

INTERNATIONAL STANDARD

NORME INTERNATIONALE

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

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



THIS PUBLICATION IS COPYRIGHT PROTECTED

Copyright © 2004 IEC, Geneva, Switzerland

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from either IEC or IEC's member National Committee in the country of the requester.

If you have any questions about IEC copyright or have an enquiry about obtaining additional rights to this publication, please contact the address below or your local IEC member National Committee for further information.

Droits de reproduction réservés. Sauf indication contraire, aucune partie de cette publication ne peut être reproduite ni utilisée sous quelque forme que ce soit et par aucun procédé, électronique ou mécanique, y compris la photocopie et les microfilms, sans l'accord écrit de la CEI ou du Comité national de la CEI du pays du demandeur.

Si vous avez des questions sur le copyright de la CEI ou si vous désirez obtenir des droits supplémentaires sur cette publication, utilisez les coordonnées ci-après ou contactez le Comité national de la CEI de votre pays de résidence.

IEC Central Office
3, rue de Varembe
CH-1211 Geneva 20
Switzerland
Email: inmail@iec.ch
Web: www.iec.ch

About the IEC

The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications

The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigenda or an amendment might have been published.

- Catalogue of IEC publications: www.iec.ch/searchpub

The IEC on-line Catalogue enables you to search by a variety of criteria (reference number, text, technical committee,...). It also gives information on projects, withdrawn and replaced publications.

- IEC Just Published: www.iec.ch/online_news/justpub

Stay up to date on all new IEC publications. Just Published details twice a month all new publications released. Available on-line and also by email.

- Electropedia: www.electropedia.org

The world's leading online dictionary of electronic and electrical terms containing more than 20 000 terms and definitions in English and French, with equivalent terms in additional languages. Also known as the International Electrotechnical Vocabulary online.

- Customer Service Centre: www.iec.ch/webstore/custserv

If you wish to give us your feedback on this publication or need further assistance, please visit the Customer Service Centre FAQ or contact us:

Email: csc@iec.ch

Tel.: +41 22 919 02 11

Fax: +41 22 919 03 00

A propos de la CEI

La Commission Electrotechnique Internationale (CEI) est la première organisation mondiale qui élabore et publie des normes internationales pour tout ce qui a trait à l'électricité, à l'électronique et aux technologies apparentées.

A propos des publications CEI

Le contenu technique des publications de la CEI est constamment revu. Veuillez vous assurer que vous possédez l'édition la plus récente, un corrigendum ou amendement peut avoir été publié.

- Catalogue des publications de la CEI: www.iec.ch/searchpub/cur_fut-f.htm

Le Catalogue en-ligne de la CEI vous permet d'effectuer des recherches en utilisant différents critères (numéro de référence, texte, comité d'études,...). Il donne aussi des informations sur les projets et les publications retirées ou remplacées.

- Just Published CEI: www.iec.ch/online_news/justpub

Restez informé sur les nouvelles publications de la CEI. Just Published détaille deux fois par mois les nouvelles publications parues. Disponible en-ligne et aussi par email.

- Electropedia: www.electropedia.org

Le premier dictionnaire en ligne au monde de termes électroniques et électriques. Il contient plus de 20 000 termes et définitions en anglais et en français, ainsi que les termes équivalents dans les langues additionnelles. Egalement appelé Vocabulaire Electrotechnique International en ligne.

- Service Clients: www.iec.ch/webstore/custserv/custserv_entry-f.htm

Si vous désirez nous donner des commentaires sur cette publication ou si vous avez des questions, visitez le FAQ du Service clients ou contactez-nous:

Email: csc@iec.ch

Tél.: +41 22 919 02 11

Fax: +41 22 919 03 00

INTERNATIONAL STANDARD

NORME INTERNATIONALE

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

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

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

COMMISSION
ELECTROTECHNIQUE
INTERNATIONALE

PRICE CODE
CODE PRIX

XA

ICS 29.060.20

ISBN 2-8318-7458-0

CONTENTS

FOREWORD.....	5
INTRODUCTION.....	7
1 Scope.....	8
2 Normative references.....	8
3 Definitions	9
3.1 Definitions of dimensional values (thicknesses, cross-sections, etc.).....	9
3.2 Definitions concerning the tests	9
4 Voltage designations and materials.....	10
4.1 Rated voltages	10
4.2 Cable insulating materials.....	10
4.3 Cable oversheathing materials.....	10
5 Precautions against water penetration in cables	11
6 Cable characteristics	11
7 Accessory characteristics.....	11
8 Test conditions	12
8.1 Ambient temperature	12
8.2 Frequency and waveform of power frequency test voltages.....	12
8.3 Waveform of lightning impulse test voltages.....	12
8.4 Relationship of test voltages to rated voltages.....	12
8.5 Determination of the cable conductor temperature	12
9 Routine tests on cables and on the main insulation of prefabricated accessories	13
9.1 General	13
9.2 Partial discharge test.....	13
9.3 Voltage test.....	13
9.4 Electrical test on oversheath of the cable	14
10 Sample tests on cables.....	14
10.1 General.....	14
10.2 Frequency of tests.....	14
10.3 Repetition of tests.....	14
10.4 Conductor examination.....	14
10.5 Measurement of electrical resistance of conductor and metallic screen	14
10.6 Measurement of thickness of cable insulation and oversheath.....	15
10.7 Measurement of thickness of metallic sheath	16
10.8 Measurement of diameter	17
10.9 Hot set test for XLPE, EPR and HEPR insulations	17
10.10 Measurement of capacitance	17
10.11 Measurement of density of HDPE insulation	17
11 Sample tests on accessories.....	17
11.1 Tests on components	17
11.2 Tests on complete accessory.....	17
12 Type tests on cable systems	18
12.1 Range of type approval.....	18
12.2 Summary of type tests	19
12.3 Electrical type tests on complete cable systems	19
12.4 Non-electrical type tests on cable components and on completed cable	23

13	Type tests on cables	28
13.1	Range of type approval	28
13.2	Summary of type tests	29
13.3	Electrical type tests on completed cables	29
14	Type tests on accessories	30
14.1	Range of type approval	30
14.2	Summary of type tests	30
14.3	Electrical type tests on accessories	31
15	Electrical tests after installation	32
15.1	DC voltage test of the oversheath	32
15.2	AC voltage test of the insulation	32
	Annex A (informative) Determination of the cable conductor temperature	39
	Annex B (normative) Rounding of numbers	43
	Annex C (informative) Summary of type tests of cable systems, of cables and of accessories	44
	Annex D (normative) Method of measuring resistivity of semi-conducting screens	45
	Annex E (normative) Determination of hardness of HEPR insulations	47
	Annex F (normative) Water penetration test	49
	Annex G (normative) Tests on components of cables with a longitudinally applied metal foil	51
	Annex H (normative) Tests of outer protection for buried joints	54
	Bibliography	56
	Figure A.1 – Typical test set-up for the reference loop and the main test loop	40
	Figure A.2 – Arrangement of the thermocouples on the conductor of the reference loop	40
	Figure D.1 – Preparation of samples for measurement of resistivity of conductor and insulation screens	46
	Figure E.1 – Test on surfaces of large radius of curvature	48
	Figure E.2 – Test on surfaces of small radius of curvature	48
	Figure F.1 – Schematic diagram of apparatus for water penetration test	50
	Figure G.1 – Adhesion of metal foil	51
	Figure G.2 – Example of overlapped metal foil	52
	Figure G.3 – Peel strength of overlapped metal foil	52
	Table 1 – Insulating compounds for cables	32
	Table 2 – Oversheathing compounds for cables	33
	Table 3 – $\tan \delta$ requirements for insulating compounds for cables	33
	Table 4 – Test voltages	33
	Table 5 – Non-electrical type tests for insulating and oversheathing compounds for cables	34
	Table 6 – Test requirements for mechanical characteristics of insulating compounds for cables (before and after ageing)	35

Table 7 – Test requirements for mechanical characteristics of oversheathing compounds for cables (before and after ageing)	36
Table 8 – Test requirements for particular characteristics of insulating compounds for cables	37
Table 9 – Test requirements for particular characteristics of PVC oversheathing compounds for cables	38
Table C.1 – Type tests on cable systems, on cables and on accessories	44
Table H.1 – Impulse voltage tests	55

Withdrawn

INTERNATIONAL ELECTROTECHNICAL COMMISSION

**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.
- 2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
- 3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
- 4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
- 5) IEC provides no marking procedure to indicate its approval and cannot be rendered responsible for any equipment declared to be in conformity with an IEC Publication.
- 6) All users should ensure that they have the latest edition of this publication.
- 7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
- 8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
- 9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

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

This third edition cancels and replaces the second edition published in 1999 and constitutes a technical revision.

The significant technical changes with respect to the previous edition are described in the introduction of this edition.

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

FDIS	Report on voting
20/684/FDIS	20/692/RVD

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

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

The committee has decided that the content of this publication will remain unchanged until 2008. At this date, the publication will be

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

Withdrawn

INTRODUCTION

This document is a major revision of IEC 60840, second edition, published in February 1999.

During the preparation of the second edition, a number of comments of principle were made on the CD and CDV and, at its meeting in February 1998, the former SC20A of TC20 agreed that these comments should be the basis of a major revision of IEC 60840 under the maintenance cycle. In addition, during the preparation of the new IEC 62067 covering cable systems above 150 kV up to 500 kV, it appeared that a number of comments were also applicable to IEC 60840. Therefore, all these comments were considered in the preparation of this third edition.

In addition, the following other aspects have been considered.

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 have suggested that a better discrimination be made between systems, cables and accessories, particularly for the lower voltages of the scope, e.g. 45 kV. This has been taken into account in this revision, which gives 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.

During the meeting of TC20 held in Stockholm in September 2000, it was agreed that WG16 consider the guidelines made by CIGRE for cables having a longitudinally applied metal foil, published in Electra n°141 in April 1992. WG16 carried out this task and, further to a survey on the experience with such cables, have concluded that only a part of these guidelines should be introduced in this standard as a normative annex.

Consideration has also been given to the recent work carried out by CIGRE on tests after installation on high voltage extruded insulation cables, the recommendations of which were published in Electra n°173 in August 1997. These recommendations state, among others, that d.c. tests should be avoided on the main insulation, as they are both ineffective and dangerous. On the other hand, d.c. tests are recommended on the oversheath.

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 International Standard specifies test methods and requirements for power cable systems for fixed installations, for rated voltages above 30 kV ($U_m = 36$ kV) up to and including 150 kV ($U_m = 170$ kV). It also separately covers cables and accessories.

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, for which modifications to the standard tests may be necessary or special test conditions may need to be devised.

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

2 Normative references

The following referenced documents are indispensable for the application 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 60060-1:1989, *High-voltage test techniques – Part 1: General definitions and test requirements*

IEC 60183:1984, *Guide to the selection of high-voltage cables*

IEC 60228:1978, *Conductors of insulated cables*

IEC 60229:1982, *Tests on cable oversheaths which have a special protective function and are applied by extrusion*

IEC 60230:1966, *Impulse tests on cables and their accessories*

IEC 60287-1-1:1994, *Electric cables – Calculation of the current rating – Part 1: Current rating equations (100 % load factor) and calculation of losses – Section 1: General*

IEC 60332-1:1993, *Tests on electric cables under fire conditions – Part 1: Test on a single vertical insulated wire or cable*

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

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

IEC 60811-1-3:1993, *Insulating and sheathing materials of electric cables – Common test methods – Part 1: General application – Section 3: Methods for determining the density – Water absorption tests – Shrinkage test*

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

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

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

IEC 60811-3-2:1985, *Common test methods for insulating and sheathing materials of electric cables – Part 3: Methods specific to PVC compounds – Section Two: Loss of mass test – Thermal stability test*

IEC 60811-4-1:1985, *Common test methods for insulating and sheathing materials of electric cables – Part 4: Methods specific to polyethylene and polypropylene compounds – Section One: Resistance to environmental stress cracking – Wrapping test after thermal ageing in air – Measurement of the melt flow index – Carbon black and/or mineral content measurement in PE*

IEC 60885-3:1988, *Electrical test methods for electric cables – Part 3: Test methods for partial discharge measurements on lengths of extruded power cables*

ISO 48:1994, *Rubber, vulcanized or thermoplastic – Determination of hardness (hardness between 10 IRHD and 100 IRHD)*

3 Definitions

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

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 Usually, in this standard, 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 the tests

3.2.1

routine tests

tests 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 tests

tests 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 tests

tests made before supplying on a general commercial basis a type of cable system or cable or accessory covered by this standard, in order to demonstrate satisfactory performance characteristics to meet the intended application. Once successfully completed, these tests need not be repeated, unless changes are made in the cable or accessory materials, or design or manufacturing process which might change the performance characteristics

3.2.4

electrical tests after installation

tests made to demonstrate the integrity of the cable system as installed

3.3

cable system

cable with installed accessories

3.4

nominal electrical stress

electrical stress calculated at U_0 using nominal dimensions

4 Voltage designations and materials

4.1 Rated voltages

In this standard, 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 materials

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

4.3 Cable oversheathing materials

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

- ST_1 and ST_2 based on polyvinyl chloride;
- ST_3 and ST_7 based on polyethylene.

The choice of the type of oversheath depends on the design of the cable and the mechanical and thermal constraints during installation and operation.

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

5 Precautions against water penetration in cables

When cable systems are installed in ground, easily flooded galleries or water, a radial water impermeable barrier around the cable is recommended.

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

Longitudinal water barriers may also be applied 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 12.4.18.

6 Cable characteristics

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

- a) Name of manufacturer, type, designation and manufacturing date or date code.
- b) Rated voltage: values shall be given for U_0 , U , U_m (see 4.1 and 8.4).
- c) Type of conductor, its material and nominal cross-sectional area, in square millimetres. If the nominal cross-sectional area is not in accordance with IEC 60228, the d.c. conductor resistance and the conductor construction shall be declared. Presence, if any, and nature of measures taken to achieve longitudinal watertightness.
- d) Material and nominal thickness of insulation (see 4.2). If the insulation is XLPE, special additives shall be declared if the higher value of $\tan \delta$ according to Table 3 is applicable.
- e) Type of manufacturing process for insulation system.
- f) Presence, if any, and nature of watertightness measures in the screening area.
- g) Material and construction of metallic screen, e.g. number and diameter of wires. The d.c. resistance of the metallic screen shall be declared. Material, construction and nominal thickness of metallic sheath, or longitudinally applied metal foil, if any.
- h) Material and nominal thickness of oversheath.
- i) Nominal diameter of the conductor (d).
- j) Nominal overall diameter of the cable (D).
- k) Inner and outer nominal diameters of the insulation.
- l) Nominal capacitance between conductor and metallic screen/sheath.

7 Accessory characteristics

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

- a) Cables used for testing accessories shall be correctly identified as in Clause 6.
- b) Conductor connections used within the accessories shall be correctly identified, where applicable, with respect to
 - assembly technique;
 - tooling, dies and necessary setting;
 - preparation of contact surfaces;

- type, reference number and any other identification of the connector;
 - details of the type test approval of the connector.
- c) 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 6 b) above);
 - installation instructions (reference and date).

8 Test conditions

8.1 Ambient temperature

Unless otherwise specified in the details for the particular test, tests shall be carried out at an ambient temperature of $(20 \pm 15) ^\circ\text{C}$.

8.2 Frequency and waveform of power frequency test voltages

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

8.3 Waveform of lightning impulse test voltages

In accordance with IEC 60230, the front time of the standard lightning impulse voltage shall be between $1 \mu\text{s}$ and $5 \mu\text{s}$. The time to half value shall be $50 \mu\text{s} \pm 10 \mu\text{s}$ as specified in IEC 60060-1.

8.4 Relationship of test voltages to rated voltages

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

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

The test voltages in this standard 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 on the main insulation of prefabricated accessories

9.1 General

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

- a) partial discharge test (see 9.2);
- b) voltage test (see 9.3);
- c) electrical test on oversheath of the cable, if required (see 9.4).

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

The main insulation of each prefabricated accessory shall undergo partial discharge (see 9.2) and voltage (see 9.3) tests 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 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 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.

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

9.2 Partial discharge test

The partial discharge test shall be carried out in accordance with IEC 60885-3 for cables, except that 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 metallic 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.

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 drum lengths of cable, taken to represent batches:

- a) conductor examination (see 10.4);
- b) measurement of electrical resistance of conductor and of metallic screen (see 10.5);
- c) measurement of thickness of insulation and oversheath (see 10.6);
- d) measurement of thickness of metallic 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) water penetration test, if applicable (see 12.4.18);
- j) tests on components of cables with a longitudinally applied metal foil (see 12.4.19).

10.2 Frequency of tests

The sample tests in items a) to h) 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 above 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 standard. If either fail, 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 metallic 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 metallic 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 metallic screen, conditioned for at least 1 h in a temperature-controlled liquid bath.

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

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

The d.c. resistance of the metallic 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 Clause 8 of IEC 60811-1-1.

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

10.6.2 Requirements for the insulation

The lowest measured thickness shall not fall below 90 % of the nominal thickness:

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

and additionally:

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

where

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

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

t_n is the nominal thickness, in millimetres.

NOTE $t_{\max}$ and $t_{\min}$ are measured at the same cross-section of the insulation.

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

10.6.3 Requirements for the cable oversheath

The lowest measured thickness shall not fall below 85 % of the nominal thickness by more than 0,1 mm:

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

where

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

t_n is the nominal thickness, in millimetres.

In addition, for oversheaths applied onto a substantially smooth surface, the average of the measured values rounded to 0,1 mm in accordance with Annex B shall 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 metallic screens of wires and/or tapes or corrugated metallic sheath.

10.7 Measurement of thickness of metallic sheath

The following tests apply if the cable has a metallic sheath of lead, lead alloy or aluminium.

10.7.1 Lead or lead alloy sheath

The minimum thickness of the sheath shall not fall below 95 % of the nominal thickness by more than 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.

10.7.1.1 Strip method

The measurement shall be made with a micrometer with plane faces of 4 mm to 8 mm diameter and an accuracy of $\pm 0,01$ 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.

10.7.1.2 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 $\pm 0,01$ 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.

10.7.2 Plain or corrugated aluminium sheath

The minimum thickness of the sheath shall not fall below 90 % of the nominal thickness by more than 0,1 mm for plain aluminium sheath:

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

and 85 % of the nominal thickness by more than 0,1 mm for corrugated 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 $\pm 0,01$ mm.

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

10.8 Measurement of diameter

If the purchaser requires that the diameter of the core and/or the overall diameter of the cable shall be measured, the measurements shall be carried out in accordance with 8.3 of IEC 60811-1-1.

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 Clause 9 of IEC 60811-2-1, 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 metallic screen/sheath.

The measured value shall not exceed the nominal value declared by the manufacturer by more than 8 %.

10.11 Measurement of density of HDPE insulation

10.11.1 Procedure

The density of HDPE shall be measured using the sampling and test procedure given in Clause 8 of IEC 60811-1-3.

10.11.2 Requirements

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

11 Sample tests on accessories

11.1 Tests on components

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 deviations 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 standard.

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 standard. If either fails, this type of accessory of the contract shall be regarded as having failed to comply.

12 Type tests on cable systems

The tests specified in this clause are intended to demonstrate the satisfactory performance of cable systems.

A summary of type tests on cable systems is given in Annex C.

NOTE Tests on terminations referring to environmental conditions are not specified in this standard.

12.1 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 standard with other cross-sections, rated voltages and constructions provided that all the following conditions are met:

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

NOTE In this context, cable systems of the same rated voltage group are those of rated voltages having a common value of U_m , highest voltage for equipment, and the same test voltage levels (see Table 4, columns 1 and 2). For example, tests on a cable system of rated voltage $U = 66$ kV would also cover cables systems of rated voltages $U = 60$ kV and $U = 69$ kV.

- b) the conductor cross-section is not larger than that of the tested cable;
- c) the cable and the accessories have the same or similar constructions as that of the tested cable system(s);

NOTE 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, e.g. for extension to three-core cables, 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 electrical stress at the conductor screen of the tested cable system(s) by more than 10 %;
- e) the calculated nominal electrical stress at the cable insulation screen does not exceed the electrical stress at the insulation screen of the tested cable system(s);
- f) 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 cable system(s).

The type tests on cable components (see 12.4) only need to be carried out on samples from cables of different voltage ratings and/or conductor cross-sectional areas if different materials are used to produce them and/or different manufacturing processes. However, repetition of the ageing tests on pieces of completed cable to check compatibility of materials (see 12.4.4) 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.

12.2 Summary of type tests

The type tests shall comprise the electrical tests on the complete cable system as specified in 12.3, and the appropriate non-electrical tests on cable components and completed cable specified in 12.4.

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

The tests listed in 12.3.2 shall be performed on one or more samples of completed 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 12.3.2, 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, e.g. there are no thermo-mechanical or compatibility effects, the protection need not be fitted.

Measurement of resistivity of semi-conducting screens described in 12.3.9 shall be made on a separate sample.

12.3 Electrical type tests on complete cable systems

12.3.1 Test voltage values

Prior to the electrical type tests, the insulation thickness of the cable shall be measured by the method specified in 8.1 of IEC 60811-1-1 on a representative piece of 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 thickness exceeding the nominal value by more than 15 %.

12.3.2 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 (see 12.3.3) followed by installation of the accessories and a partial discharge test at ambient temperature (see 12.3.4);

b) $\tan \delta$ measurement (see 12.3.5);

NOTE This test may be carried out on a different cable sample with special test terminations from that used for the remainder of the sequence of tests.

c) heating cycle voltage test (see 12.3.6);

d) partial discharge tests (see 12.3.4),

- at ambient temperature, and
- at high temperature.

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

e) lightning impulse voltage test followed by a power frequency voltage test (see 12.3.7);

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

g) tests of outer protection for buried joints (see Annex H);

NOTE 1 These tests may be applied to a joint which has passed test in item c), heating cycle voltage test, or to a separate joint which has undergone at least three thermal cycles (see Annex H).

NOTE 2 If the cable and joint are not to be subjected to wet conditions in service (i.e. not directly buried in earth or not intermittently or continuously immersed in water), the tests in item g) may be omitted.

h) examination of the cable system with cable and accessories on completion of the above tests (see 12.3.8).

The resistivity of the cable semi-conducting screens (see 12.3.9) shall be measured on a separate sample.

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

12.3.3 Bending test

The cable sample shall be bent around a test cylinder (for example, the hub of a 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 diameter of the test cylinder shall not be greater than:

- for cables with plain aluminium sheaths:
 - $36 (d + D) + 5 \%$ for single-core cables;
 - $25 (d + D) + 5 \%$ for three-core cables;
- for cables with lead, lead-alloy, corrugated metallic sheaths or with longitudinally applied metal foils (overlapped or welded) bonded to the oversheath:
 - $25 (d + D) + 5 \%$ for single-core cables;
 - $20 (d + D) + 5 \%$ for three-core cables;
- for other cables:
 - $20 (d + D) + 5 \%$ for single-core cables;
 - $15 (d + D) + 5 \%$ for three-core cables.

where

d is the nominal diameter of the conductor, in millimetres (see 6 i));

D is the nominal overall diameter of the cable, in millimetres (see 6 j)).

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

12.3.4 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 °C to 10 °C 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.

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

12.3.5 Tan δ measurement

The sample shall be heated by a suitable method and the temperature of the conductor determined either by measuring its resistance or by thermocouples on the surface of the screen/sheath, or by thermocouples 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 °C to 10 °C above the maximum conductor temperature in normal operation.

The tan δ shall then be measured at a power frequency voltage of U_0 at the temperature specified above.

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

12.3.6 Heating cycle voltage test

The cable shall have a U-bend with a diameter as specified in 12.3.3.

The assembly shall be heated by conductor current until the cable conductor reaches a steady temperature 5 °C to 10 °C above the maximum conductor temperature in normal operation.

NOTE 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 within 10 °C of the test ambient temperature. 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).

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

The test shall be performed on the assembly with the cable conductor temperature 5 °C to 10 °C above the maximum conductor temperature in normal operation.

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

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 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 4). 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.

12.3.8 Examination

12.3.8.1 Systems and accessories

Examination of the cable and, whenever possible, of the accessories, with normal or corrected vision without magnification, shall reveal no signs of deterioration (e.g. electrical degradation, leakage, corrosion or harmful shrinkage) which could affect the system in service operation.

12.3.8.2 Cables with a longitudinally applied metal foil

A 1 m sample shall be taken from the cable length and subjected to the tests in 12.4.19.

12.3.9 Resistivity of semi-conducting screens

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

The resistivity of extruded semi-conducting screens applied over the conductor and over the insulation shall be determined by measurements on test pieces taken from the core of a sample of cable as manufactured and a sample of cable which has been subjected to the ageing treatment to test the compatibility of component materials specified in 12.4.4.

12.3.9.1 Procedure

The test procedure shall be in accordance with Annex D.

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

12.3.9.2 Requirements

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

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

12.4 Non-electrical type tests on cable components and on completed cable

The tests are as follows:

- a) check of cable construction (see 12.4.1);
- b) tests for determining the mechanical properties of insulation before and after ageing (see 12.4.2);
- c) tests for determining the mechanical properties of oversheaths before and after ageing (see 12.4.3);
- d) ageing tests on pieces of complete cable to check compatibility of materials (see 12.4.4);
- e) loss of mass test on PVC oversheaths of type ST₂ (see 12.4.5);
- f) pressure test at high temperature on oversheaths (see 12.4.6);
- g) tests on PVC oversheaths (ST₁ and ST₂) at low temperature (see 12.4.7);
- h) heat shock test for PVC oversheaths (ST₁ and ST₂) (see 12.4.8);
- i) ozone resistance test for EPR and HEPR insulations (see 12.4.9);
- j) hot set test for EPR, HEPR and XLPE insulations (see 12.4.10);
- k) measurement of density of HDPE insulation (see 12.4.11);
- l) measurement of carbon black content of black PE oversheaths (ST₃ and ST₇, see 12.4.12);
- m) shrinkage test for PE, HDPE and XLPE insulations (see 12.4.13);
- n) shrinkage test for PE oversheaths (ST₃ and ST₇, see 12.4.14);
- o) determination of hardness of HEPR insulation (see 12.4.15);
- p) determination of the elastic modulus of HEPR insulation (see 12.4.16);
- q) test under fire conditions (see 12.4.17);
- r) water penetration test (see 12.4.18);
- s) tests on components of cables with a longitudinally applied metal foil (see 12.4.19).

12.4.1 Check of cable construction

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

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

12.4.2.1 Sampling

Sampling and preparation of test pieces shall be carried out in accordance with 9.1 of IEC 60811-1-1.

12.4.2.2 Ageing treatment

The ageing treatment shall be carried out in accordance with 8.1 of IEC 60811-1-2 under the conditions specified in Table 6.

12.4.2.3 Conditioning and mechanical tests

Conditioning and the measurement of mechanical properties shall be carried out in accordance with 9.1 of IEC 60811-1-1.

12.4.2.4 Requirements

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

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

12.4.3.1 Sampling

Sampling and preparation of test pieces shall be carried out in accordance with 9.2 of IEC 60811-1-1.

12.4.3.2 Ageing treatment

The ageing treatment shall be carried out in accordance with 8.1 of IEC 60811-1-2 under the conditions given in Table 7.

12.4.3.3 Conditioning and mechanical tests

Conditioning and the measurement of mechanical properties shall be carried out in accordance with 9.2 of IEC 60811-1-1.

12.4.3.4 Requirements

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

12.4.4 Ageing tests on pieces of completed cable to check compatibility of materials

12.4.4.1 General

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

The test is applicable to cables of all types.

12.4.4.2 Sampling

Samples for the test on insulation and oversheath shall be taken from the completed cable as described in 8.1.4 of IEC 60811-1-2.

12.4.4.3 Ageing treatment

The ageing treatment of the pieces of cable shall be carried out in an air oven, as described in 8.1.4 of IEC 60811-1-2, under the following conditions:

- temperature: $(10 \pm 2) ^\circ\text{C}$ above the maximum conductor temperature of the cable in normal operation (see Table 1);
- duration: 7×24 h.

12.4.4.4 Mechanical tests

Test pieces of insulation and oversheath from the aged pieces of cable shall be prepared and subjected to mechanical tests as described in 8.1.4 of IEC 60811-1-2.

12.4.4.5 Requirements

The variations between the median values of tensile strength and elongation at break after ageing and the corresponding values obtained without ageing (see 12.4.2 and 12.4.3) 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.

12.4.5 Loss of mass test on PVC oversheaths of type ST₂

12.4.5.1 Procedure

The loss of mass test for ST₂ oversheaths shall be carried out as described in 8.2 of IEC 60811-3-2 under the conditions given in Table 9.

12.4.5.2 Requirements

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

12.4.6 Pressure test at high temperature on oversheaths

12.4.6.1 Procedure

The pressure test at high temperature for ST₁, ST₂ and ST₇ oversheaths shall be carried out as described in 8.2 of IEC 60811-3-1, employing the test conditions given in the test method and in Table 7.

12.4.6.2 Requirements

The results shall comply with the requirements given in 8.2 of IEC 60811-3-1.

12.4.7 Test on PVC oversheaths (ST₁ and ST₂) at low temperature

12.4.7.1 Procedure

The test at low temperature for ST₁ and ST₂ oversheaths shall be carried out as described in Clause 8 of IEC 60811-1-4, employing the test temperature given in Table 9.

12.4.7.2 Requirements

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

12.4.8 Heat shock test for PVC oversheaths (ST₁ and ST₂)

12.4.8.1 Procedure

The heat shock test on ST₁ and ST₂ oversheaths shall be carried out as described in 9.2 of IEC 60811-3-1, the test temperature and duration being in accordance with Table 9.

12.4.8.2 Requirements

The results of the test shall comply with the requirements given in 9.2 of IEC 60811-3-1.

12.4.9 Ozone resistance test for EPR and HEPR insulations

12.4.9.1 Procedure

EPR and HEPR insulations shall be tested for resistance to ozone using the sampling and test procedure described in Clause 8 of IEC 60811-2-1. The ozone concentration and test duration shall be in accordance with Table 8.

12.4.9.2 Requirements

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

12.4.10 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.

12.4.11 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.

12.4.12 Measurement of carbon black content of black PE oversheaths (ST₃ and ST₇)

12.4.12.1 Procedure

The carbon black content of ST₃ and ST₇ oversheaths shall be measured using the sampling and test procedure described in Clause 11 of IEC 60811-4-1.

12.4.12.2 Requirements

The nominal value of the carbon black content shall be 2,5 %, with a tolerance of $\pm 0,5$ %.

12.4.13 Shrinkage test for PE, HDPE and XLPE insulations

12.4.13.1 Procedure

The shrinkage test shall be carried out on insulations of PE, HDPE or XLPE using the sampling and test procedure described in Clause 10 of IEC 60811-1-3 and the conditions specified in Table 8.

12.4.13.2 Requirements

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

12.4.14 Shrinkage test for PE oversheaths (ST₃ and ST₇)

12.4.14.1 Procedure

The shrinkage test shall be carried out on PE oversheaths using the sampling and test procedure described in Clause 11 of IEC 60811-1-3 under the following conditions:

- temperature: $(80 \pm 2) ^\circ\text{C}$
- duration of heating: 5 h
- number of heating cycles: 5

12.4.14.2 Requirements

The shrinkage shall not exceed 3 %.

12.4.15 Determination of hardness of HEPR insulation

12.4.15.1 Procedure

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

12.4.15.2 Requirements

The results of the test shall comply with Table 8.

12.4.16 Determination of the elastic modulus of HEPR insulation

12.4.16.1 Procedure

Sampling, preparation of the test pieces and the test procedure shall be carried out in accordance with Clause 9 of IEC 60811-1-1.

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 moduli at 150 % elongation.

The elastic modulus shall be the median value.

12.4.16.2 Requirements

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

12.4.17 Test under fire conditions

The test under fire conditions in accordance with IEC 60332-1 shall be carried out on a sample of completed cable, if it has an ST₁ or ST₂ oversheath and if the manufacturer wishes to claim that the particular design of cable complies with the requirements.

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

12.4.18 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 6 c) and 6 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 apparatus, sampling, test procedure and requirements shall be in accordance with Annex F.

For cables with a longitudinally applied metal foil, a 1 m sample shall be taken from the cable length and subjected to the tests in 12.4.19.

12.4.19 Tests on components of cables with a longitudinally applied metal foil

A 1 m sample shall be taken from the completed cable and subjected to the following tests:

- a) visual examination (see Clause G.1);
- b) adhesion strength of metal foil (see Clause G.2);
- c) peel strength of overlapped metal foil (see Clause G.3).

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

13 Type tests on cables

The tests specified in this clause are intended to demonstrate the satisfactory performance of cables alone.

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

13.1 Range of type approval

When type tests have been successfully performed on 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 cables within the scope of this standard with other cross-sections, rated voltages and constructions, provided that all the following conditions are met:

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

NOTE In this context, cables of the same rated voltage group are those of rated voltages having a common value of U_m , highest voltage for equipment, and the same test voltage levels (see Table 4, columns 1 and 2). For example, tests on a cable of rated voltage $U = 66$ kV would also cover cables of rated voltages $U = 60$ kV and $U = 69$ kV.

- 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);

NOTE 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 difference 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, e.g. for extension to three-core cables, 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 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 electrical stress at the insulation screen of the tested cable(s).

The type tests on cable components (see 12.4) only need to be carried out on samples from cables of different voltage ratings and/or conductor cross-sectional areas if different materials are used to produce them and/or different manufacturing processes. However, repetition of the ageing tests on pieces of completed cables to check compatibility of materials (see 12.4.4) 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 laboratory, shall be acceptable as evidence of type testing.

13.2 Summary of type tests

The type tests shall comprise the electrical tests on the completed cable, as specified in 12.3.1 and 13.3, and the appropriate non-electrical tests on cable components and complete cable, as specified in 12.4.

The non-electrical tests on cable components and on completed cable are summarized in Table 5, indicating which tests are applicable to each insulating and oversheathing material. The test under fire conditions is only required if the manufacturer wishes to claim compliance with this test as a special feature of the design of the cable.

13.3 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 12.3.3) followed by installation of the test terminations and a partial discharge test (see 12.3.4);
- b) $\tan \delta$ measurement (see 12.3.5);

NOTE This test may be carried out on a different sample from that used for the remainder of the sequence of tests.

- c) heating cycle voltage test (see 12.3.6), followed by partial discharge measurement at ambient temperature (see 12.3.4), 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 12.3.7);
- e) partial discharge test at ambient temperature (see 12.3.4), if not previously carried out in c) above;
- f) examination of the cable on completion of the above tests (see 12.3.8).

The resistivity of semi-conducting screens (see 12.3.9) shall be measured on a separate sample.

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

14 Type tests on accessories

The tests specified in this clause are intended to demonstrate the satisfactory performance of accessories alone.

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

NOTE Tests on terminations referring to environmental conditions are not specified in this standard.

14.1 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 standard with other rated voltages, constructions and with other cables, provided that all the following conditions are met:

- a) the voltage group is not higher than that of the tested accessory(ies);

NOTE In this context, accessories of the same rated voltage group are those of rated voltages having a common value of U_m , highest voltage for equipment, and the same test voltage levels (see Table 4, columns 1 and 2). For example, tests on an accessory of rated voltage $U = 66$ kV would also cover accessories of rated voltages $U = 60$ kV and $U = 69$ kV.

- b) the cable with another conductor cross-section, rated voltage and construction is within the range of type approval as stated in 13.1. When the calculated nominal electrical stress at the cable insulation screen does not exceed 2,5 kV/mm, the type approval shall be considered as valid for accessories on all cables in this range;

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

NOTE 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).

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.

14.2 Summary of type tests

Accessories shall comply with the tests specified in 14.3.1 and 14.3.2.

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 14.3.2, 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, e.g. there are no thermo-mechanical or compatibility effects, the protection need not be fitted.

14.3 Electrical type tests on accessories

14.3.1 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 voltages values adjusted, if necessary, as stated in 12.3.1.

14.3.2 Tests and sequence of tests

Accessories shall be subjected to the following sequence:

- a) partial discharge test at ambient temperature (see 12.3.4);
- b) heating cycle voltage test (see 12.3.6);

NOTE The cable may have a U-bend with the diameter as specified in 12.3.3.

- c) partial discharge tests (see 12.3.4)
 - at ambient temperature, and
 - at high temperature.

The tests shall be carried out after the final cycle of item b) above or, alternatively, after the lightning impulse voltage test in item d) below;

- d) lightning impulse voltage test followed by a power frequency voltage test (see 12.3.7);
- e) partial discharge tests, if not previously carried out in item c) above;
- f) tests of outer protection for buried joints (see Annex H);

NOTE 1 These tests may be applied to a joint which has passed the test in item b), heating cycle voltage test, or to a separate joint which has passed at least three thermal cycles (see Annex H).

NOTE 2 If the joint is not to be subjected to wet conditions in service (i.e. not directly buried in earth or not intermittently or continuously immersed in water), the tests in item f) may be omitted.

- g) examination of the accessories after completion of the above tests (see 12.3.8.1).

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

15 Electrical tests after installation

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

A d.c. oversheath test according to 15.1 and/or an a.c. insulation test according to 15.2 is recommended. For installations where only the oversheath test according to 15.1 is carried out, quality assurance procedures during installation of accessories may, by agreement between the purchaser and contractor, replace the insulation test.

15.1 DC voltage test of the oversheath

The voltage level and duration specified in Clause 5 of IEC 60229 shall be applied between each metal sheath or metallic screen 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.

15.2 AC voltage test of the insulation

The a.c. test voltage to be applied shall be 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. A voltage according to Table 4, column 9, shall be applied for 1 h.

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

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

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 ¹⁾
High density thermoplastic polyethylene (HDPE)	80	160 ¹⁾
Cross-linked polyethylene (XLPE)	90	250
Ethylene-propylene rubber (EPR)	90	250
High modulus or hard grade ethylene-propylene rubber (HEPR)	90	250
¹⁾ For PE and HDPE, short-circuit temperatures up to 20 °C in excess of those shown may be acceptable with suitable semi-conducting layers 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	ST ₃	80
	ST ₇	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 ¹⁾
1) For cables produced with an XLPE compound containing special additives, the maximum tan δ is 50 × 10 ⁻⁴ .					

Table 4 – Test voltages

1	2	3	4 ¹⁾	5 ¹⁾	6 ¹⁾	7 ¹⁾	8 ¹⁾	9
Rated voltage	Highest voltage for equipment	Value of U_0 for determination of test voltages	Voltage test of 9.3 and 12.3.7	Partial discharge test of 9.2 and 12.3.4	Tan δ measurement of 12.3.5	Heating cycle voltage test of 12.3.6	Lightning impulse voltage test of 12.3.7	Voltage test after installation of 15.2
U	U_m	U_0	$2,5 U_0$	$1,5 U_0$	U_0	$2 U_0$		
kV	kV	kV	kV	kV	kV	kV	kV	kV
45 to 47	52	26	65	39	26	52	250	52
60 to 69	72,5	36	90	54	36	72	325	72
110 to 115	123	64	160	96	64	128	550	128
132 to 138	145	76	190	114	76	152	650	132
150 to 161	170	87	218	131	87	174	750	150
1) If necessary, these test voltages shall be adjusted as stated in 12.3.1.								