nominal du câble (D);

l) le diamètre nominal intérieur (d_{ii}) et le diamètre nominal extérieur calculé (D_{io}) de l'enveloppe isolante;

m) la capacité linéique, rapportée à une longueur de 1 km, entre l'âme et l'écran/la gaine métallique;

n) la valeur calculée du gradient électrique nominal sur l'écran sur âme (E_i) et celle du gradient nominal sous l'écran sur enveloppe isolante (E_o):

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

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

où

U_0 est la valeur déclarée au point b) ci-dessus en kV;

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

D_{io} est le diamètre nominal extérieur calculé de l'enveloppe isolante, en mm;

d_{ii} est le diamètre nominal intérieur déclaré de l'enveloppe isolante, en mm;

t_n est l'épaisseur nominale déclarée de l'enveloppe isolante, en mm;

o) la conception des éléments optiques intégrés, le cas échéant.

7 Caractéristiques des accessoires

7.1 Extrémités de câble immergées dans du gaz

Les extrémités de câble immergées dans du gaz doivent être conçues conformément à l'IEC 62271-209.

7.2 Isolateurs pour extrémités de câble extérieures

Les isolateurs pour extrémités de câble extérieures doivent satisfaire aux exigences indiquées dans le Tableau 11 pour une charge de flexion de service maximale de niveau I ou II (ou MML dans le cas d'isolateurs composites). Le niveau I correspond à la charge normale et doit généralement être appliqué, sauf si l'acheteur spécifie une charge lourde de niveau II. A défaut, une valeur différente de charge de flexion de service maximale (MML) peut faire l'objet d'un accord entre l'acheteur et le fabricant.

7.3 Caractéristiques des accessoires à déclarer

Pour les essais du système de câble ou des accessoires décrits dans le présent document et l'enregistrement des résultats, l'accessoire doit être identifié.

Le fabricant doit déclarer les caractéristiques suivantes:

a) les câbles utilisés pour les essais des accessoires doivent être correctement identifiés, conformément à l'Article 6;

b) un plan qui représente l'ensemble des éléments pertinents soumis à l'essai selon l'Annexe H doit être fourni (voir Article H.1);

c) les connexions qui conduisent du courant et qui sont utilisées dans les accessoires doivent être correctement identifiées, pour l'âme comme pour l'écran/la gaine métallique, notamment:

- la technique de montage employée;
- le type, le numéro de référence et tout autre moyen d'identification du raccord de connexion;
- les détails de l'acceptation d'essai de type du raccord de connexion, le cas échéant;

d) les accessoires à soumettre à l'essai doivent être correctement identifiés, en incluant notamment:

- le nom du fabricant;
- le type, la désignation, la date de fabrication ou le code de date;
- la tension assignée (voir Article 6, point b));
- le type de matériau employé pour les moulages en caoutchouc qui constituent l'isolation principale (par exemple, caoutchouc silicone ou caoutchouc éthylène propylène);
- le type de matériau du fluide de remplissage diélectrique, le cas échéant;
- le type de protection externe;

- si la conception comprend un arrêt d'écran;
- les instructions de montage (référence et date);

e) des exigences supplémentaires pour les extrémités immergées dans du gaz:
- la pression de calcul pour l'extérieur de l'isolateur d'extrémité (voir IEC 62271-209);
- le type de gaz isolant à utiliser dans l'enveloppe du raccordement de câble (SF_6 ou détails de l'autre type de gaz);
- si l'isolateur d'extrémité est apte à la livraison au fabricant de l'appareillage afin de confirmer la compatibilité et les performances pour l'installation dans l'appareillage avant livraison sur site (voir IEC 62271-209);
- si applicables, les mesurages exigés pour réaliser l'essai individuel de série de l'appareillage qui doit être effectué sans le câble;

f) les exigences supplémentaires pour les isolateurs composites pour extrémités extérieures:
- la valeur MML pour les isolateurs composites (voir 7.2);
- pour les isolateurs qui sont sous pression en service, la pression de service maximale (MSP);

g) les exigences supplémentaires pour les isolateurs en matière céramique pour extrémités extérieures:
- la charge de flexion de service maximale;
- pour les isolateurs qui sont sous pression en service, la pression de calcul.

8 Conditions d'essai

8.1 Température ambiante

Sauf spécification contraire dans la procédure d'essai applicable, les essais doivent être effectués à une température ambiante de (20 ± 15) °C.

8.2 Essais à haute tension

Sauf indication contraire dans le présent document, les essais à haute tension doivent être effectués conformément à l'IEC 60060-1. Tous les essais à haute tension du présent document sont des essais de tenue en tension.

Aucune "correction atmosphérique pour les essais à sec" (IEC 60060-1) ne doit être appliquée aux valeurs de tension d'essai spécifiées dans le présent document.

8.3 Forme d'onde des tensions d'essai de choc

Les formes d'onde des essais de tenue au choc de foudre et aux chocs de manœuvre doivent être conformes à l'IEC 60230.

8.4 Relations entre les tensions d'essai et les tensions assignées

Lorsque le présent document spécifie des tensions d'essai comme des multiples de la tension assignée U_0, la valeur U_0 utilisée pour la détermination des tensions d'essai doit être conforme aux valeurs spécifiées dans le Tableau 4.

Pour les câbles et accessoires dont la tension assignée ne figure pas dans ce tableau, la valeur U_0 utilisée pour la détermination des tensions d'essai peut prise selon la tension assignée indiquée la plus proche, sous réserve que la valeur U_m spécifiée pour le câble et l'accessoire ne soit pas supérieure à la valeur indiquée dans le tableau. Dans le cas contraire, notamment si la tension assignée n'est pas proche de l'une des valeurs indiquées dans le tableau, la valeur U_0 à partir de laquelle sont déterminées les tensions d'essai doit être égale à la valeur assignée, à savoir U, divisée par $\sqrt{3}$. Les tensions d'essai associées doivent être déterminées par calcul, en utilisant les multiplicateurs indiqués dans le Tableau 4, ou par interpolation lorsqu'aucun multiplicateur n'est donné.

Les tensions d'essai spécifiées dans le présent document ont été établies en retenant l'hypothèse que les câbles et accessoires sont utilisés sur un système de la catégorie A, définie dans l'IEC 60183 [7].

8.5 Détermination de la température de l'âme du câble

Il est recommandé d'utiliser l'une des méthodes décrites à l'Annexe A pour déterminer la température réelle de l'âme.

8.6 Essais des extrémités immergées dans du gaz

Les essais électriques des extrémités immergées dans du gaz doivent être effectués dans une enveloppe du raccordement de câble du diamètre spécifié dans l'IEC 62271-209 selon la valeur de tension assignée applicable. Les exigences de pression du gaz spécifiées dans l'IEC 62271-209 pour les essais de type électriques doivent également être remplies.

9 Essais individuels de série des câbles et des accessoires

9.1 Généralités

Les essais suivants doivent être effectués sur chaque longueur de câble fabriquée:

a) essai de décharges partielles (voir 9.2);

b) essai de tension (voir 9.3);

c) essai électrique sur la gaine extérieure, s'il est exigé (voir 9.4).

L'ordre des essais est laissé à l'appréciation du fabricant.

L'isolation principale des accessoires préfabriqués doit être soumise aux essais individuels de série de décharges partielles (voir 9.2) et de tension (voir 9.3), selon l'une des variantes 1), 2) ou 3) ci-dessous:

1) sur l'isolation principale des accessoires préfabriqués montés sur le câble;

2) en utilisant un accessoire hôte dans lequel le composant soumis à l'essai est inséré en substitution du composant correspondant de l'accessoire hôte;

3) en utilisant un dispositif de simulation de l'accessoire, dans lequel est reproduit l'environnement électrique d'un composant de l'isolation principale.

Dans les cas 2) et 3), la tension d'essai doit être choisie de façon à obtenir des gradients électriques au moins égaux à ceux appliqués au composant dans un accessoire complet soumis aux tensions d'essai spécifiées en 9.2 et en 9.3.

L'isolateur d'une extrémité immergée dans du gaz doit également être soumis aux essais individuels de série décrits dans l'IEC 62271-209.

Les isolateurs pour extrémités extérieures soumis à une pression gazeuse interne en service doivent être soumis à un essai individuel de série avec une pression conforme à l'IEC 61462 pour les isolateurs composites ou à l'IEC 62155 pour les isolateurs en matière céramique. Aucune défaillance ne doit se produire.

Les essais individuels de série ne s'appliquent pas aux accessoires rubanés et/ou moulés sur site.

NOTE L'isolation principale des accessoires préfabriqués est constituée des composants qui sont en contact direct avec l'enveloppe isolante du câble ou qui sont nécessaires au contrôle de la répartition des gradients électriques dans l'accessoire. Les composants isolants prémoulés ou coulés en élastomère ou en résine époxyde, qui peuvent être utilisés de manière isolée ou conjointe de façon à assurer la reconstitution d'une enveloppe isolante ou d'un écran des accessoires, constituent des exemples.

9.2 Essai de décharges partielles

L'essai de décharges partielles doit être réalisé conformément à l'IEC 60885-3 pour les câbles, et la sensibilité selon l'IEC 60885-3 doit être égale d'au moins 10 pC. L'essai des accessoires respecte les mêmes principes, mais la sensibilité doit être de 5 pC ou mieux.

La tension d'essai doit être augmentée progressivement et maintenue à 1,75 U_0 pendant 10 s, puis ramenée lentement à 1,5 U_0 (voir Tableau 4, colonne 5).

Il ne doit pas y avoir de décharge détectable, supérieure à la sensibilité déclarée, en provenance de l'objet à l'essai à 1,5 U_0.

9.3 Essai de tension

L'essai de tension doit être effectué à la température ambiante en appliquant une tension d'essai alternative à la fréquence industrielle.

La tension d'essai doit être augmentée progressivement jusqu'à la valeur spécifiée et doit être maintenue à cette valeur entre l'âme et l'écran/la gaine métallique pendant la durée spécifiée, comme cela est indiqué dans le Tableau 4, colonne 4.

Aucun claquage de l'enveloppe isolante ne doit se produire.

9.4 Essai électrique sur la gaine extérieure du câble

Selon accord entre l'acheteur et le fabricant, la gaine extérieure du câble doit être soumise à l'essai électrique spécifié à l'Article 3 de l'IEC 60229:2007.

10 Essais sur échantillons de câbles

10.1 Généralités

Les essais suivants doivent être effectués sur des échantillons qui, pour les essais des points b) et g) ci-dessous, doivent être des longueurs complètes de câble sur touret, représentatives de lots:

a) examen de l'âme (voir 10.4);
b) mesurage de la résistance électrique de l'âme et de l'écran/la gaine métallique (voir 10.5);
c) mesurage de l'épaisseur de l'enveloppe isolante et de la gaine extérieure (voir 10.6);
d) mesurage de l'épaisseur de la gaine métallique (voir 10.7);
e) mesurage des diamètres, si cela est exigé (voir 10.8);
f) essai d'allongement à chaud des enveloppes isolantes en XLPE et en EPR (voir 10.9);
g) mesurage de la capacité (voir 10.10);

h) mesurage de la masse volumique des enveloppes isolantes en PEHD (voir 10.11);

i) essai au choc de foudre (voir 10.12);

j) essai de pénétration d'eau, si applicable (voir 10.13);

k) essais sur les composants de câbles qui comportent une feuille ou un ruban métallique appliqué en longueur et contrecollé à la gaine extérieure (voir 10.14).

10.2 Fréquence des essais

Les essais sur prélèvements indiqués aux points a) à h) et k) en 10.1 doivent être effectués sur une longueur de câble prélevée dans chaque lot (fabrication en série) de câbles de type et section identiques, mais le nombre de longueurs doit être limité à 10 %, arrondi au nombre entier le plus proche, du nombre total de longueurs stipulées dans tout contrat.

Les essais des points i) et j) en 10.1 doivent être effectués à la fréquence indiquée dans les procédures de contrôle qualité fixées par accord. En l'absence d'un tel accord, un essai doit être réalisé pour les contrats qui portent sur une longueur de câble comprise entre 4 km et 20 km et deux essais doivent être réalisés pour les contrats qui portent sur les longueurs de câbles supérieures.

10.3 Répétition des essais

Si l'échantillon choisi échoue à l'un des essais répertoriés à l'Article 10, de nouveaux échantillons doivent être prélevés sur deux autres longueurs de câble du même lot et doivent être soumis aux essais auxquels l'échantillon initial a échoué. Si ces deux échantillons supplémentaires satisfont aux essais, les autres câbles du lot dans lequel ont été prélevés les échantillons doivent être considérés comme étant conformes aux exigences du présent document. Si l'un des échantillons échoue à l'essai, le lot de câbles doit être considéré comme n'étant pas conforme.

10.4 Examen de l'âme

La conformité aux exigences de l'IEC 60228 relatives à la constitution de l'âme, ou à la constitution déclarée, doit être vérifiée par examen et par mesurage, lorsque cela est possible.

10.5 Mesurage de la résistance électrique de l'âme et de l'écran/la gaine métallique

La longueur de câble (ou un échantillon prélevé sur celle-ci) doit être placée dans le local d'essai qui doit être maintenu à une température raisonnablement constante pendant au moins 12 h avant l'essai. En cas de doute sur la coïncidence entre la température de l'âme ou de l'écran/la gaine métallique et la température du local, la résistance doit être mesurée après avoir laissé le câble dans le local d'essai pendant 24 h. A défaut, la résistance peut être mesurée sur un échantillon d'âme ou d'écran/de gaine métallique conditionné pendant au moins 1 h dans un bain de liquide à température régulée.

La résistance en courant continu de l'âme ou de l'écran/la gaine métallique doit être rapportée à une température de 20 °C et à une longueur de 1 km à l'aide des formules spécifiées dans l'IEC 60228:

– en appliquant les coefficients de température spécifiés dans l'IEC 60228 pour les âmes ou les écrans/gaines métalliques en cuivre ou en aluminium; ou

– en appliquant les coefficients de température spécifiés dans l'IEC 60287-1-1 pour les écrans/gaines métalliques réalisés dans un matériau autre que le cuivre ou l'aluminium.

La résistance en courant continu, rapportée à 20 °C, de l'âme ne doit pas dépasser la valeur maximale applicable spécifiée dans l'IEC 60228 ou, lorsqu'une valeur de résistance maximale en courant continu de l'âme est déclarée à l'Article 6, point d), la résistance en courant continu, rapportée à 20 °C, de l'âme ne doit pas dépasser la valeur déclarée.

La résistance en courant continu, rapportée à 20 °C, de l'écran/la gaine métallique ne doit pas être supérieure à la valeur déclarée.

10.6 Mesurage de l'épaisseur de l'enveloppe isolante et de la gaine extérieure

10.6.1 Généralités

La méthode d'essai doit être conforme à l'IEC 60811-201 pour l'enveloppe isolante. Pour la gaine extérieure, la méthode d'essai conforme à l'IEC 60811-202:2012 et à l'IEC 60811-202:2012/AMD1:2017 doit être appliquée, excepté que pour les gaines dont la surface sous-jacente n'est pas irrégulière, le mesurage peut être effectué à l'aide d'un micromètre dont la touche sphérique a un rayon compris entre 2,5 mm et 3 mm. La précision du micromètre doit être de ± 0,01 mm.

Chaque longueur de câble choisie pour l'essai doit être représentée par une éprouvette prélevée à une extrémité après avoir éliminé, si nécessaire, les parties qui peuvent être endommagées.

Les symboles suivants sont utilisés en 10.6:

t_{max} est l'épaisseur mesurée maximale, en mm;

t_{min} est l'épaisseur mesurée minimale, en mm;

t_n est l'épaisseur nominale, en mm.

10.6.2 Exigences relatives à l'enveloppe isolante

L'épaisseur mesurée minimale ne doit pas être inférieure à 90 % de l'épaisseur nominale:

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

En outre:

$$\frac{t_{max} - t_{min}}{t_{max}} \leq 0{,}10$$

t_{max} et t_{min} doivent être mesurées sur une seule et même section de l'enveloppe isolante.

L'épaisseur des écrans semiconducteurs sur l'âme et sur l'enveloppe isolante ne doit pas être comprise dans l'épaisseur de l'enveloppe isolante.

10.6.3 Exigences relatives à la gaine extérieure du câble

L'épaisseur mesurée minimale ne doit pas être inférieure de plus de 0,1 mm à 85 % de l'épaisseur nominale:

$$t_{min} \geq 0{,}85\ t_n - 0{,}1$$

En outre, pour les gaines extérieures appliquées sur une surface pratiquement lisse, la moyenne des valeurs mesurées arrondie à 0,1 mm près ne doit pas être inférieure à l'épaisseur nominale.

Cette dernière exigence ne s'applique pas aux gaines extérieures appliquées sur une surface irrégulière, par exemple sur les écrans métalliques constitués de fils et/ou de rubans ou sur les gaines métalliques ondulées.

10.7 Mesurage de l'épaisseur de la gaine métallique

10.7.1 Généralités

Si le câble comporte une gaine métallique constituée de plomb, d'alliage de plomb, de cuivre ou d'aluminium, les essais suivants s'appliquent. Les feuilles appliquées à des fins d'étanchéité radiale à l'eau uniquement sont exclues de ces essais.

Les symboles suivants sont utilisés en 10.7:

t_{min} est l'épaisseur mesurée minimale, en mm;

t_n est l'épaisseur nominale, en mm.

10.7.2 Gaine constituée de plomb ou d'alliage de plomb

10.7.2.1 Généralités

L'épaisseur mesurée minimale de la gaine métallique ne doit pas être inférieure de plus de 0,1 mm à 95 % de l'épaisseur nominale:

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

L'épaisseur de la gaine doit être mesurée selon l'une des méthodes suivantes, à la discrétion du fabricant.

10.7.2.2 Méthode "à plat"

Le mesurage doit être effectué à l'aide d'un micromètre à faces planes, de touches d'un diamètre compris entre 4 mm à 8 mm. La précision du micromètre doit être de ± 0,01 mm.

Le mesurage doit être effectué sur une éprouvette de gaine de 50 mm de longueur environ, prélevé sur le câble complet. L'échantillon doit être fendu longitudinalement, puis soigneusement redressé. Après nettoyage de l'éprouvette, l'épaisseur doit être mesurée le long de la périphérie de la gaine, à au moins 10 mm du bord de l'éprouvette redressée, en un nombre de points suffisant pour s'assurer que l'épaisseur minimale est mesurée.

10.7.2.3 Méthode de l'anneau

Les mesurages doivent être effectués à l'aide d'un micromètre qui possède soit une touche plane et une touche sphérique, soit une touche plane et une touche rectangulaire plane de 0,8 mm de largeur et de 2,4 mm de longueur. La touche sphérique ou la touche rectangulaire plane doit être appliquée sur la face intérieure de l'anneau. La précision du micromètre doit être de ± 0,01 mm.

Les mesurages doivent être effectués sur un anneau de gaine, soigneusement prélevé sur l'échantillon. L'épaisseur doit être mesurée en un nombre de points suffisant sur la périphérie de l'anneau pour s'assurer que l'épaisseur minimale est mesurée.

10.7.3 Gaine constituée de cuivre ou d'aluminium

Pour une gaine lisse en cuivre ou en aluminium, l'épaisseur mesurée minimale de la gaine ne doit pas être inférieure de plus de 0,1 mm à 90 % de l'épaisseur nominale:

$$t_{min} \geq 0{,}9\ t_n - 0{,}1$$

L'épaisseur mesurée minimale d'une gaine ondulée en cuivre ou en aluminium ne doit pas être inférieure de plus de 0,1 mm à 85 % de l'épaisseur nominale:

$$t_{min} \geq 0{,}85\ t_n - 0{,}1$$

Les mesurages doivent être effectués à l'aide d'un micromètre dont les touches sphériques ont un rayon de 3 mm environ. La précision du micromètre doit être de ± 0,01 mm.

Les mesurages doivent être effectués sur un anneau de gaine de 50 mm de largeur environ, soigneusement prélevé sur le câble. L'épaisseur doit être mesurée en un nombre de points suffisant sur la périphérie de l'anneau pour s'assurer que l'épaisseur minimale est mesurée.

10.7.4 Ruban métallique pour conception CD

L'épaisseur mesurée minimale du ruban métallique ne doit pas être inférieure à 90 % de l'épaisseur nominale:

$$t_{min} \geq 0{,}9\ t_n$$

Les mesurages doivent être effectués à l'aide d'un micromètre dont les touches sphériques ont un rayon de 3 mm environ. La précision du micromètre doit être de ± 0,01 mm.

Les mesurages doivent être effectués sur un anneau de ruban et de gaine extérieure de 50 mm de largeur environ, soigneusement prélevé sur le câble. L'épaisseur doit être mesurée en un nombre de points suffisant sur la périphérie et aux extrémités latérales de l'anneau pour s'assurer que l'épaisseur minimale est mesurée.

10.8 Mesurage des diamètres

Si l'acheteur exige que le diamètre du conducteur et/ou le diamètre extérieur du câble soient mesurés, les mesurages doivent être effectués conformément à l'IEC 60811-203.

10.9 Essai d'allongement à chaud des enveloppes isolantes en XLPE et en EPR

10.9.1 Procédure

L'échantillonnage et l'essai doivent être effectués conformément à l'IEC 60811-507, dans les conditions d'essai spécifiées dans le Tableau 8.

Les éprouvettes doivent être prélevées dans la partie de l'enveloppe isolante, où le degré de réticulation est estimé être le plus faible pour le procédé de réticulation utilisé.

10.9.2 Exigences

Les résultats de l'essai doivent satisfaire aux exigences indiquées dans le Tableau 8.

10.10 Mesurage de la capacité

La capacité doit être mesurée entre l'âme et l'écran/la gaine métallique à la température ambiante, et la température ambiante doit être enregistrée en même temps que les données d'essai.

La valeur mesurée de la capacité doit être rapportée à une longueur de 1 km et ne doit pas dépasser la valeur nominale déclarée de plus de 8 %.

10.11 Mesurage de la masse volumique des enveloppes isolantes en PEHD

10.11.1 Procédure

La masse volumique du PEHD doit être mesurée selon la procédure d'échantillonnage et d'essai spécifiée dans l'IEC 60811-606.

10.11.2 Exigences

Les résultats de l'essai doivent satisfaire aux exigences indiquées dans le Tableau 8.

10.12 Essai de tension de choc de foudre

L'essai doit être effectué sur un câble d'au moins 10 m de longueur, en excluant les accessoires, la température de l'âme du câble étant comprise entre 5 K et 10 K au-dessus de la température maximale de l'âme en service normal.

Le montage doit être chauffé par circulation de courant dans l'âme uniquement, jusqu'à ce que l'âme atteigne la température exigée.

Si, pour des raisons pratiques, la température d'essai ne peut pas être atteinte, un calorifugeage supplémentaire peut être appliqué. La température de l'âme doit être maintenue dans les limites de température indiquées pendant au moins 2 h.

La tension de choc de foudre doit être appliquée, conformément à la procédure spécifiée dans l'IEC 60230, après la période de chauffage de 2 h indiquée ci-dessus et lorsque la température de l'âme se situe dans les limites établies ci-dessus.

Le câble doit supporter 10 chocs positifs et à 10 chocs négatifs à la tension adéquate indiquée dans le Tableau 4, colonne 8, sans défaillance.

Aucun claquage de l'enveloppe isolante ne doit se produire.

10.13 Essai de pénétration d'eau

Le cas échéant, des échantillons doivent être prélevés sur le câble, l'essai doit être réalisé et les exigences spécifiées en 12.5.15 doivent être remplies.

10.14 Essais des composants de câbles qui comportent une feuille ou un ruban métallique appliqué en longueur et contrecollé à la gaine extérieure

Pour les câbles qui comportent une feuille ou un ruban métallique appliqué en longueur et contrecollé à la gaine extérieure, un échantillon de 1 m doit être prélevé sur le câble et soumis aux essais et exigences du 12.5.16.

11 Essais sur échantillons d'accessoires

11.1 Essais des composants d'accessoire

Les caractéristiques de chaque composant doivent être vérifiées par rapport aux spécifications du fabricant d'accessoires, soit en consultant les rapports d'essai fournis par le fabricant du composant considéré, soit en réalisant des essais internes.

Le fabricant de l'accessoire doit fournir une liste des essais à effectuer sur chaque composant et préciser la fréquence de chaque essai.

Les composants doivent être examinés par rapport à leurs plans. Il ne doit y avoir aucun écart en dehors des tolérances déclarées.

NOTE Comme les composants diffèrent d'un fabricant à l'autre, il n'est pas possible de définir des essais sur prélèvements communs pour ces composants dans le présent document.

11.2 Essais sur accessoire complet

Pour les accessoires dont l'isolation principale ne peut pas être soumise aux essais individuels de série (voir 9.1), les essais électriques suivants doivent être effectués par le fabricant sur un accessoire complètement monté:

a) essai de décharges partielles (voir 9.2);

b) essai de tension (voir 9.3).

L'ordre des essais est laissé à la discrétion du fabricant.

NOTE Les isolations rubanées et/ou moulées sur site sont des exemples d'isolations principales qui ne sont pas soumises aux essais individuels de série.

Un accessoire de chaque type stipulé dans le contrat doit être soumis à ces essais, si le contrat comporte plus de 50 accessoires de ce type.

Si l'échantillon échoue à l'un des deux essais ci-dessus, deux autres échantillons d'accessoires du même type stipulé dans le contrat doivent être prélevés et soumis aux mêmes essais. Si ces deux échantillons supplémentaires satisfont aux essais, les autres accessoires du même type stipulé dans le contrat doivent être considérés comme étant conformes aux exigences du présent document. Si l'un d'eux échoue, ce type d'accessoire stipulé dans le contrat doit être considéré comme n'étant pas conforme.

12 Essais de type des systèmes de câbles

12.1 Généralités

Les essais spécifiés à l'Article 12 ont pour objet de démontrer le comportement satisfaisant des systèmes de câbles.

Il n'est pas nécessaire de répéter les essais de type lorsque ceux-ci ont été réalisés avec succès, sous réserve que les matériaux, le procédé de fabrication, la conception ou les niveaux calculés de gradient électrique du câble ou des accessoires n'aient subi aucune modification susceptible de compromettre leurs caractéristiques de performance.

L'Annexe C fournit les références des articles ou paragraphes à consulter dans le cadre des essais de type sur les systèmes de câbles.

Les extrémités de câble immergées dans du gaz doivent être soumises aux essais de type conformément à l'IEC 62271-209, en plus des essais spécifiés dans le présent document.

Des essais de type électriques supplémentaires sont exigés dans l'IEC 62271-209 lorsque l'isolateur d'une extrémité immergée dans du gaz doit être fourni au fabricant de l'appareillage afin de démontrer que l'extrémité peut satisfaire aux essais individuels de série de l'appareillage et aux essais sur site.

NOTE Le présent document ne spécifie pas les essais pour les extrémités exposées sous des conditions d'environnement, telles que les précipitations et/ou la pollution.

12.2 Périmètre de l'acceptation de type

Lorsque les essais de type ont été réalisés avec succès sur un ou plusieurs systèmes de câbles de sections spécifiques, de tension assignée et constitution identiques, l'acceptation de type doit être considérée comme étant valable pour les systèmes de câbles qui relèvent du domaine d'application du présent document avec d'autres sections, tensions assignées et constitutions si l'ensemble des conditions a) à h) suivantes sont remplies.

Les essais de type qui ont été réalisés avec succès selon les éditions précédentes de la présente norme restent valables si les conditions suivantes sont réunies:

a) le groupe de tension n'est pas supérieur à celui du ou des systèmes de câbles soumis aux essais. Les systèmes de câbles du même groupe de tension sont ceux dont les tensions assignées ont la même valeur U_m, tension la plus élevée pour le matériel, et les mêmes niveaux de tension d'essai (voir Tableau 4, colonnes 1 et 2) ;

b) la section nominale de l'âme n'est pas supérieure à celle du câble soumis aux essais;

c) le câble et les accessoires ont la même constitution ou une constitution similaire à celle du ou des systèmes de câbles soumis aux essais.

   Les câbles et accessoires sont considérés comme étant de constitution similaire si le type et le procédé de fabrication de leurs enveloppes isolantes et écrans semiconducteurs sont identiques. Il n'est pas nécessaire de répéter les essais de type électriques en cas de différences entre le type ou le matériau de l'âme ou du raccord de connexion, ou dans les couches protectrices appliquées au-dessus de l'écran semiconducteur sur enveloppe isolante, ou sur l'isolation principale de l'accessoire, sous réserve que ces différences ne soient pas susceptibles d'avoir une incidence significative sur les résultats de l'essai. Dans certains cas, il peut être approprié de répéter un ou plusieurs des essais de type (l'essai d'enroulement, l'essai de cycles de chauffage et/ou l'essai de compatibilité, par exemple);

d) la valeur du gradient électrique nominal et du gradient de tension de choc sur l'écran sur âme du câble, calculée en utilisant les dimensions nominales du câble, ne dépasse pas de plus de 10 % les gradients respectifs calculés pour le ou les systèmes de câbles soumis à l'essai;

e) la valeur du gradient électrique nominal et du gradient de tension de choc sur l'écran sur enveloppe isolante, calculée en utilisant les dimensions nominales du câble, ne dépasse pas les gradients respectifs calculés pour le ou les systèmes de câbles soumis à l'essai;

f) les valeurs du gradient électrique nominal et du gradient de tension de choc, calculées en utilisant les dimensions nominales, dans l'isolation principale de l'accessoire et aux interfaces entre câble et accessoire, ne dépassent pas les gradients respectifs calculés pour le ou les systèmes de câbles soumis à l'essai;

g) le même type de gaz ou mélange de gaz et la même pression sont utilisés pour l'enveloppe du raccordement de câble d'une extrémité immergée dans du gaz;

   NOTE L'Article H.6 fournit les exigences relatives à l'acceptation d'une extrémité immergée dans du gaz avec un autre type de gaz.

h) une extrémité immergée dans du gaz comporte la même séparation isolante, le même cône déflecteur et le même câble que ceux utilisés lors des essais de type, en tenant compte des tolérances et des exigences applicables indiquées aux points a) à g) ci-dessus.

Il n'est pas nécessaire de réaliser les essais de type des composants du câble (voir 12.5) sur des échantillons de câble de tensions assignées et/ou de sections d'âme nominales différentes, sous réserve que les câbles soient conçus dans les mêmes matériaux et/ou qu'ils aient été fabriqués selon le même procédé de fabrication. Cependant, la répétition des essais de vieillissement sur câble complet pour vérifier la compatibilité des matériaux (voir 12.5.5) peut faire l'objet d'un accord avec l'acheteur si la combinaison des matériaux appliqués au-dessus de l'écran semiconducteur sur enveloppe isolante est différente de celle du câble précédemment soumis aux essais de type.

Un certificat d'essai de type signé par le représentant d'un organisme de contrôle compétent, ou un rapport de résultats d'essai établi par le fabricant et signé par le responsable habilité, ou encore un certificat d'essai de type établi par un laboratoire d'essais indépendant doivent constituer des preuves acceptables de l'exécution des essais de type.

12.3 Récapitulatif des essais de type

Les essais de type doivent comprendre les essais électriques effectués sur le système de câble complet, spécifiés en 12.4, et les essais non électriques appropriés effectués sur les composants du câble et sur câble complet, spécifiés en 12.5.

Les essais non électriques sur câble et sur les composants du câble sont répertoriés du Tableau 5 au Tableau 10, qui indiquent les essais applicables à chaque matériau pour enveloppe isolante et pour gaine extérieure. Les essais de tenue au feu, répertoriés dans le Tableau 10, sont exigés uniquement si le fabricant souhaite revendiquer la conformité à ces essais comme caractéristique particulière de la conception du câble.

Les essais répertoriés en 12.4.2 doivent être effectués sur un ou plusieurs échantillons de câble, en fonction du nombre d'accessoires concernés.

Une longueur de câble suffisante doit être soumise à l'essai d'enroulement du 12.4.2 a) afin de permettre la construction d'un montage d'essai pour les essais du 12.4.2 c) à g) et pour l'essai du 12.4.2 b), le cas échéant.

L'essai de décharges partielles du 12.4.2 a) et les essais du 12.4.2 c) à g) doivent être réalisés sur un montage d'essai qui comprend au moins un échantillon de chaque type d'accessoire à soumettre à l'essai. Les accessoires doivent être montés sur un câble de manière à obtenir une longueur de câble libre (c'est-à-dire sans tenir compte du câble compris dans la longueur des accessoires) entre accessoires adjacents d'au moins 5 m et une longueur totale de câble libre d'au moins 10 m.

Le mesurage de tan δ en 12.4.2 b) peut être effectué à l'aide du montage d'essai décrit ci-dessus ou sur un échantillon de câble séparé, prélevé dans le même lot de fabrication. Dans ce dernier cas, aucun essai d'enroulement n'est exigé sur le câble, et les extrémités d'essai peuvent être différentes de celles utilisées pour les autres essais. La longueur totale de câble libre doit être d'au moins 10 m. Pour les essais décrits en 12.4.2 c) à g), les accessoires doivent être montés après l'essai d'enroulement du câble.

Les câbles et accessoires doivent être montés conformément aux instructions du fabricant, avec les qualités et quantités de matériaux fournis, lubrifiants éventuels compris.

La surface extérieure des accessoires doit être propre et sèche, mais les câbles et accessoires ne doivent être soumis à aucun type de conditionnement non spécifié dans les instructions du fabricant, qui est susceptible de modifier leurs caractéristiques électriques, thermiques ou mécaniques.

Si le système de câble à soumettre aux essais c) à g) du 12.4.2 comporte des jonctions, il est nécessaire de réaliser l'essai avec les protections externes en place.

Le mesurage de la résistivité des écrans semiconducteurs décrit en 12.4.9 doit être effectué sur un échantillon séparé.

12.4 Essais de type électriques sur systèmes de câbles complets

12.4.1 Valeurs des tensions d'essai

Avant de procéder aux essais de type électriques, l'épaisseur de l'enveloppe isolante doit être mesurée selon la méthode spécifiée dans l'IEC 60811-201, sur un échantillon représentatif prélevé sur la longueur du câble à soumettre aux essais, afin de vérifier que l'épaisseur moyenne n'est pas trop élevée par rapport à la valeur nominale.

Si l'épaisseur moyenne de l'enveloppe isolante ne dépasse pas la valeur nominale de plus de 5 %, les tensions d'essai doivent être prises parmi les valeurs déterminées conformément au 8.4 pour la tension assignée du câble.

Si l'épaisseur moyenne de l'enveloppe isolante dépasse la valeur nominale de plus de 5 %, sans dépasser 15 %, la tension d'essai doit être ajustée afin que le gradient électrique sur l'écran sur âme soit égal à celui appliqué lorsque l'épaisseur moyenne de l'enveloppe isolante est égale à la valeur nominale et que les tensions d'essai sont les valeurs normales spécifiées pour la tension assignée du câble.

L'épaisseur moyenne de l'enveloppe isolante de la longueur de câble utilisée pour les essais de type électriques ne doit pas dépasser la valeur nominale de plus de 15 %.

12.4.2 Essais et séquence d'essais

Les essais des points a) à i) doivent être effectués selon la séquence suivante (voir également 12.3):

a) essai d'enroulement du câble suivi d'un examen visuel, lorsque cela est applicable (voir 12.4.3). Les accessoires doivent ensuite être installés par le fabricant, puis un essai de décharges partielles est réalisé à la température ambiante (voir 12.4.4);

b) mesurage de tan δ (voir 12.4.5 et 12.3);

c) essai de cycles de chauffage sous tension (voir 12.4.6);

d) essais de décharges partielles (voir 12.4.4):

- à température ambiante; et
- à température élevée.

Les essais doivent être effectués après le dernier cycle du point c) ci-dessus ou, à défaut, après le point f) ci-dessous;

e) essai de tension de choc de manœuvre (exigé si U_m ≥ 300 kV, voir 12.4.7.1);

f) essai de tension de choc de foudre, suivi d'un essai de tension à la fréquence industrielle (voir 12.4.7.2);

g) essais de décharges partielles, si ceux-ci n'ont pas été effectués au point d) ci-dessus;

h) essais supplémentaires des accessoires (voir Annexe H);

i) examen du système de câble avec le câble et les accessoires après réalisation des essais ci-dessus (voir 12.4.8);

j) la résistivité des écrans semiconducteurs du câble (voir 12.4.9) doit être mesurée sur un échantillon séparé. Aucun essai d'enroulement n'est exigé sur l'échantillon d'essai.

Les tensions d'essai doivent être déterminées conformément au 8.4 et, si nécessaire, ajustées conformément au 12.4.1.

12.4.3 Essai d'enroulement

L'échantillon de câble doit être enroulé autour d'un cylindre d'essai (par exemple, le tambour d'un touret) à la température ambiante, sur un tour complet au moins, et déroulé sans rotation axiale. Une rotation de 180° doit ensuite être appliquée à l'échantillon, en répétant l'opération.

Ce cycle d'opérations doit être effectué trois fois au total.

Le cylindre d'essai doit avoir le diamètre nominal suivant:

– pour les câbles à gaine lisse en cuivre ou en aluminium:
  - 36 (d + D);
– pour les câbles à gaine en plomb ou en alliage de plomb et les câbles à gaine métallique ondulée:
  - 25 (d + D);
– pour les câbles qui comportent une feuille ou un ruban métallique appliqué en longueur (avec recouvrement ou soudé) et contrecollé à la gaine extérieure:
  - 20 (d + D) pour les conceptions CD;
  - 25 (d + D) pour les conceptions SD et CD + fils;
  - 10 D_s pour les conceptions SscD;

– pour les autres câbles:

  • 20 (d + D);

  où:

  d est le diamètre nominal de l'âme, en mm (voir Article 6, point j));

  D est le diamètre extérieur nominal du câble, en mm (voir Article 6, point k));

  D_s est le diamètre nominal de l'écran métallique, en mm.

Le diamètre du cylindre d'essai correspond au diamètre nominal avec une tolérance de 0 % à +5 %. Des diamètres d'enroulement inférieurs peuvent être utilisés, à la discrétion du fabricant.

Pour les câbles qui comportent une feuille ou un ruban métallique laminé, un examen visuel doit être réalisé conformément à l'Article G.1, après avoir réalisé trois cycles d'enroulement.

12.4.4 Essais de décharges partielles

Les essais doivent être effectués conformément à l'IEC 60885-3, avec une sensibilité de 5 pC ou mieux.

La tension d'essai doit être augmentée progressivement et maintenue à 1,75 U_0 pendant 10 s, puis ramenée lentement à 1,5 U_0 (voir Tableau 4, colonne 5).

A température élevée, l'essai doit être effectué sur le montage, la température de l'âme du câble étant comprise entre 5 K et 10 K au-dessus de la température maximale de l'âme en service normal. Le montage doit être chauffé par circulation de courant dans l'âme uniquement. La température de l'âme doit être maintenue dans les limites de température indiquées pendant au moins 2 h avant de procéder au mesurage des décharges partielles.

Si, pour des raisons pratiques, la température d'essai ne peut pas être atteinte, un calorifugeage supplémentaire peut être appliqué.

Il ne doit pas y avoir de décharge détectable, supérieure à la sensibilité déclarée, en provenance de l'objet à l'essai à 1,5 U_0.

12.4.5 Mesurage de tan δ

L'échantillon doit être chauffé par circulation de courant dans l'âme uniquement et la température de l'âme est déterminée soit en mesurant sa résistance, soit par des capteurs de température placés à la surface de l'écran/de la gaine, soit par des capteurs de température placés sur l'âme d'un autre échantillon du même câble chauffé selon la même méthode.

L'échantillon doit être chauffé jusqu'à ce que l'âme atteigne une température qui doit être comprise entre 5 K et 10 K au-dessus de la température maximale de l'âme en service normal.

Si, pour des raisons pratiques, la température d'essai ne peut pas être atteinte, un calorifugeage supplémentaire peut être appliqué.

La température de l'âme doit être maintenue dans les limites de température indiquées pendant au moins 2 h.

La tan δ doit être mesurée sous la tension U_0 à la fréquence industrielle et à la température spécifiée ci-dessus (voir Tableau 4, colonne 6).

La valeur mesurée ne doit pas dépasser la valeur indiquée dans le Tableau 3.

12.4.6 Essai de cycles de chauffage sous tension

Le câble doit être courbé en forme de U selon un diamètre inférieur ou égal à celui du cylindre d'essai pour l'essai d'enroulement du 12.4.3. Le diamètre et les tolérances admises doivent être conformes aux spécifications du 12.4.3.

Le montage doit être chauffé par circulation de courant dans l'âme uniquement, jusqu'à ce que l'âme atteigne une température de régime établi comprise entre 5 K et 10 K au-dessus de la température maximale de l'âme en service normal.

Si, pour des raisons pratiques, la température d'essai ne peut pas être atteinte, un calorifugeage supplémentaire peut être appliqué.

Le chauffage doit être appliqué pendant au moins 8 h.

La température de l'âme doit être maintenue dans les limites de température indiquées pendant au moins 2 h au cours de chaque période de chauffage. Le montage doit ensuite être laissé à refroidir naturellement pendant au moins 16 h jusqu'à ce que l'âme atteigne une température inférieure ou égale à 30 °C ou une température qui ne dépasse pas de plus de 15 K la température ambiante, si celle-ci est supérieure, la température maximale étant fixée à 45 °C. Le courant qui circule dans l'âme doit être enregistré pendant les deux dernières heures de chaque période de chauffage.

Si le câble subit des pertes diélectriques trop élevées à la tension d'essai, cela peut compromettre le refroidissement. Dans des cas extrêmes, cela peut même empêcher le refroidissement de l'âme dans les limites de la plage de températures spécifiée. Ce comportement doit être considéré comme étant un échec de l'essai.

Les cycles de chauffage et de refroidissement doivent être réalisés 20 fois.

Pendant toute la période d'essai, une tension de 2 U_0 doit être appliquée au montage (voir Tableau 4, colonne 7).

Les cycles de chauffage où l'âme atteint une température de plus de 10 K au-dessus de la température maximale de l'âme en service normal sont considérés comme étant valables.

Une interruption de l'essai est admise pour autant que l'échantillon ait subi un nombre total de 20 cycles de chauffage sous tension. L'Annexe J fournit des recommandations pour l'interruption de l'essai et la détermination des cycles de chauffage valides.

12.4.7 Essais de tension de choc

12.4.7.1 Essai de tension de choc de manœuvre

Pour les systèmes, câbles et accessoires de tension U_m ≥ 300 kV, le montage doit être soumis à un essai de tension de choc de manœuvre.

Le montage doit être chauffé par circulation de courant dans l'âme uniquement, jusqu'à ce que l'âme atteigne une température de régime établi comprise entre 5 K et 10 K au-dessus de la température maximale de l'âme en service normal.

La température de l'âme doit être maintenue dans les limites de température indiquées pendant au moins 2 h avant d'appliquer la première tension de choc de manœuvre. La température doit être maintenue dans les limites indiquées ci-dessus jusqu'à la fin de l'essai.

Si, pour des raisons pratiques, la température d'essai ne peut pas être atteinte, un calorifugeage supplémentaire peut être appliqué.

La tension de choc de manœuvre doit être appliquée conformément à la procédure spécifiée dans l'IEC 60230 en utilisant les niveaux de tension de tenue au choc de manœuvre normalisés indiqués dans le Tableau 4, colonne 10.

Le montage doit supporter 10 chocs positifs et 10 chocs négatifs, sans défaillance ni contournement.

12.4.7.2 Essai de tension de choc de foudre suivi d'un essai de tension à la fréquence industrielle

Le montage doit être chauffé par circulation de courant dans l'âme uniquement, jusqu'à ce que l'âme atteigne une température de régime établi comprise entre 5 K et 10 K au-dessus de la température maximale de l'âme en service normal.

La température de l'âme doit être maintenue dans les limites de température indiquées pendant au moins 2 h avant d'appliquer la première tension de choc de foudre. La température doit être maintenue dans les limites indiquées ci-dessus jusqu'à la fin de l'essai.

Si, pour des raisons pratiques, la température d'essai ne peut pas être atteinte, un calorifugeage supplémentaire peut être appliqué.

La tension de choc de foudre doit être appliquée, conformément à la procédure spécifiée dans l'IEC 60230, lorsque la température de l'âme se situe dans les limites établies ci-dessus.

Le montage doit supporter 10 chocs positifs et 10 chocs négatifs à la tension adéquate indiquée dans le Tableau 4, colonne 8, sans défaillance ni contournement.

Après l'essai de tension de choc de foudre, le montage doit être soumis à un essai de tension à la fréquence industrielle, à 2 U_0, pendant 15 min (voir Tableau 4, colonne 9). L'essai peut être effectué pendant la période de refroidissement ou à la température ambiante, à la discrétion du fabricant.

Aucun claquage ni contournement ne doivent se produire au niveau de l'enveloppe isolante.

12.4.8 Examen

12.4.8.1 Câble et accessoires

L'examen en vision normale ou corrigée sans grossissement d'un échantillon disséqué et, si possible, des accessoires après démontage ne doit révéler aucun signe de détérioration (dégradation électrique, fuite, corrosion ou rétraction nuisible, par exemple) susceptible de compromettre les performances du système en service.

L'Annexe I informative fournit des recommandations supplémentaires pour l'examen du câble et des accessoires.

12.4.8.2 Câbles qui comportent une feuille ou un ruban métallique appliqué en longueur et contrecollé à la gaine extérieure

Un échantillon de 1 m doit être prélevé sur la partie courbée en U de la longueur de câble et soumis aux essais du 12.5.16.

12.4.9 Résistivité des écrans semiconducteurs

12.4.9.1 Généralités

La résistivité des écrans semiconducteurs du câble doit être mesurée sur des échantillons prélevés dans le même lot de fabrication que le câble soumis à l'essai.

La résistivité des écrans semiconducteurs extrudés, appliqués sur l'âme et sur l'enveloppe isolante, doit être déterminée en réalisant des mesurages sur des éprouvettes prélevées sur le conducteur d'un échantillon de câble fabriqué, et sur un échantillon de câble qui a été soumis au traitement de vieillissement spécifié en 12.5.5 pour évaluer la compatibilité des matériaux constitutifs dans le cadre d'un essai.

12.4.9.2 Procédure

La procédure d'essai doit être conforme à l'Annexe D.

Les mesurages doivent être effectués à la température maximale de l'âme en service normal, à ± 2 K près.

12.4.9.3 Exigences

Avant et après vieillissement, la résistivité ne doit pas dépasser les valeurs suivantes:

– écran sur âme: 1 000 Ω · m;
– écran sur enveloppe isolante: 500 Ω · m.

12.5 Essais de type non électriques sur câble et sur les composants du câble

12.5.1 Généralités

Les essais sont les suivants:

a) examen de la constitution du câble (voir 12.5.2);
b) essais de détermination des propriétés mécaniques des enveloppes isolantes avant et après vieillissement (voir 12.5.3);
c) essais de détermination des propriétés mécaniques des gaines extérieures avant et après vieillissement (voir 12.5.4);
d) essais de vieillissement sur éprouvettes de câbles pour vérifier la compatibilité des matériaux (voir 12.5.5);
e) essai de perte de masse sur les gaines extérieures en PVC de type ST_2 (voir 12.5.6);
f) essai de pression à température élevée sur les gaines extérieures (ST_1, ST_2, ST_7 et ST_{12}) (voir 12.5.7);
g) essais à basse température sur les gaines extérieures en PVC et en LSHF (ST_1, ST_2 et ST_{12}) (voir 12.5.8);
h) essai de choc thermique sur les gaines extérieures en PVC (ST_1 et ST_2) (voir 12.5.9);
i) essai de résistance à l'ozone des enveloppes isolantes en EPR (voir 12.5.10);
j) essai d'allongement à chaud des enveloppes isolantes en EPR et en XLPE (voir 12.5.11);
k) mesurage de la masse volumique des enveloppes isolantes en PEHD (voir 12.5.12);
l) mesurage du taux de noir de carbone des gaines extérieures en PE de couleur noire (ST_3 et ST_7) (voir 12.5.13);
m) essai de tenue au feu (ST_1, ST_2 et ST_{12}) (voir 12.5.14);
n) essai de pénétration d'eau (voir 12.5.15);
o) essais sur les composants de câbles qui comportent une feuille ou un ruban métallique appliqué en longueur et contrecollé à la gaine extérieure (voir 12.5.16).

12.5.2 Examen de la constitution du câble

L'examen de l'âme et les mesurages d'épaisseur de l'enveloppe isolante, de la gaine extérieure et de la gaine métallique doivent être effectués conformément au 10.4, au 10.6 et au 10.7 et doivent satisfaire aux exigences applicables.

12.5.3 Essais de détermination des propriétés mécaniques des enveloppes isolantes avant et après vieillissement

12.5.3.1 Echantillonnage

L'échantillonnage et la préparation des éprouvettes doivent être effectués conformément à l'IEC 60811-501:2012 et à l'IEC 60811-501:2012/AMD1:2018.

12.5.3.2 Traitement de vieillissement

Le traitement de vieillissement doit être effectué conformément à l'IEC 60811-401, dans les conditions spécifiées dans le Tableau 6.

12.5.3.3 Conditionnement et essais mécaniques

Le conditionnement et le mesurage des propriétés mécaniques doivent être effectués conformément à l'IEC 60811-501:2012 et à l'IEC 60811-501:2012/AMD1:2018, avec les exceptions suivantes:

a) il n'est pas obligatoire d'effectuer en succession immédiate les essais de traction sur éprouvettes vieillies et non vieillies; et

b) tout instrument de mesure approprié peut être utilisé, par exemple un micromètre.

12.5.3.4 Exigences

Les résultats des essais sur les éprouvettes vieillies et non vieillies doivent satisfaire aux exigences indiquées dans le Tableau 6.

12.5.4 Essais de détermination des propriétés mécaniques des gaines extérieures avant et après vieillissement

12.5.4.1 Echantillonnage

L'échantillonnage et la préparation des éprouvettes doivent être effectués conformément à l'IEC 60811-501:2012 et à l'IEC 60811-501:2012/AMD1:2018.

12.5.4.2 Traitement de vieillissement

Le traitement de vieillissement doit être effectué conformément à l'IEC 60811-401, dans les conditions spécifiées dans le Tableau 7.

12.5.4.3 Conditionnement et essais mécaniques

Le conditionnement et le mesurage des propriétés mécaniques doivent être effectués conformément à l'IEC 60811-501:2012 et à l'IEC 60811-501:2012/AMD1:2018, avec les exceptions suivantes:

a) il n'est pas obligatoire d'effectuer en succession immédiate les essais de traction sur éprouvettes vieillies et non vieillies; et

b) tout instrument de mesure approprié peut être utilisé, par exemple un micromètre.

12.5.4.4 Exigences

Les résultats des essais sur les éprouvettes vieillies et non vieillies doivent satisfaire aux exigences indiquées dans le Tableau 7.