IEC 60840

Edition 5.0 2020-05

INTERNATIONAL STANDARD

NORME INTERNATIONALE

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

Câbles d'énergie à isolation extrudée et leurs accessoires pour des tensions assignées supérieures à 30 kV (U_m = 36 kV) et jusqu'à 150 kV (U_m = 170 kV) – Méthodes et exigences d'essai

IEC 60840:2020-05(en-fr)

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Câbles d'énergie à isolation extrudée et leurs accessoires pour des tensions assignées supérieures à 30 kV (U_m = 36 kV) et jusqu'à 150 kV (U_m = 170 kV) – Méthodes et exigences d'essai

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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

FOREWORD

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International Standard IEC 60840 has been prepared by IEC technical committee 20: Electric cables.

This fifth edition cancels and replaces the fourth edition, published in 2011. This edition constitutes a technical revision.

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

- Gas immersed cable terminations for use at rated voltages above 52 kV are required to be designed, type and routine tested in accordance with IEC 62271-209 in addition to the routine and type tests specified in this document.
- Requirements are introduced for composite outdoor termination insulators.
- The test cylinder diameters specified for the bending test (type and prequalification tests) have been modified in line with IEC TR 61901:2016.
- A low smoke halogen free oversheath material, designated ST_{12} is introduced.

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- Additional tests under fire conditions are introduced: vertical flame spread, smoke density, acidity and conductivity, which shall be applied according to the fire performance declared for the cable.
- A test for water penetration in the conductor is added.
- In addition to tests on the outer protection of joints, type tests on the screen sectionalizing insulation of all accessories have been introduced.

NOTE For a more detailed history of events leading up to this fifth edition, see the Introduction.

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

FDIS	Report on voting
20/1909/FDIS	20/1910/RVD

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

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

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- reconfirmed,
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INTRODUCTION

The first edition of IEC 60840, published in 1988, dealt only with cables. Accessories were added to the second edition, published in February 1999, which separately covered test methods and test requirements for

a) cables alone,

b) cables together with accessories (a cable system).

Some countries then suggested that a better discrimination be made between systems, cables and accessories, particularly for the lower voltages of the scope, for example 45 kV. This was taken into account in the third edition (2004) and has been retained subsequently, giving the type approval requirements and the range of approvals for:

a) cable systems,

b) cables alone,

c) accessories alone.

Manufacturers and users may choose the most appropriate option for type approval.

The fourth edition (2011) introduced the prequalification test procedure, as a cable system inclusive of accessories, for cables with high electrical stresses at the conductor screen and/or insulation screen.

Other significant changes in the fourth edition were:

a) The clause numbering of this document and IEC 62067 was coordinated to achieve as much commonality as possible.

b) In the case of the sample test, the lightning impulse voltage test is no longer followed by a power frequency voltage test.

In this fifth edition the principle changes are as follows:

a) New definitions have been added for three different cable screen designs following IEC TR 61901:2016.

b) Gas immersed cable terminations for use at rated voltages above 52 kV are required to be designed, type and routine tested in accordance with IEC 62271-209 in addition to the routine and type tests specified in this document.

c) Requirements are introduced for composite outdoor termination insulators.

d) The test cylinder diameters specified for the bending test (type and prequalification tests) have been modified in line with IEC TR 61901:2016.

e) A low smoke halogen free oversheath material, designated ST_{12} is introduced.

f) Additional tests under fire conditions are introduced: vertical flame spread, smoke density, acidity and conductivity, which are applied according to the fire performance declared for the cable.

g) A test for water penetration in the conductor is added.

h) In addition to tests on the outer protection of joints, type tests on the screen sectionalizing insulation of all accessories have been introduced.

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

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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

1 Scope

This document specifies test methods and requirements for power cable systems, cables alone and accessories alone, for fixed installations and for rated voltages above 30 kV (U_m = 36 kV) up to and including 150 kV (U_m = 170 kV).

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

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 60060-1:2010, *High-voltage test techniques – Part 1: General definitions and test requirements*

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 60332-3-24, *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 60811-201, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 201: General tests – Measurement of insulation thickness*

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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 60811-502:2012, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 502: Mechanical tests – Shrinkage test for insulations*

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

IEC 60811-505, *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 – Test 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*

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Full document details: IEC 60840 ed 5.0 2020 (2)

IEC 61462:2007, *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 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*

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

3 Terms and definitions

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

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

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

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

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

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

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

3.2 Definitions concerning tests

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

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

3.2.3
type test
test made before supplying on a general commercial basis a type of cable system or cable or accessory covered by IEC 60840, 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.

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3.2.4
prequalification test
test made before supplying on a general commercial basis a type of cable system covered by IEC 60840, in order to demonstrate satisfactory long-term performance of the complete cable system

3.2.5
extension of prequalification test
test made before supplying on a general commercial basis a type of cable system covered by IEC 60840, 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 customer request. Tests to be defined on agreement between customer and manufacturer.

3.3 Other definitions

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

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

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

Note 2 to entry: Nominal 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
conductor cross section
nominal conductor cross section in accordance with IEC 60228

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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
joint with screen or metal sheath interruption
joint, where the metallic sheath, shield and insulation screen of the cable are electrically interrupted

3.3.9
cable accessory with screen or metallic sheath interruption
cable accessory, where the metallic sheath, shield and insulation screen of the cable are electrically interrupted

3.3.10
termination with sectionalizing insulation
termination, where the metallic sheath, shield and insulation 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.

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 crosslinked insulation system in accordance with this document 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 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;

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– SscD: a metal screen design using a thin lead or Al 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. Typically, the aluminium foil and the semi-conductive plastic are each 0,05 mm thick;

NOTE 1 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).

NOTE 2 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 are preferred.

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 client. 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 zero halogen 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 easily flooded galleries or in water, a radial water impermeable barrier is recommended.

Longitudinal water barriers may 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.

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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, then the subclauses of 12.5.14 to which compliance is claimed, apply.

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). If the insulation is XLPE, special additives shall be declared if the higher value of tan δ according to Table 3 is applicable.

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, 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 foils bonded to the oversheath whether the type CD or SD or SscD;

– maximum DC resistance of the metal screen.

i) Compound (as defined in 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:

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

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.

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Standard values of U_0 in kV are given in Table 4.

If the calculated nominal electrical stress at the conductor screen is higher than 8,0 kV/mm and/or the calculated nominal electrical stress at the insulation screen is higher than 4,0 kV/mm, then a prequalification test according to Clause 13 is required.

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

p) Whether a prequalification test is required and/or detailed test report(s) for existing relevant PQ test(s) covering the cable system, if any.

7 Accessories characteristics

7.1 Gas immersed cable terminations

Gas immersed cable terminations for use at rated voltages above 52 kV shall be designed in accordance with IEC 62271-209.

7.2 Composite insulators for outdoor cable terminations

Composite insulators for outdoor cable terminations shall have an MML complying with Table 10, Level I or II. 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 MML may be agreed between purchaser and supplier.

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, with respect to:

- assembly technique,
- type, reference number and any other identification of the connector(s),
- details of the type test approval of the connector(s), 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 b) above),
- 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 requirement for gas immersed terminations:

- 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,

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- 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 maximum service pressure (MSP).

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 for dry tests" (IEC 60060-1:2010, 4.3) shall be applied to the test voltage values specified in this document.

8.3 Waveform of lightning impulse test voltages

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.

8.4 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 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 √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 systems of category A or B, as defined in IEC 60183.

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.

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);

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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 each prefabricated accessory shall undergo partial discharge (see 9.2) and voltage routine tests (see 9.3) according to either 1), 2) or 3) below:

1) on accessories installed on 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 electrical stresses at least the same 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.

Composite outdoor termination insulators which will be subjected to internal gas pressure in service shall be subjected, at normal atmospheric pressure and normal ambient temperature, to a routine hydraulic or gas (e.g. air, SF_6, helium) test pressure corresponding to 2,0 × MSP for at least 1 min. No failure shall occur.

Routine tests do not apply to heat or cold shrink accessories or 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 2,5 U_0 (see Table 4, column 4) and then be held for 30 min between the conductor and metal screen/sheath.

No breakdown of the insulation shall occur.

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9.4 Electrical test on oversheath of the cable

When the test is required by the particular contract, 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), may 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 (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, EPR and HEPR 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 for a cable with calculated nominal electrical stress at conductor screen > 8,0 kV/mm when calculated according to Clause 6, item n) (see 10.12);

j) water penetration test, if applicable (see 10.13);

k) tests on components of cables with a 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 greater than 20 km.

10.3 Repetition of tests

If the sample from any length selected for the tests fails in any of the tests in 10.1, 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.

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10.5 Measurement of electrical resistance of conductor and metal screen

The cable length, or a sample thereof, shall be placed in the test room, which shall be maintained at a reasonably constant temperature for at least 12 h before the test. If there is a doubt that the conductor or metal screen temperature is not the same as the room temperature, the resistance shall be measured after the cable has been in the test room for 24 h. Alternatively, the resistance can be measured on a sample of conductor or metal screen, conditioned for at least 1 h in a temperature-controlled liquid bath.

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

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

10.6 Measurement of thickness of cable 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 may 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 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:

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

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.

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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 be not 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.

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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 a 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 a 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 shall be ±0,01 mm.

The measurements shall be made on a ring of the 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 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 complete 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, EPR and HEPR 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.

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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

This test is only required for cables with a nominal electric conductor stress > 8,0 kV/mm.

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 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 may 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, 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 longitudinal water blocking measures are employed in the cable, 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 Additional 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.

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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 accessories manufacturer, either through test reports from the supplier 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 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 heat shrink insulations and insulations taped and/or moulded on site.

These tests shall be performed on one accessory of each type per contract if the 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 references to be considered during a type test on a cable system are given in Annex C, Table C.1.

Type tests on gas immersed cable terminations for use at system voltages above 52 kV 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.

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NOTE 1 It can be convenient to carry out these additional tests using the same cable and insulator as employed for the cable system type test given in this document.

NOTE 2 Tests on terminations under extraneous precipitation 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) are met:

Type tests which have been successfully performed according to the previous edition of this document are valid.

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, column 1 and 2).

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

c) The cable and the accessories have the same or similar constructions as those 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 may 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 at the cable conductor screen calculated using nominal dimensions 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 at the cable insulation screen calculated using nominal dimensions do not exceed the respective calculated stresses of the tested cable system(s).

f) The calculated nominal electrical stresses and the impulse voltage stresses calculated using nominal dimensions within the main insulation parts of the accessory and at the cable and accessory interfaces do not exceed the respective calculated stresses of the tested cable system(s).

g) For plug-in type bushings, full compliance is given only with the combination of the bushing and separable connector and cable used in the type test.

   Users should be aware that separable connector performance and compatibility shall be checked if the bushing installed in the separable connector is different from that used for the insulated termination qualification.

   For the extension of compliance to other combinations of separable connectors and bushings, in order to ensure an interchangeability of bushings, it is appropriate to repeat one or more of the electrical type tests (e.g. partial discharge test).

The type tests on cable components (see 12.5) only need to be carried out on samples from cables of different voltage ratings and/or conductor cross-sectional areas if different materials and/or different manufacturing processes are used to produce them. However, repetition of the ageing tests on pieces of completed cable to check compatibility of materials (see 12.5.5) is to be mutually agreed with the client 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.

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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 and Table 9, indicating which tests are applicable to each insulation and oversheath compound. The tests under fire conditions 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.

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 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.

During tests c) to g) of 12.4.2, it is necessary to test joints with their 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 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 specified in Table 4 for the rated voltage of the cable.

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

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

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12.4.2 Tests and sequence of tests

The tests in items a) to h) shall be made in the following sequence:

a) bending test on the cable followed by visual inspection, where applicable, (see 12.4.3) and installation of the accessories and a partial discharge test at ambient temperature (see 12.4.4);

b) tan δ measurement (see 12.4.5);

   This test may be carried out on a different cable sample taken from the same manufacturing batch, with test terminations which may be different from those 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 item e) below;

e) lightning impulse voltage test followed by a power frequency voltage test (see 12.4.7);

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

g) additional tests for accessories (see Annex H);

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

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

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

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:

1) for cables with non-corrugated copper or non-corrugated aluminium sheaths:

   – 36 (d + D) for single-core cables;

   – 25 (d + D) for three-core cables;

2) for cables with lead, lead-alloy or corrugated metal sheaths:

   – 25 (d + D) for single-core cables;

   – 20 (d + D) for three-core cables;

3) 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.

4) for other cables:

   – 20 (d + D) for single-core cables;

   – 15 (d + D) for three-core cables;

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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/sheath layer, in mm.

The tolerance for the diameter of the test cylinder is −0 % + 5 % of the nominal diameter. Smaller bending diameters may 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 Annex G, 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 conductor temperature shall be maintained within the stated temperature limits for at least 2 h. The assembly shall be heated by conductor current only.

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

There shall be no detectable discharge exceeding the declared sensitivity from the test 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 may 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, including the +5 % tolerance, as specified in 12.4.3.

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

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

During the whole of the test period, a voltage of 2 U_0 shall be applied to the 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 is allowed during the test, provided at least 20 valid heating cycles, with applied voltage, are completed.

12.4.7 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.

If, for practical reasons, the test temperature cannot be reached, additional thermal insulation may be applied. The lightning impulse voltage shall be applied, according to the procedure given in IEC 60230, 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 2,5 U_0 for 15 min (see Table 4, column 9). At the discretion of the manufacturer, this test may be carried out either during the cooling period or at ambient temperature.

No breakdown of the insulation or flashover shall occur.

12.4.8 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.

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

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.

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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 Ωm;
– insulation screen: 500 Ωm.

12.5 Non-electrical type tests 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 for 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, 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 and HEPR insulations (see 12.5.10);
j) hot set test for EPR, HEPR 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);
p) shrinkage test for PE, HDPE and XLPE insulations (see 12.5.17);
q) shrinkage test for PE and LSHF oversheaths (ST_3, ST_7 and ST_{12}) (see 12.5.18);

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r) determination of hardness for HEPR insulation (see 12.5.19);

s) determination of the elastic modulus for HEPR insulation (see 12.5.20)

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 10.4, 10.6 and 10.7, and shall comply with the requirements given therein.

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 may be used, e.g. 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 may be used, e.g. a micrometer.

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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 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 screens and the oversheath are not liable to excessive deterioration in operation due to contact with other components in the cable.

The test is applicable to cables of all types.

12.5.5.2 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:

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a) either an oven with natural air circulation or one with fan assisted circulation may 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 on PVC oversheaths (ST_1, 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 IEC 60811-505 and IEC 60811-506.

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 and HEPR insulations

12.5.10.1 Procedure

EPR and HEPR insulations 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, HEPR and XLPE insulations

EPR, HEPR 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 HDPE insulation

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

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12.5.13 Measurement of carbon black content of 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 customer lower values are allowed for special applications not exposed to UV.

12.5.14 Test under fire conditions

12.5.14.1 General

Tests shall be carried out following the relevant subclauses below, in accordance with the fire performance claimed in Clause 6, item c).

12.5.14.2 Flame spread test on single cables

The test under fire conditions in accordance with IEC 60332-1-2 shall be carried out on a sample of completed cable.

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

If a failure 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 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 requirements of IEC 60332-3-22 or IEC 60332-3-23 can be agreed between manufacturer and customer. The fire performance level achieved depends on cable design as well as material performance.

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

12.5.14.4 Measurement of smoke density of cables under defined conditions

The test for measurement of smoke density of cables 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 9.

12.5.14.5 Determination of acidity (by pH measurement) and conductivity of gases evolved during combustion of the oversheath

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

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

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

This test shall only be carried out if the test in 12.5.14.5 is also carried out.

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

The weighted values (determined in accordance with Annex K) of pH and conductivity of the cable shall be calculated according to IEC 60754-2 and shall comply with the requirements given in Table 9.

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 c) and Clause 6, item f). 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 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 and peel strength of the laminated metal foil (see Clause G.2);

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

12.5.17 Shrinkage test for PE, HDPE and XLPE insulations

12.5.17.1 Procedure

The shrinkage test shall be carried out on insulations of PE, HDPE and XLPE using the sampling and test procedure described in IEC 60811-502 and the conditions specified in Table 8.

12.5.17.2 Requirements

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

12.5.18 Shrinkage test for PE oversheaths (ST_3, ST_7) and LSHF oversheaths (ST_{12})

12.5.18.1 Procedure

The shrinkage test shall be carried out on PE oversheaths of ST_3 and ST_7 and on LSHF oversheaths of ST_{12} using the sampling and test procedure described in IEC 60811-503 and the conditions specified in Table 7.

12.5.18.2 Requirements

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

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12.5.19 Determination of hardness of HEPR insulation

12.5.19.1 Procedure

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

12.5.19.2 Requirements

The results of the test shall comply with Table 8.

12.5.20 Determination of the elastic modulus of HEPR insulation

12.5.20.1 Procedure

Sampling, preparation of the test pieces and the test procedure shall be carried out in accordance with IEC 60811-501:2012 and IEC 60811-501:2012/AMD1:2018.

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

The elastic modulus shall be the median value.

12.5.20.2 Requirements

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

13 Prequalification test of the cable system

13.1 General and range of prequalification test approval

When a prequalification 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 prequalification test shall be performed on cable systems where the calculated nominal electrical stresses at the conductor screen are higher than 8,0 kV/mm and/or at the insulation screen higher than 4,0 kV/mm. The prequalification 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 following a national or customer specification on a cable system with the same construction and accessories of the same family.

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.

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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 prequalification test on this new complete cable system shall be performed by meeting all requirements of 13.2.

A list of prequalification tests as well as extension of prequalification tests is given in Annex C.

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

NOTE 1 A substantial change is defined as that which might adversely affect the performance of the cable system. In this case, the supplier provides a detailed case, including test evidence, if modifications are introduced, which are claimed not to constitute a substantial change.

NOTE 2 A prequalification test is carried out using a cable of a large conductor cross-section in order to cover thermo-mechanical aspects.

A prequalification 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 prequalification test certificate issued by an independent test laboratory shall be acceptable as evidence of prequalification testing.

13.2 Prequalification test on complete system

13.2.1 Summary of prequalification tests

The prequalification test shall comprise the electrical tests on the complete cable system with a minimum of 20 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 prequalification tests in 13.2. After repair of the test assembly the prequalification tests may 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. However, the test may 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 prequalification test of the complete system is considered to start after the repair.

13.2.2 Test voltage values

Prior to the prequalification test of the cable system, the insulation thickness of the cable shall be measured and the test voltage values adjusted, if necessary, as stated in 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 may be performed in a laboratory and not necessarily in a situation simulating the real installation conditions.

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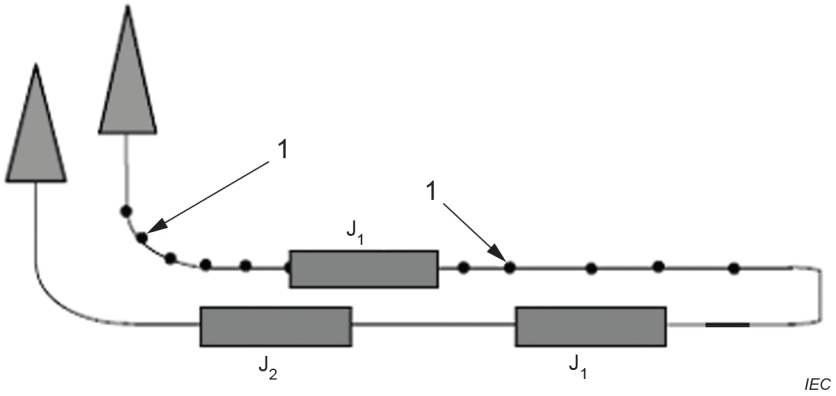
If a joint is designed for use both in flexible and rigid installations, one joint shall be installed in a flexible configuration and another in a rigid configuration, see Figure 1. If the joint is designed only for use in rigid installations, the joint shall be installed rigidly fixed at both sides. If a joint is designed only for flexible installations, the joint shall be installed in a flexible configuration at both sides.

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

NOTE The example in Figure 1 is easier to realize than a full simulation of practical laying conditions. Thermo-mechanical aspects of the design will not be tested with this test set-up.

In special cases where thermo-mechanical aspects shall be considered, special test arrangements representative of installation design conditions should be considered. Ambient conditions may vary between installations and during the test and are not considered to have any major influence.

As an outdoor test facility may be used, the commonly specified limits on ambient temperature (20 ± 15) °C do not apply.



Key

1 cleats

J_1 joint designed for rigid and flexible fixation

J_2 joint designed for flexible installation only

Figure 1 – Example of the test arrangement for the prequalification test

13.2.4 Heating cycle voltage test

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

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

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

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During the whole of the test period, a voltage of 1,7 U_0 shall be applied to the assembly.

The cycle 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 may also be counted as valid cycles. At least 180 valid heating cycles, with applied voltage, shall be completed.

Interruption of the heating cycles or the test voltage is allowed during the test.

No breakdown shall occur.

NOTE Partial discharge measurements are preferred 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, with the cable conductor temperature 0 K to 5 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. If, for practical reasons, the test temperature cannot be reached, additional thermal insulation may be applied.

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

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

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 extension of prequalification 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.

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, 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 minimum length of cable between accessories shall be 5 m. The minimum total cable length shall be 20 m.

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.

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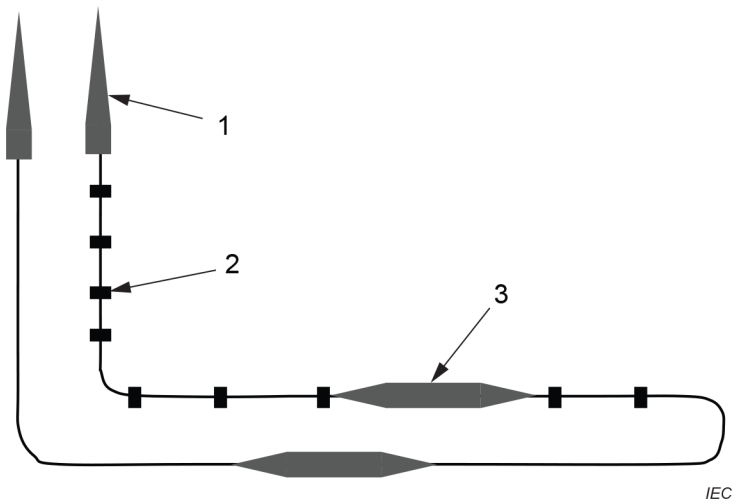
If the prequalification of a joint is to be extended for use both in flexible and in rigid installations, one joint shall be installed in a flexible configuration and the other one in a rigid configuration, see Figure 2.

If the cable is part of the extension of prequalification, the test loop shall have a U-bend with a diameter not greater than the test cylinder diameter, including the +5 % tolerance, specified in 12.4.3.

With the exception of the provisions of 13.3.2.2 and the tan δ measurement (see 13.3.2.3 d)), the tests listed in 13.3.2.3 a) to j) shall be applied successively to the same sample. The accessories shall be installed after the bending test on the cable.

Measurement of the resistivity of semi-conducting screens (see 13.3.2.3 k)) described in 12.4.9 shall be made on a separate sample from the same manufacturing batch of cable.

Measurement of the resistivity of semi-conducting screens is not required if the extension of the prequalification is only for accessories.



Key

1 termination

2 cleat

3 joint

Figure 2 – Example of extension of prequalification test arrangement for the prequalification of a system with another joint, designed for rigid as well as flexible installation

13.3.2.2 Test voltage values

Prior to the electrical extension of prequalification tests, the insulation thickness of the cable shall be measured and the test voltage values adjusted, if necessary, as stated in 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 extension of prequalification tests shall be as follows:

a) bending test (see 12.4.3) without final partial discharge test (see 12.4.4) followed by installation of the accessories that are part of the tests for the extension of the prequalification;

b) partial discharge test at ambient temperature (see 12.4.4);

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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 may 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 g) below;

g) lightning impulse voltage test followed by a power frequency voltage test (see 12.4.7);

h) partial discharge tests at ambient and at high temperature, if not previously carried out in item f) above;

i) additional tests for accessories (see Annex H);

j) examination of the cable, if it is subject to the extension of the prequalification test, and accessories shall be carried out after completion of the tests above (see 12.4.8). If the extension to prequalification test is only for accessories, then 12.4.8.2 is not required;

k) the resistivity of semi-conducting screens (see 12.4.9) shall be measured on a separate sample taken from the same manufacturing batch.

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 may be applied.

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

14 Type tests on cables

14.1 General

The tests specified in Clause 14 are intended to demonstrate the satisfactory performance of cables alone.

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

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This test procedure shall be performed on cables where the calculated nominal electrical stress at the conductor screen is not higher than 8,0 kV/mm and at the insulation screen not higher than 4,0 kV/mm. In other cases, the type tests on the cable system according to Clause 12 shall apply.

Type tests which have been successfully performed in accordance with the previous edition of this document are deemed to be valid.

A list of type tests on cables is given in Annex C.

14.2 Range of type approval

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

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

   Cables 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 conductor cross-section is not larger than that of the tested cable.

c) The cable has the same or similar construction to that of the tested cable(s).

   Cables 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 type or material or of the protective layers applied over the screened cores, unless these are likely to have a significant effect on the results of the test. In some instances, it may 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 at the cable conductor screen does not exceed the nominal electrical stress at the conductor screen of the tested cable(s) by more than 10 %.

e) The calculated nominal electrical stress at the cable insulation screen does not exceed the nominal electrical stress at the insulation screen of the tested cable(s).

The type tests on cable components (see 12.5) only need to be carried out on samples from cables of different voltage ratings and/or conductor cross-sectional areas if different materials and/or different manufacturing processes have been 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 be required if the combination of materials applied over the screened core is different from that of the cable on which type tests have been carried out previously.

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.

14.3 Summary of type tests

The type tests shall comprise the electrical tests on the completed cable (see 14.4), adjusted as required in 12.4.1, and the appropriate non-electrical tests on cable components and completed cable specified in 12.5.

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

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14.4 Electrical type tests on completed cables

The tests a) to f) shall be performed in sequence on a sample of completed cable at least 10 m in length excluding the test accessories:

a) bending test (see 12.4.3) followed by installation of the test terminations and a partial discharge test at ambient temperature (see 12.4.4);

b) tan δ measurement (see 12.4.5);

This test may be carried out on a different cable sample, taken from the same manufacturing batch, from that used for the remainder of the sequence of tests.

c) heating cycle voltage test (see 12.4.6), followed by partial discharge measurement at ambient temperature (see 12.4.4), which shall be carried out after the final cycle or, alternatively, after the lightning impulse voltage test (see item d) below);

d) lightning impulse voltage test followed by a power frequency voltage test (see 12.4.7);

e) partial discharge test at ambient temperature (see 12.4.4), if not previously carried out in c) above;

f) examination of the cable on completion of the above tests (see 12.4.8);

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

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

15 Type tests on accessories

15.1 General

The tests specified in Clause 15 are intended to demonstrate the satisfactory performance of accessories alone.

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

This test procedure shall be performed on accessories for cables where the calculated nominal electrical stress at the conductor screen is not higher than 8,0 kV/mm and at the insulation screen not higher than 4,0 kV/mm. In other cases, the type tests on the cable system according to Clause 12 and the prequalification test according to Clause 13 shall apply to the cable system.

A list of type tests on accessories is given in Annex C.

NOTE Tests on outdoor terminations under extraneous precipitation or pollution are not specified in this document.

15.2 Range of type approval

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

Type tests which have been successfully performed in accordance with the previous edition of this document are deemed to be valid.

a) The voltage group is not higher than that of the tested accessory(ies).

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Accessories 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 cable conductor cross-section, rated voltage and construction are within the range of type approval as stated in 14.2.

c) Accessories have the same or a similar construction as that of the tested accessory(ies).

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 connector type or material or of the protective layers applied 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 be appropriate to repeat one or more of the type tests (e.g. partial discharge test).

d) The calculated nominal electrical stresses within the main insulation parts of the accessory and at the cable and accessory interfaces do not exceed those of the tested accessory(ies).

e) For plug-in type bushings, full compliance is given only with the combination of the bushing and separable connector and cable used in the type test. Users should be aware that separable connector performance and compatibility shall be checked if the bushing installed in the separable connector is different from that used for the insulated termination qualification.

For extension of compliance to other combinations of separable connectors and bushings, in order to ensure an interchangeability of bushings, it is appropriate to repeat one or more of the electrical type tests (e.g. partial discharge test).

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.

15.3 Summary of type tests

Accessories shall comply with the tests specified in 15.4.1 and 15.4.2.

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

One sample of each accessory type shall be tested.

The accessories shall be installed before the first partial discharge test.

The accessories shall be assembled on the cable 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.

During tests a) to e) of 15.4.2, it is necessary to test joints with their outer protection fitted. If it can be shown that the outer protection does not influence the performance of the joint insulation, for example there are no thermo-mechanical or compatibility effects, the protection need not be fitted.

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15.4 Electrical type tests on accessories

15.4.1 Test voltage values

Prior to the electrical type tests of the accessories, the insulation thickness of the cable used shall be measured and the test voltage values adjusted, if necessary, as stated in 12.4.1.

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

15.4.2 Tests and sequence of tests

Accessories shall be subjected to the following sequence:

a) partial discharge test at ambient temperature (see 12.4.4);

b) heating cycle voltage test (see 12.4.6);

   A U-bend in the cable is not required.

c) 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 b) above or, alternatively, after item d) below.

d) lightning impulse voltage test followed by a power frequency voltage test (see 12.4.7);

e) partial discharge tests at ambient and at high temperature, if not previously carried out in item c) above;

f) additional tests for accessories (see Annex H);

g) examination of the accessories after completion of the above tests (see 12.4.8.1).

16 Electrical tests after installation

16.1 General

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

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

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

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, connected together if both are present in the cable, and the ground.

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.

16.3 AC voltage test of the insulation

The AC test voltage to be applied shall be:

– in accordance with Table 4, column 10, for 1 h, or

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– U_0 applied for 24 h, or

– a voltage and time subject to agreement between the purchaser and the contractor.

The waveform shall be substantially sinusoidal and the frequency shall be between 20 Hz and 300 Hz. In the case of very long lengths the minimum frequency may be reduced to 10 Hz subject to agreement between the purchaser and the contractor. For installations which have been in use, lower voltages than given in Table 4, column 10 and/or shorter durations may be used. Values should be negotiated, taking into account the age, environment, history of breakdowns and the purpose of carrying out the test.

PD tests under AC voltage may be carried out by agreement between the customer and the contractor. The test procedure, voltage(s) and pass criteria should also be agreed.

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	(EPR)	90	250
High modulus or hard grade ethylene-propylene rubber	(HEPR)	90	250

[a] For PE and HDPE, short-circuit temperatures up to 20 K in excess of those shown may be acceptable with suitable semi-conducting screens over the conductor and the insulation and by agreement between manufacturer and purchaser.

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/ HEPR	XLPE
Maximum tan δ	10^{-4}	10	10	50	10 [a]

[a] For cables produced with an XLPE compound containing special additives, the maximum tan δ is 50×10^{-4}.

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