AS/NZS IEC 60840:2020
(IEC 60840, Ed. 5.0:2020, IDT)

Australian/New Zealand Standard

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

Superseding AS/NZS 60840:2006

AS/NZS IEC 60840:2020

This joint Australian/New Zealand standard was prepared by Joint Technical Committee EL-003, Electric Wires and Cables. It was approved on behalf of the Council of Standards Australia on 9 September 2020 and by the New Zealand Standards Approval Board on 2 September 2020.

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Australian Industry Group
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Electrical Compliance Testing Association of Australia
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This standard was issued in draft form for comment as DR AS/NZS IEC 60840:2020.

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

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Preface

This Standard was prepared by the Joint Standards Australia/Standards New Zealand Committee EL-003, Electric Wires and Cables, to supersede AS/NZS 60840:2006, *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*.

The objective of this document is to specify 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 and their accessories, 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.

This document is identical with, and has been reproduced from, IEC 60840:2020, *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*.

As this document has been reproduced from an International Standard, a full point substitutes for a comma when referring to a decimal marker.

Australian or Australian/New Zealand Standards that are identical adoptions of international normative references may be used interchangeably. Refer to the online catalogue for information on specific Standards.

The terms “normative” and “informative” are used in Standards to define the application of the appendices or annexes to which they apply. A “normative” appendix or annex is an integral part of a Standard, whereas an “informative” appendix or annex is only for information and guidance.

NOTES

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

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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

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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International Standard IEC 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.

- 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.

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

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

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.

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*

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*

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.

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

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;

– 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.

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.

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,

- 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 $\sqrt{3}$. The associated test voltages shall be established by calculation using the multipliers given in Table 4 or interpolation where no multiplier is given.

The test voltages in this document are based on the assumption that the cables and accessories are used on 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);

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.

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.

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.

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.

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.

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.

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.

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.

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 %.

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;

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.

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.

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);

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.

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:

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.

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.

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.

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.

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.

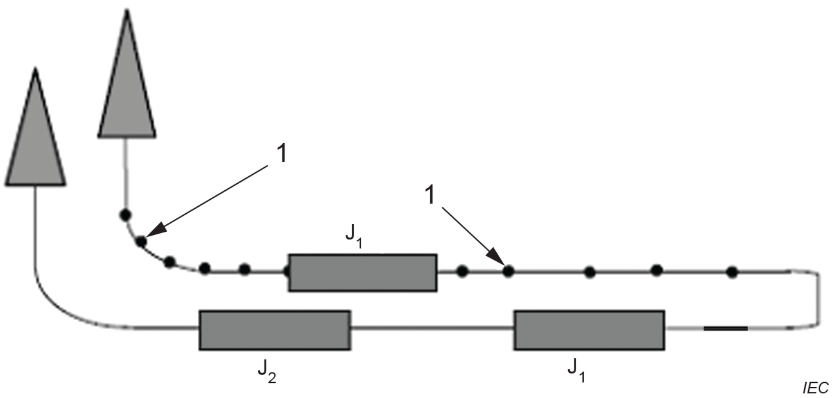
If a joint is designed for use both in flexible and rigid installations, one joint shall be installed in a flexible configuration and another in a rigid configuration, see Figure 1. If the joint is designed only for use in rigid installations, the joint shall be installed rigidly fixed at both sides.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

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.

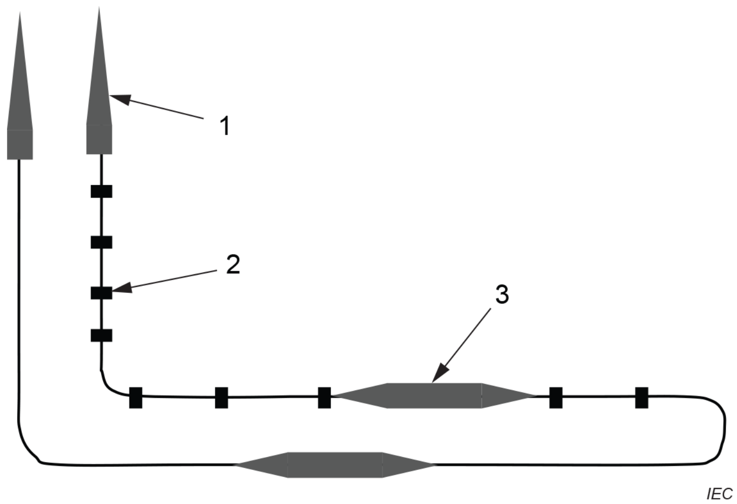
If the prequalification of a joint is to be extended for use both in flexible and in rigid installations, one joint shall be installed in a flexible configuration and the other one in a rigid configuration, see Figure 2.

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);

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.

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.

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).

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.

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

– 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}.

Table 4 – Test voltages

1 [c]	2	3	4 [a]	5 [a]	6 [a]	7 [a]	8 [a]	9 [a]	10 [b]
Rated voltage	Highest voltage for equipment	Value of U_0 for determination of test voltages	Voltage test of 9.3	Partial discharge test of 9.2 and 12.4.4	Tan δ measurement of 12.4.5	Heating cycle voltage test of 12.4.6	Lightning impulse voltage test of 10.12, 12.4.7 and 13.2.5	Voltage test of 12.4.7	Voltage test after installation of 16.3
U	U_m	U_0	2,5 U_0	1,5 U_0	U_0	2 U_0		2,5 U_0	
kV	kV	kV	kV	kV	kV	kV	kV	kV	kV
45 to 47	52	26	65	39	26	52	250	65	52
60 to 69	72,5	36	90	54	36	72	325	90	72
110 to 115	123	64	160	96	64	128	550	160	128
132 to 138	145	76	190	114	76	152	650	190	132
150 to 161	170	87	218	131	87	174	750	218	150

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

[b] If necessary, these test voltages shall be adjusted as stated in 16.3.

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

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

Designation of compound	Insulation					Oversheath				
(see 4.2 and 4.4)	PE	HDPE	EPR	HEPR	XLPE	ST_1	ST_2	ST_3	ST_7	ST_{12}
Checks on construction *Water penetration test* [a]	Applicable irrespective of insulation and oversheathing compounds									
Mechanical properties (Tensile strength and elongation at break)										
a) Without ageing	x	x	x	x	x	x	x	x	x	x
b) After ageing in air oven	x	x	x	x	x	x	x	x	x	x
c) After ageing of the completed cable (compatibility test)	x	x	x	x	x	x	x	x	x	x
Pressure test at high temperature	–	–	–	–	–	x	x	–	x	x
Behaviour at low temperature										
a) Cold elongation test	–	–	–	–	–	x	x	–	–	x
b) Cold impact test	–	–	–	–	–	x	x	–	–	x
Loss of mass in air oven	–	–	–	–	–	–	x	–	–	–
Heat shock test	–	–	–	–	–	x	x	–	–	–
Ozone resistance test	–	–	x	x	–	–	–	–	–	–
Hot set test	–	–	x	x	x	–	–	–	–	–
Measurement of density	–	x	–	–	–	–	–	–	–	–
Carbon black content [b]	–	–	–	–	–	–	–	x	x	–
Shrinkage test	x	x	–	–	x	–	–	x	x	x
Determination of hardness	–	–	–	x	–	–	–	–	–	–
Determination of elastic modulus	–	–	–	x	–	–	–	–	–	–
pH value	–	–	–	–	–	–	–	–	–	x
Conductivity test	–	–	–	–	–	–	–	–	–	x

Key
x: the test is to be applied
–: the test is not to be applied
[a] To be applied to those designs of cable where the manufacturer claims that barriers to longitudinal water penetration have been included.
[b] For black oversheaths only.

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

Designation of compound (see Table 1)	**Unit**	**PE**	**HDPE**	**XLPE**	**EPR**	**HEPR**
Maximum conductor temperature in normal operation	°C	70	80	90	90	90
Without ageing (IEC 60811-501:2012 and IEC 60811-501:2012/AMD1:2018)						
Minimum tensile strength	N/mm^2	10,0	12,5	12,5	4,2	8,5
Minimum elongation at break	%	300	350	200	200	200
After ageing in air oven (IEC 60811-401)						
Treatment: temperature	°C	100	110	135	135	135
tolerance	K	±2	±2	±3	±3	±3
duration	h	240	240	168	168	168
Tensile strength:						
a) minimum value after ageing	N/mm^2	–	–	–	–	–
b) maximum variation[a]	%	–	–	±25	±30	±30
Elongation at break:						
a) minimum value after ageing	%	300	350	–	–	–
b) maximum variation	%	–	–	±25	±30	±30

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

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

Designation of compound (see 4.4)	**Unit**	**ST_1**	**ST_2**	**ST_3**	**ST_7**	**ST_{12}**
Without ageing (IEC 60811-501:2012 and IEC 60811-501:2012/AMD1:2018)						
Minimum tensile strength	N/mm^2	12,5	12,5	10,0	12,5	12,5
Minimum elongation at break	%	150	150	300	300	300
After ageing in air oven (IEC 60811-401)						
Treatment: temperature	°C	100	100	100	110	110
tolerance	K	±2	±2	±2	±2	±2
duration	h	168	168	240	240	240
Tensile strength:						
a) minimum value after ageing	N/mm^2	12,5	12,5	–	–	10
b) maximum variation [a]	%	±25	±25	–	–	±30
Elongation at break:						
a) minimum value after ageing	%	150	150	300	300	300
b) maximum variation [a]	%	±25	±25	–	–	–
Pressure test at high temperature (IEC 60811-508:2012 and IEC 60811-508:2012/AMD1:2017)						
Test temperature	°C	80	90	–	110	110
Tolerance	K	±2	±2	–	±2	±2
Maximum indentation	%	50	50	–	50	50
Shrinkage test						
(IEC 60811-503)						
Test temperature	°C	–	–	80	80	80
Tolerance	K	–	–	±2	±2	±2
Duration	h	–	–	5	5	5
Number of heating cycles		–	–	5	5	5
Maximum shrinkage allowed	%	–	–	3,0	3,0	3,0

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

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

Designation of compound (see 4.2)	**Unit**	**PE**	**HDPE**	**XLPE**	**EPR**	**HEPR**
Ozone resistance test (IEC 60811-403)						
Ozone concentration (by volume)	%	–	–	–	0,025 to 0,030	0,025 to 0,030
Test duration without cracks	h	–	–	–	24	24
Hot set test (IEC 60811-507)						
Treatment: air temperature	°C	–	–	200	250	250
tolerance	K	–	–	±3	±3	±3
tensile stress	N/cm²	–	–	20	20	20
Maximum elongation under load	%	–	–	175	175	175
Maximum permanent elongation after cooling	%	–	–	15	15	15
Shrinkage test (IEC 60811-502:2012)						
Distance L between marks	mm	200	200	200	–	–
Temperature	°C	100	115	130	–	–
Tolerance	K	±2	±2	±3	–	–
Duration	h	6	6	6	–	–
Maximum permissible shrinkage	%	4,5	4,5	4,5	–	–
Density (IEC 60811-606)						
Minimum density	g/cm³	–	0,940	–	–	–
Determination of hardness (see Annex I)						
Minimum	IRHD [a]	–	–	–	–	80
Determination of elastic modulus (see 12.5.20)						
Modulus at 150 % elongation, minimum	N/mm²	–	–	–	–	4,5

[a] IRHD: international rubber hardness degree.

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

Designation of compound (see 4.4)	**Unit**	**ST$_1$**	**ST$_2$**	**ST$_{12}$**
Loss of mass in air oven (IEC 60811-409)				
Treatment: temperature	°C	–	100	–
tolerance	K	–	±2	–
duration	h	–	168	–
Maximum permissible loss of mass	mg/cm^2	–	1,5	–
Behaviour at low temperature [a]				
Tests to be carried out without previous ageing:				
a) Cold elongation test on dumb-bells (IEC 60811-505)				
Test temperature	°C	−15	−15	−15
Tolerance	K	±2	±2	±2
Requirement	%	≥ 20	≥ 20	≥ 20
b) Cold impact test (IEC 60811-506)				
Test temperature	°C	−15	−15	−15
Tolerance	K	±2	±2	±2
Requirement		no cracks	no cracks	no cracks
Heat shock test (IEC 60811-509)				
Treatment: test temperature	°C	150	150	–
tolerance	K	±3	±3	–
test duration	h	1	1	–
Requirement		no cracks	no cracks	–
Flame spread test on single cables (complete cable) (IEC 60332-1-2)				
Distance between the lower edge of the top support and the onset of charring	mm	> 50	> 50	> 50
The lower extent of charring below the lower edge of the top support	mm	≤ 540	≤ 540	≤ 540
Flame spread test on bunched cables (complete cable) (IEC 60332-3-24)				
Upper limit of char above bottom edge of burner	m	–	–	≤ 2,5
Smoke density test on cables (complete cables) (IEC 61034-2)				
Ø ≤ 80 mm light transmittance T min	%	–	–	60
Ø > 80 mm light transmittance T min	%	–	–	45
pH value and conductivity tests, for the oversheath or as weighted values for the cable				
(IEC 60754-2) pH ≥	–	–	–	4,3
conductivity ≤	μS/mm			10

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

Table 10 – Maximum mechanical load for composite insulators for outdoor terminations

Highest voltage for equipment U_m kV	**Rated current** A			
	< 800		1 000 to 1 600	
	Maximum mechanical load (MML) N			
	Bushing installed < 30° from the vertical			
	I	II	I	II
52	500	800	625	800
72,5	500	1 000	625	1 000
123 and 145	625	1 575	800	1 575
170	625	2 000	800	2 000

Key

Level I = normal load, Level II = heavy load

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

This table is derived from IEC 60137.

Annex A
(informative)

Determination of the cable conductor temperature

A.1 Purpose

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

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

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

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

Guidance is given hereafter on commonly used methods.

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

A.2.1 General

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

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

A.2.2 Installation of cable and temperature sensors

The calibration should be performed on a minimum cable length of 5 m, taken from the same cable as tested. The length should be such that the longitudinal heat transfer to the cable ends does not affect the temperature in the centre 2 m of cable by more than 2 K.

Two temperature sensors should be attached to the middle of the reference cable: one on the conductor (TC_{1c}), and one on the external surface or directly under the external surface (TC_{1s}).

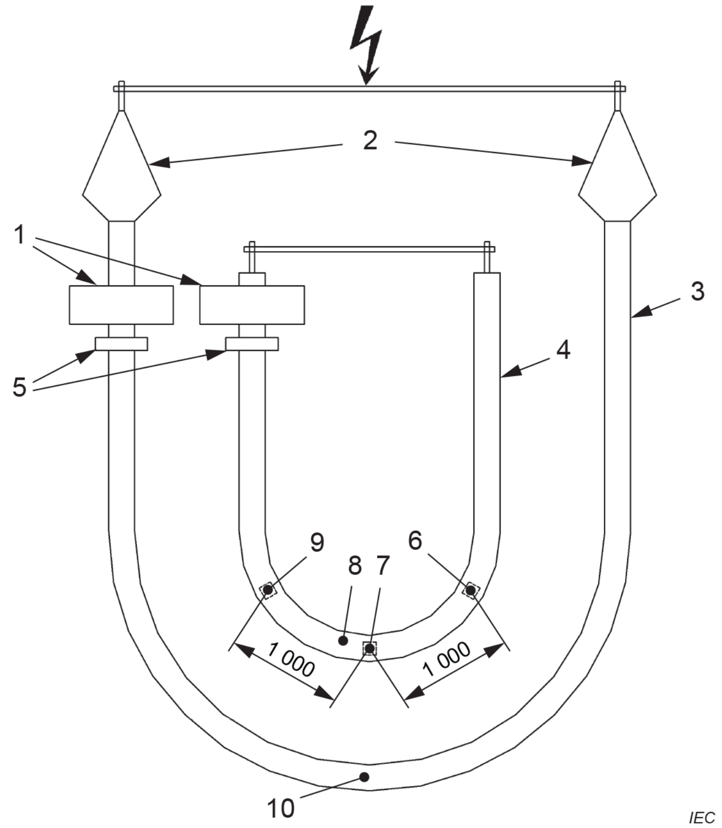
Two other temperature sensors, TC_{2c} and TC_{3c}, should be installed on the conductor of the reference cable (see Figure A.1), each one about 1 m from the middle.

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

To prove a negligible heat transfer towards the cable ends, it is recommended that the difference between the readings of TC_{1c}, TC_{2c} and TC_{3c} be less than 2 K.

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

Dimensions in mm

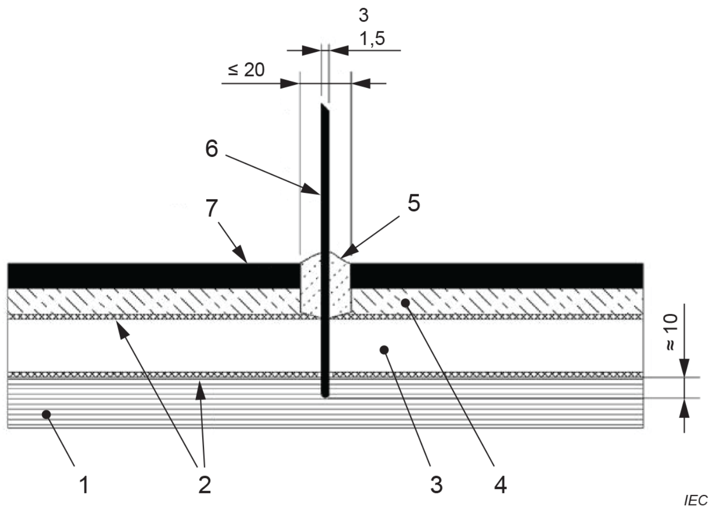


Key

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

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

Dimensions in mm



Key

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

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

A.2.3 Calibration method

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

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

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

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

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

– oversheath temperature at position TC_{1s};

– ambient temperature;

– heating current.

A.3 Heating for the test

A.3.1 Method 1 – Test using a reference cable

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

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

The test arrangement should be such that

– the reference cable carries the same current as the main test loop at any time; small current changes are allowed in order to equalize the surface temperatures on the test cable and the reference cable;
– it is installed in such a way that mutual heating effects are taken into account throughout the test.

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

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

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

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

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

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

A.3.2.1 Calibration of the test cable conductor temperature

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

The cable used for calibration should be identical to that to be used for the test, and the way of heating should be identical.

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

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

A.3.2.2 Test based on measurement of the external temperature

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

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

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

Annex B
(normative)

Rounding of numbers

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

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

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

EXAMPLE

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

Annex C
(informative)

List of type, prequalification and extension of prequalification tests for cable systems, cables and accessories

Type tests for cable systems, cables and accessories are covered by Clauses 12, 14 and 15, respectively.

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

Prequalification tests of cable systems with a calculated nominal conductor electric stress above 8,0 kV/mm or a calculated nominal insulation electric stress above 4,0 kV/mm are covered by 13.1 and 13.2.

Extension of the prequalification tests of cable systems with a calculated nominal conductor electric stress above 8,0 kV/mm or a calculated nominal insulation electric stress above 4,0 kV/mm are covered by 13.1 and 13.3.

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

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

Table C.1 – Type tests on cable systems, on cables and on accessories

Item	Test	Clauses		
		Cable systems	Cables	Accessories
a	General	12.1	14.1	15.1
b	Range of type approval	12.2	14.2	15.2
c	Electrical type tests	12.4	14.4	15.4
d	Test voltage values	12.4.1	12.4.1	12.4.1
e	Bending test	12.4.3	12.4.3	–
	Partial discharge test at ambient temperature	12.4.4	12.4.4	12.4.4
f	Tan δ measurement	12.4.5	12.4.5	–
g	Heating cycle voltage test	12.4.6	12.4.6	12.4.6
h	Partial discharge test at high temperature	12.4.4	–	12.4.4
	Partial discharge test at ambient temperature (after final cycle or after lightning impulse voltage test in item i) below)	12.4.4	12.4.4	12.4.4
i	Lightning impulse voltage test followed by power frequency voltage test	12.4.7	12.4.7	12.4.7
j	Partial discharge test at high temperature (if not carried out after item g) above)	12.4.4	–	12.4.4
	Partial discharge test at ambient temperature (if not carried out after item g) above)	12.4.4	12.4.4	12.4.4
k	Additional tests for accessories	Annex H	–	Annex H
l	Examination	12.4.8	12.4.8	12.4.8.1
m	Resistivity of semi-conducting screens	12.4.9	12.4.9	–
n	Non-electrical type tests on cable components and on completed cable	12.5	12.5	–

Table C.2 – Prequalification tests on cable systems with a calculated nominal conductor electric stress above 8,0 kV/mm or a calculated nominal insulation electric stress above 4,0 kV/mm

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

Table C.3 – Extension of prequalification tests on cable systems with a calculated nominal conductor electric stress above 8,0 kV/mm or a calculated nominal insulation electric stress above 4,0 kV/mm

Item	Test	Clauses
		Cable systems
a	Tests for the extension of the prequalification of a cable system	13.3
b	Summary of the extension of the prequalification test	13.3.1
c	Electrical part of the extension of prequalification tests on complete cables system	13.3.2
d	General	13.3.2.1
e	Test voltage values	13.3.2.2
f	Sequence of the electrical part of the extension of prequalification tests	13.3.2.3
g	Heating cycle test without voltage	13.3.2.4

Annex D
(normative)

Method of measuring resistivity of semi-conducting screens

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

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

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

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

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

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

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

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

a) conductor screen:

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

where

ρ_{c} is the volume resistivity, in ohm metres ($\Omega \cdot$ m);

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

L_{c} is the distance between potential electrodes, in metres (m);

D_{c} is the diameter over the conductor screen, in metres (m);

T_{c} is the average thickness of conductor screen, in metres (m).

b) Insulation screen:

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

where

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

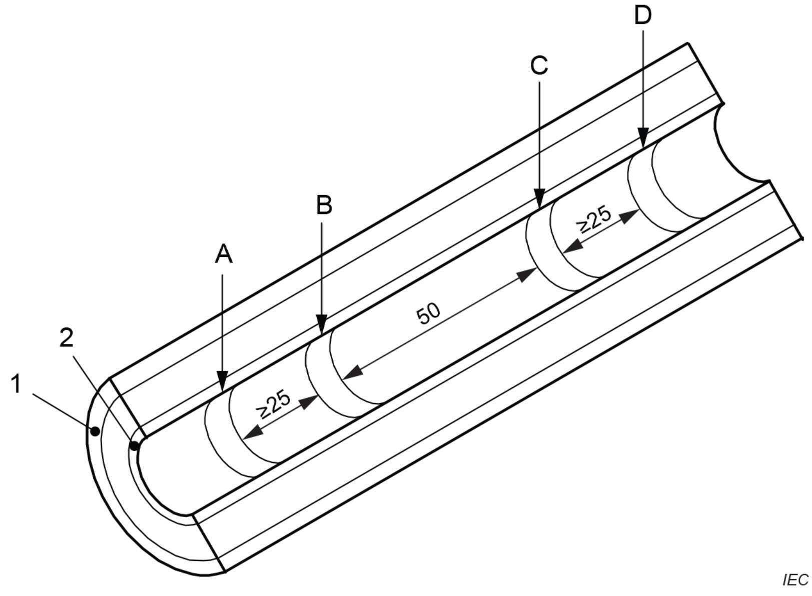
R_{i} is the measured resistance, in ohms (Ω);

L_{i} is the distance between potential electrodes, in metres (m);

D_{i} is the diameter over the insulation screen, in metres (m);

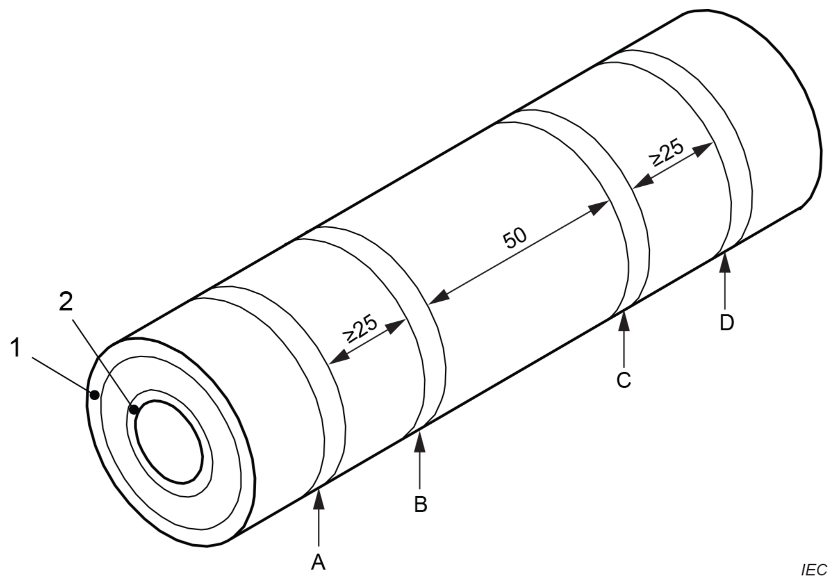
T_{i} is the average thickness of insulation screen, in metres (m).

Dimensions in mm



a) Measurement of the volume resistivity of the conductor screen

Dimensions in mm



b) Measurement of the volume resistivity of the insulation screen

Key

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

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

Annex E
(normative)

Water penetration test

E.1 Test piece

A sample of completed cable at least 6 m in length which has not previously been subjected to any of the tests described in 12.4 or 14.4 shall be subjected to the bending test described in 12.4.3.

A 6 m length of cable shall be cut from the length which has been subjected to the bending test and placed horizontally. A ring approximately 50 mm wide shall be removed from the centre of the length. This ring shall comprise all the layers external to the insulation screen. Where the conductor is also claimed to contain a longitudinal water barrier, the ring shall comprise all layers external to the conductor.

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

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

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

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

E.2 Test

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

The sample shall be allowed to stand for 24 h.

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

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

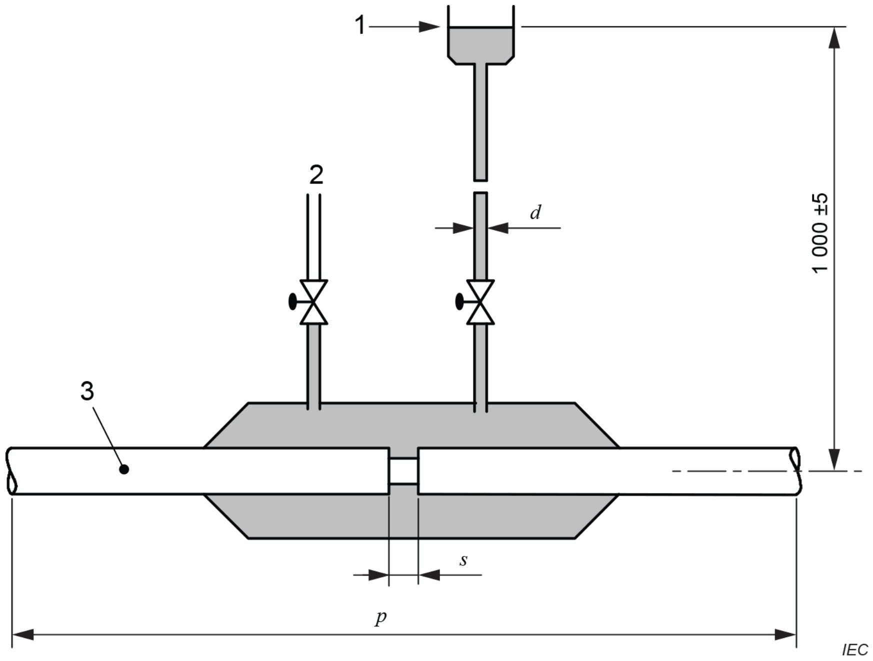
The water head shall be maintained at 1 m.

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

E.3 Requirements

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

Dimensions in mm



Key

1	water header tank	*d*	Ø10 mm minimum (inner)
2	vent	*s*	50 mm approximately
3	cable	*p*	length ≤ 6 000 mm

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

Annex F
(normative)

Test for water penetration in the conductor

F.1 Test piece

A 3 m sample of cable which has been subjected to the bending test of 12.4.3 shall be placed horizontally.

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

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

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

F.2 Test

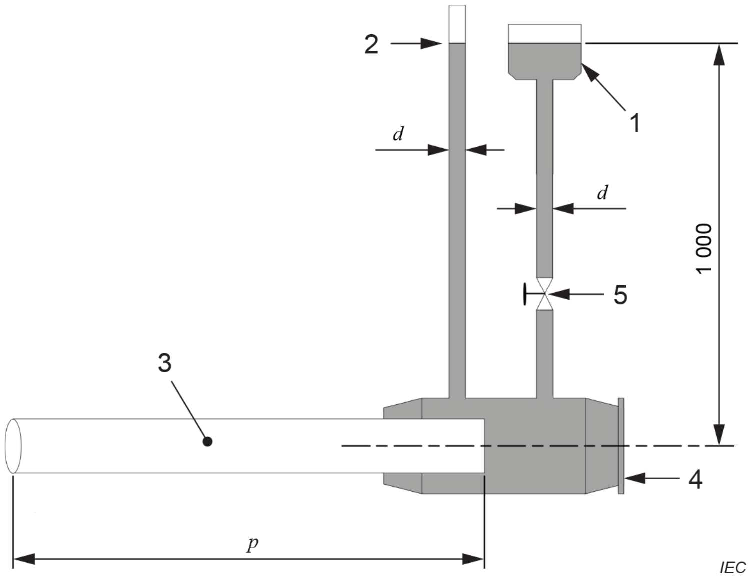
The tube shall be filled within 5 min with tap water at a temperature of (20 ± 10) °C so that the height of the water in the tube is 1 m above the cable centre (see Figure F.1).

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

F.3 Requirements

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

Dimensions in mm



Key

1 water header tank

2 air vent

3 test piece

4 chamber

5 full bore valve (optional)

d internal Ø = 10 mm minimum

p length ≤ 3 000 mm

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

Annex G
(normative)

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

G.1 Visual examination

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

G.2 Adhesion and peel strength

G.2.1 General

Adhesion and peel strength are defined as

$$F / w$$

where

F is the force (N);

w is the width of tape (mm).

In the case of a CD design (combined design – CD metal screen that combines radial watertightness and electrical properties), the concern is that delamination could damage the metal component and alter the electric functionality of the screen. Therefore, the adhesion strength and peel strength of the laminated covering shall be as high as possible.

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

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

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

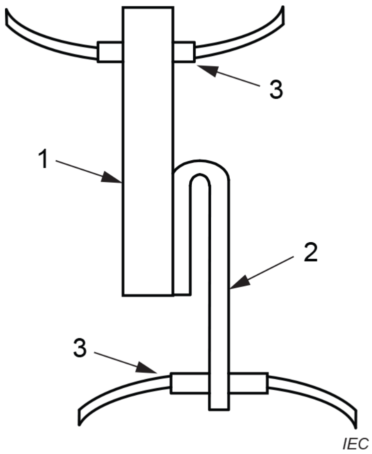
G.2.2 Test: Adhesion strength

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

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

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

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



Key

1 oversheath

2 metal tape or foil

3 grips

Figure G.1 – Adhesion of metal tape or foil

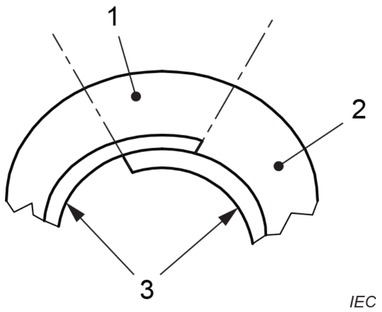
The specimen should be held approximately vertically in the plane of the grips during the test.

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

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

G.2.3 Test: Peel strength of overlapped metal foil

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



Key

1 specimen

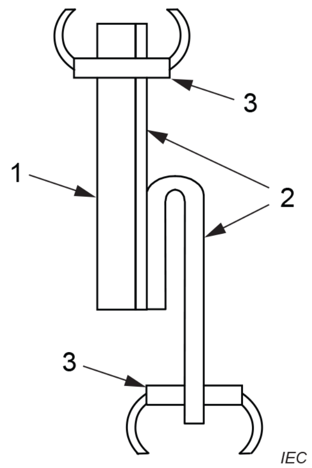
2 oversheath

3 metal foil or laminated metal foil

Figure G.2 – Example of overlapped metal foil

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

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



Key

1 oversheath

2 metal foil or laminated metal foil

3 grips

Figure G.3 – Peel strength of overlapped metal foil

G.2.4 Requirements

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

The first part of the curve is linked to the sample preparation. The decreasing end part corresponds to the end of the sample. In-between, a steady state is achieved. The minimum strength F_{min} in Table G.1 shall be determined for an increase in the spacing between the grips of at least 50 mm. A tensile testing machine with either a direct output for the minimum value or a graphical output may be used. Figure G.4 and Figure G.5 below give typical curves from a graphical output machine and indicate how they shall be interpreted.

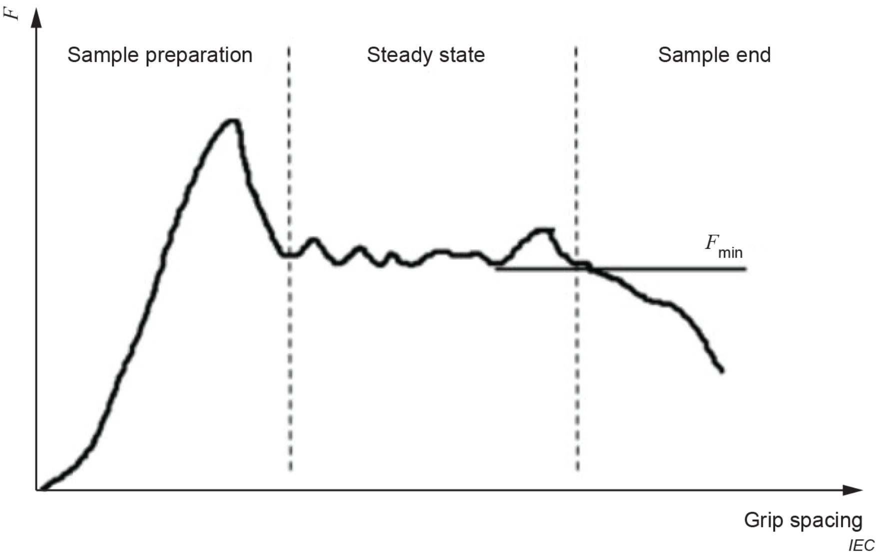


Figure G.4 – Typical strength versus grip spacing curve (1)

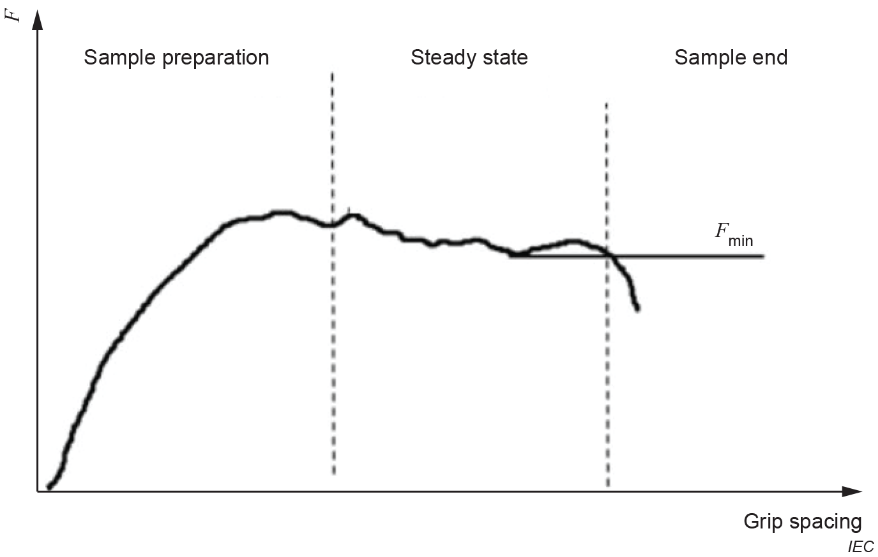


Figure G.5 – Typical strength versus grip spacing curve (2)

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

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

Key

NA: The test cannot be performed.

Annex H
(normative)

Additional tests for accessories

H.1 General

Annex H specifies the procedure for additional type tests for accessories for:

– joints with or without screen interruption;
– accessories for cable screen interruption and/or earth connection;
– terminations with sectionalizing insulation;
– composite insulators for outdoor terminations.

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

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

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

Table H.1 gives the test sequence for different types of accessories.

Table H.1 – Test sequence

Test sequence	Joints without screen or metal sheath interruption and cable accessories without a screen or metal sheath/screen interruption (e.g. earth connection)	Joints with screen or metal sheath interruption and cable accessories with a screen or metal sheath/screen interruption (e.g. earth connection and/or cross bonding applications)	Terminations with sectionalizing insulation	Composite insulators for outdoor terminations
	Clause H.3	Clause H.3	Clause H.4	Clause H.6
Subjected to 20 thermal cycles with or without voltage	X	X		
Water immersion conditioning (20 thermal cycles)	X[a]	X[a]		
DC voltage withstand test screen to earth	X	X	X	
DC voltage withstand test screen to screen		X		

Test sequence	Joints without screen or metal sheath interruption and cable accessories without a screen or metal sheath/screen interruption (e.g. earth connection)	Joints with screen or metal sheath interruption and cable accessories with a screen or metal sheath/screen interruption (e.g. earth connection and/or cross bonding applications)	Terminations with sectionalizing insulation	Composite insulators for outdoor terminations
	Clause H.3	Clause H.3	Clause H.4	Clause H.6
LI withstand test screen to earth	X	X	X	
LI withstand test screen to screen		X		
Internal pressure test				X
Cantilever load test				X
Examination (Clause H.5)	X	X	X	
[a] Not for accessories for installation in air, tested without water immersion.				

H.2 Range of approval

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

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

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

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

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

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

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

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

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

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

H.2.4 Range of approval for terminations with sectionalizing insulation

When the test sequence according to this annex has been successfully performed for terminations with sectionalizing insulation, the type approval shall be considered as valid for all terminations with sectionalizing insulation offered by the same manufacturer, embodying the same basic design principles, at equal or lower voltage group.

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

H.3.1 Water immersion

The water immersion of joints or cables shall be applied successively to a joint which has passed the heating cycle voltage test (see 12.4.6) or to a separate joint which has undergone at least 20 thermal cycles without voltage, as specified in 12.4.2, item g).

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

Additional voltage tests according to H.3.2 may be carried out before commencing the heating/cooling cycles, at the discretion of the manufacturer.

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

H.3.2 Electrical tests

H.3.2.1 General

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

No breakdown on joints with or without screen interruption or cables with screen interruption shall occur during any of the electrical withstand tests.

No flash-over on terminations shall occur during any of the electrical withstand tests.

All tests in this annex shall be carried out at ambient temperature if not specified otherwise.

In the case of accessories with a water immersion test, the electrical tests in H.3.2.2 and H.3.2.4 shall be carried out whilst the assembly is still immersed in water. If it is not practicable to carry out the electrical tests whilst the assembly is still immersed in water, the assembly may be removed from the water and electrically tested with a minimum of delay. In this case, earthing of the test object may be achieved by wrapping with a wet fabric, or using a conductive coating applied over the entire exterior surface of the test assembly.

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

H.3.2.2 DC voltage withstand test between screen and earth

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

H.3.2.3 DC voltage withstand test between screen and screen

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

H.3.2.4 Lightning impulse voltage withstand test between screen and earth

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

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

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

Highest voltage for equipment U_m [a] kV	**Lightning impulse level**	
	Each part to earth	
	Bonding leads ≤ 3 m [c] kV	Bonding leads > 3 m and ≤ 10 m [b] kV
≤ 72,5	30	30
> 72,5	30	37,5

[a] See Table 4, column 2.

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

[c] Including accessories with sheath voltage limiters fitted directly – cable side to earth only.

H.3.2.5 Lightning impulse voltage withstand test between screen and screen

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

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

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

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

Highest voltage for equipment U_m [a] kV	Lightning impulse level	
	Between parts [c]	
	Bonding leads ≤ 3 m kV	Bonding leads > 3 m and ≤ 10 m [b] kV
≤ 72,5	60	60
> 72,5	60	75

[a] See Table 4, column 2.

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

[c] Between parts is used here synonymously for tests between screen to screen of joints with screen or metal sheath interruption or accessories for cable screen interruption and/or earth connection.

H.4 Tests of terminations with sheath sectionalizing insulation

H.4.1 DC voltage withstand test between screen and earth

A test voltage of 25 kV DC shall be applied for 1 min across the sheath sectionalizing insulation of the termination.

H.4.2 Lightning impulse voltage withstand test between screen and earth

To test sheath sectionalizing insulation of terminations, a test voltage in accordance with Table H.4 shall be applied between the screen and earth, across the sectionalizing insulation.

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

Table H.4 – Lightning impulse voltage withstand tests between screen and earth of terminations with sheath sectionalizing insulation

Highest voltage for equipment U_m [a] kV	Lightning impulse level Sheath sectionalizing insulation of terminations kV
≤ 72,5	30
> 72,5	37,5

[a] See Table 4, column 2.

H.5 Examination

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

The test assembly as described in Clause H.3 shall be examined with respect to the defined and clearly identified water-protection barriers (see Clause H.1).

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

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

H.6 Tests for composite insulators for outdoor terminations

H.6.1 General

One insulator of each type shall be tested as given in H.6.2 and H.6.3.

H.6.2 Internal pressure test

For insulators which will be pressurized in service, the test according to 8.4 of IEC 61462:2007 shall be carried out. The requirements of 8.4 of IEC 61462:2007 shall be met.

H.6.3 Cantilever load test

The insulator shall be tested according to 8.5 of IEC 61462:2007. The requirements of 8.5 of IEC 61462:2007 shall be met.

Annex I
(normative)

Determination of hardness of HEPR insulations

I.1 Test piece

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

I.2 Test procedure

I.2.1 General

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

I.2.2 Surfaces of large radius of curvature

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

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

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

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

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

I.2.3 Surfaces of small radius of curvature

On surfaces with too small a radius of curvature for the procedures described in I.2.1, the test piece shall be supported on the same rigid base as the test instrument, in such a way as to minimize bodily movement of the HEPR insulation when the indenting force increment is applied to the indenter and so that the indenter is vertically above the axis of the test piece. Suitable procedures are as follows:

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

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

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

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

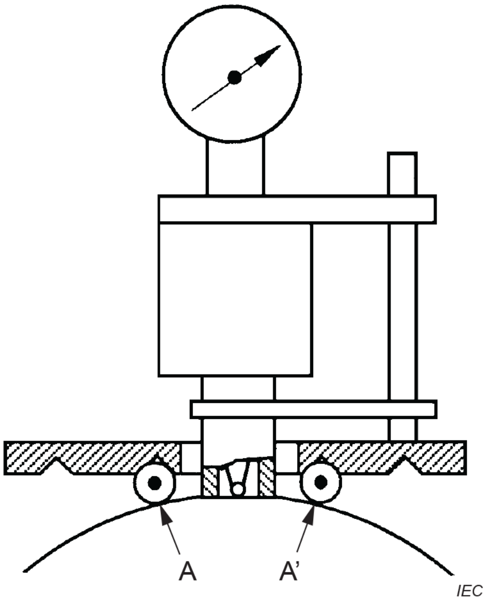
I.2.4 Conditioning and test temperature

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

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

I.2.5 Number of measurements

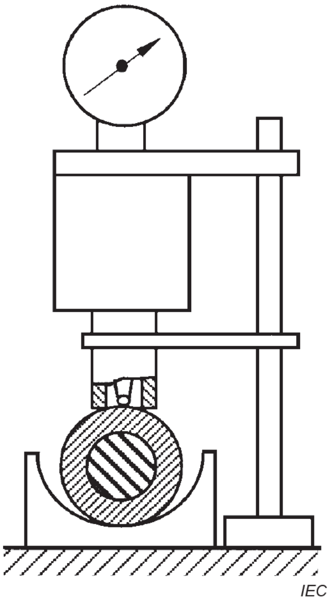
One measurement shall be made at each of three or five different points distributed around the test piece. The median of the results shall be taken as the hardness of the test piece, reported to the nearest whole number in international rubber hardness degrees (IRHD).



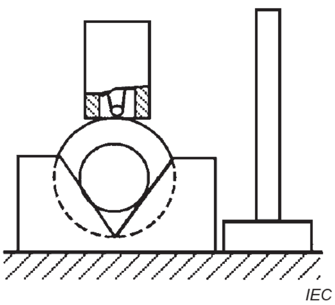
Key

A and A' parallel rods

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



a) Test piece in groove



b) Test piece in V-blocks

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

Annex J
(informative)

Guidance on examination of cable and accessories

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

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

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

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

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

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

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

Annex K
(normative)

Methods of determining the weighted value of the cable for measurement of halogen content

K.1 Calculating the weighted value of the cable when the halogen content of individual materials is tested

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

The weighted value for the cable of halogen content, H_i', for each halogen, is calculated as follows:

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

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

K.2 Preparation of the test sample for measurement of halogen content on a sample representative of the cable construction

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

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

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NOTES

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