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Low-frequency cables and wires with PVC insulation and PVC sheath – Part 1: General test and measuring methods

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IEC Central Office
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

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LOW-FREQUENCY CABLES AND WIRES WITH PVC INSULATION AND PVC SHEATH –

Part 1: General test and measuring methods

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 60189-1 has been prepared by subcommittee 46C: Wires and symmetric cables, of IEC technical committee 46: Cables, wires, waveguides, RF connectors, RF and microwave passive components and accessories.

This fourth edition cancels and replaces the third edition published in 2007. This edition constitutes a technical revision. This edition includes the following significant technical changes with respect to the previous edition:

a) Test methods for dielectric strength and insulation resistance that were referenced in the previous edition have been withdrawn. They have been replaced with references to similar test methods described in current standards.
b) References to the IEC 60811 series have been updated as the numbering of this series has completely been changed.

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

FDIS	Report on voting
46C/1099/FDIS	46C/1100/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.

A list of all the parts in the IEC 60189 series, under the general title *Low-frequency cables and wires with PVC insulation and PVC sheath*, can be found on the IEC website.

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.

A bilingual version of this publication may be issued at a later date.

LOW-FREQUENCY CABLES AND WIRES WITH PVC INSULATION AND PVC SHEATH –

Part 1: General test and measuring methods

1 Scope

This part of IEC 60189 specifies mechanical, electrical and climatic test methods for low-frequency cables and wires designed for use in telecommunication inside plants and equipment and in electronic devices employing similar techniques.

NOTE The other parts of IEC 60189 describe the construction and characteristics of each type of cable and wire.

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 60068 (all parts), *Environmental testing*

IEC 60068-2-20:1979[1], *Basic environmental testing procedures – Part 2: Tests – Test T: Soldering*

IEC 60227-2:1997, *Polyvinyl chloride insulated cables of rated voltages up to and including 450/750 V – Part 2: Test methods*

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

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

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

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

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

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1 This fourth edition was replaced in 2008 by a fifth edition *Environmental testing – Part 2-20: Tests – Test T: Test methods for solderability and resistance to soldering heat of devices with leads.*

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

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

IEC 60811-504, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 504: Mechanical tests – Bending tests at low temperature for insulation and sheaths*

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

IEC 60811-509, *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)*

ISO 6892-1, *Metallic materials – Tensile testing – Part 1: Method of test at room temperature*

EN 50289-1-5, *Communication cables – Specifications for test methods – Part 1-5: Electrical test methods – Capacitance.SEC5:Capacitance*

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
conductor
part of the cable or wire intended to carry electric current

Note 1 to entry: The conductor may be

a) solid – made of a single strand of circular cross-section;

b) stranded – made of several strands of circular cross-section assembled either by laying up concentrically or by bunching, and without insulation between them.

3.2
low-frequency wire
insulated conductor or assembly of several insulated conductors, laid up together and which may be provided with a screen

Note 1 to entry: The wire may be

a) single – consists of a single insulated conductor;

b) multiple – consists of several insulated conductors.

Note 2 to entry: The following designations are used:

pair – for multiple wire with two conductors;

triple – for multiple wire with three conductors;

quad – for multiple wire with four conductors;

quintuple – for multiple wire with five conductors.

3.3
low-frequency cables – sheathed cable
assembly of insulated conductors enclosed in a common continuous protective covering

4 Standard conditions for testing

Unless otherwise specified, all tests shall be carried out under the conditions specified in IEC 60068.

Unless otherwise specified, tests shall be made at room temperature.

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

5 Dimensions

5.1 Selection and preparation of samples

5.1.1 Insulation

Samples of insulated conductors, approximately 100 mm in length, shall be taken at both ends of the cable or wire.

One sample shall be taken at each end. Any covering(s) shall be removed from the insulation and the conductor withdrawn, care being taken not to damage the insulation. Each test piece shall consist of a thin slice of insulation. The slice shall be cut with a suitable device along a plane perpendicular to the longitudinal axis of the conductor.

5.1.2 Sheath

Samples, approximately 100 mm in length, shall be taken from the finished cable at both ends.

One sample shall be taken at each end. The insulated conductors binding tapes and screening, if any, shall then be removed from the sheath, and each test piece shall be prepared by cutting with a suitable device a thin slice along a plane perpendicular to the axis of the cable. If necessary, the planes of the cuts shall be carefully smoothed.

If not specified differently by the respective detail specification, the following rules shall apply. If a marking is stamped into the sheath, thus giving rise to a local reduction of thickness, the test piece shall be taken so as to include such marking. The test piece shall not include such a reduction of thickness if it is made by the rip cord.

5.1.3 Finished cable or wire

Samples of finished cable or wire, approximately 100 mm in length, shall be taken at both ends. One sample shall be taken at each end.

5.2 Measurement of dimensions

5.2.1 Minimum thickness of insulation or sheath

5.2.1.1 Insulation

Both samples (one at each end) shall be measured. Each test piece shall be placed under the measuring equipment with the plane of the cut perpendicular to the optical axis.

Each test piece shall be measured with equipment in accordance with IEC 60811-201.

The readings shall be made, in millimetres, to two decimal places, if the thickness of insulation is 0,5 mm or above, and to three estimated decimal places, if the thickness of insulation is less than 0,5 mm.

The minimum thickness shall be found and measured.

Alternative test methods may be used, provided that they give equivalent results.

5.2.1.2 Sheath

Both samples (one at each end) shall be measured. Each test piece shall be placed under the measuring equipment with the plane of the cut perpendicular to the optical axis.

Each test piece shall be measured with equipment in accordance with IEC 60811-202.

A micrometer applying a pressure of between 50 kPa and 80 kPa can also be used for measurement of samples of the sheath.

The readings shall be made in millimetres to two decimal places.

The minimum thickness shall be found and measured.

Alternative test methods may be used, provided that they give equivalent results.

5.2.2 Mean thickness of insulation or sheath

Each test piece shall be placed under the measuring equipment with the plane of the cut perpendicular to the optical axis.

Six measurements shall be made radially, as far as possible equally spaced around the circumference.

When the insulation is taken from a stranded conductor, six measurements shall be made radially in the positions where the insulation is thinnest, i.e. between the ridges caused by strands.

In all cases, the first measurement shall be made at the place where the insulation is thinnest.

The readings shall be made, in millimetres, to two decimal places, if the thickness of insulation is 0,5 mm or above, and to three estimated decimal places, if the thickness of insulation is less than 0,5 mm.

In the case of mechanical tests, the mean value of thickness of each test piece shall be calculated from the six measurement results obtained on that test piece.

5.2.3 Diameter of finished cable or wire

Both samples (one at each end) shall be measured.

Measurements shall be made in accordance with the method specified in IEC 60811-203.

6 Mechanical tests

6.1 Selection, marking and preparation of samples for tensile tests

6.1.1 Conductors

Solid conductors only shall be subjected to the tensile tests. Samples of convenient length shall be taken at the end of the cable or wire.

6.1.2 Insulation

6.1.2.1 General

These tests are to determine the tensile strength and elongation at break of the insulating material in the condition as manufactured (i.e. without any ageing) and, when required, after accelerated ageing treatment.

When the ageing treatment is to be carried out on prepared test pieces of the insulation (in accordance with 7.1), the test pieces for treatment shall be taken from positions adjacent to the test pieces used for the test without ageing and the tensile tests on the aged and unaged test piece shall be made in immediate succession.

6.1.2.2 Sampling

A sample of the insulated conductor shall be taken to provide a minimum of five test pieces each for the tensile tests without ageing and the tensile tests after each of the required ageing treatments. Any sample that shows signs of mechanical damage shall not be used for the tests.

6.1.2.3 Preparation of test pieces

The samples of insulation shall be cut into pieces approximately 100 mm long and the conductor and any outer coverings removed, care being taken not to damage the insulation. The tubes shall be marked to identify the sample from which they were prepared and their relative positions in the sample.

The central 20 mm shall be marked by two lines immediately before the tensile test.

6.1.3 Sheath

6.1.3.1 General

These tests are to determine the tensile strength and elongation-at-break of the sheathing material of the cable in the condition as manufactured and, when required, after one or more accelerated ageing treatment(s).

When the ageing treatment is to be carried out on prepared test pieces (in accordance with 7.1), the test pieces for treatment shall be taken from positions adjacent to the test pieces used for the test without ageing, and the tensile tests on the treated and untreated test pieces shall be made in immediate succession.

6.1.3.2 Sampling

A sample of the cable to be tested, or of the sheath removed from the cable, shall be taken of sufficient size to provide a minimum of five test pieces for the tensile tests without ageing and the required number of test pieces for each of the tensile tests after ageing specified for the sheathing material in the relevant cable standard. Any sample that shows signs of mechanical damage shall not be used for tests.

6.1.3.3 Preparation of test pieces

Test pieces shall be prepared from the samples of sheath, dumb-bell test pieces being used whenever possible.

Each sample of sheath shall be cut into pieces of sufficient size for the test and the pieces marked to identify the sample from which they are cut and their position relative to each other in the original sheath.

The pieces of sheath shall be ground or cut, so as to obtain two parallel surfaces between the marker lines mentioned below, care being taken to avoid undue heating. After grinding or cutting, the thickness of the pieces shall be not less than 0,6 mm and not more than 2,0 mm.

A dumb-bell test piece in accordance with Figure 1 shall then be punched from each prepared piece of sheath or if possible two dumb-bell test pieces shall be punched side by side.

Dimensions in millimetres

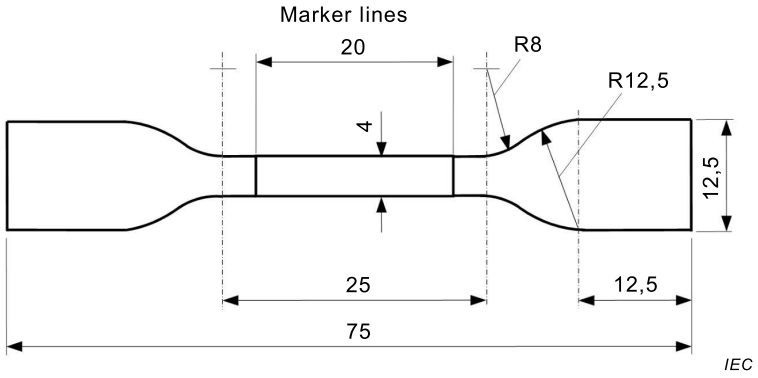

Figure 1 – Dumb-bell test piece

When the diameter of the core is too small to allow the dumb-bell in accordance with Figure 1 to be used, then a smaller dumb-bell test piece in accordance with Figure 2 shall be punched from each prepared piece of sheath.

Dimensions in millimetres

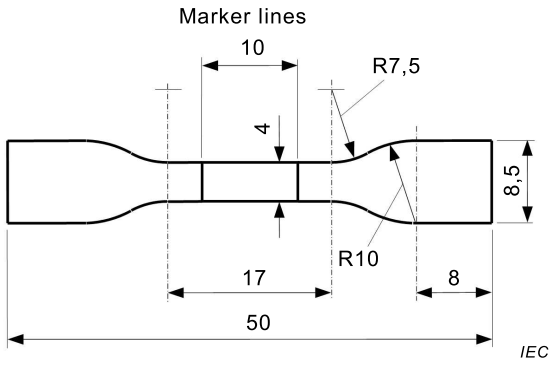

Figure 2 – Small dumb-bell test piece

The central 20 mm for the larger dumb-bells, or 10 mm for the smaller dumb-bells, shall be marked by two lines on each test piece, as shown in Figures 1 and 2, immediately before the tensile tests. Tubular test pieces shall be used only when the sheath is of such small size that it is not possible to prepare dumb-bell test pieces. The tubular test pieces shall be prepared from samples of sheath in the same way as specified for insulation in 6.1.2.3.

6.2 Measurement of cross-sectional area for tensile test

6.2.1 General

The cross-sectional area of the samples shall be determined by one or other of the methods described below.

In the case of the samples to be subjected to accelerated ageing, the dimensions used for the calculation of cross-sectional area shall be measured before ageing.

6.2.2 Insulation

The cross-sectional area of tubular test pieces shall be determined in accordance with the method specified in IEC 60811-501.

6.2.3 Sheath

The cross-sectional area of each test piece shall be determined in accordance with the method specified in IEC 60811-501.

6.3 Tensile test

6.3.1 Conditioning of test pieces

Before the tensile test, all test pieces aged and unaged shall be kept for at least 3 h at a temperature of 23 °C ± 5 °C, except for insulation and sheath, which shall be kept at 23 °C ± 2 °C.

6.3.2 Tensile testing procedure

a) Conductor

The tensile testing of solid conductors shall be carried out in accordance with the method specified in ISO 6892-1 and the rate of separation of jaws shall be 100 mm/min ± 20 mm/min.

b) Insulation and sheath

The test shall be made in accordance with the method specified in IEC 60811-501.

6.3.3 Expression of results

The value of the breaking load and the elongation at break shall be calculated in accordance with IEC 60811-501.

6.4 Stripping properties of insulation

6.4.1 General

The object of this test is to determine the extent to which the insulation can be easily stripped from the conductor.

Therefore, five samples of insulated conductors approximately 300 mm in length shall be taken at each end of the cable or wire.

6.4.2 Test method

Over a length AB of about 25 mm from one end of the samples, the insulation shall be cleanly cut and carefully stripped from the conductor (see Figure 3).

Dimensions in millimetres

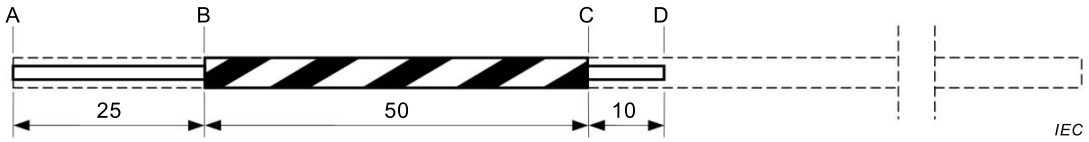

Figure 3 – Stripping properties of insulation

The insulation shall be cleanly cut at right angles to its longitudinal axis.

The sample shall then be cut at D and the insulation at C, about 85 mm and 75 mm respectively from the stripped end in the case of solid conductors, or at about 55 mm and 45 mm respectively from the stripped end in the case of stranded conductors. This leaves a length of 50 mm of undisturbed insulation in the case of solid conductors and of 20 mm in the case of stranded conductors. The insulation between C and D shall be stripped from the conductor, care being taken neither to displace the remaining part of the insulation nor to damage the conductor.

Cutting the sample at D shall be carried out preferably by means of normal cutting pliers suitably sharpened so as to avoid any burring of the metal at the cut point.

The sample is then placed in the test apparatus similar to that shown in Figure 4.

Dimensions in millimetres

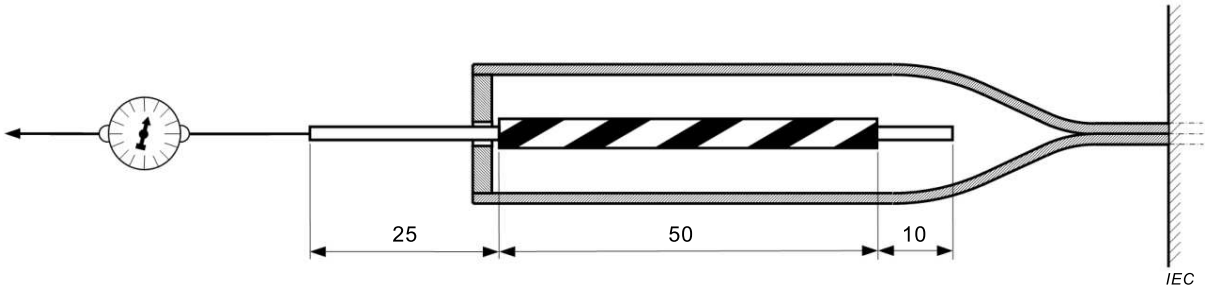

Figure 4 – Position of the sample in the text apparatus

The metal plate is provided with a round hole which is 10 % greater than the nominal diameter of the conductor.

The force necessary to start the sliding of the insulation over the conductor shall be measured, the force being exerted on the conductor. The speed of the tensile machine shall be between 250 mm/min and 350 mm/min.

7 Thermal stability and climatic tests

7.1 Accelerated ageing

The object of accelerated ageing is to condition the sample of insulation and sheath so that they are brought rapidly to a state normally reached after a long time.

The accelerated ageing test shall be carried out in accordance with the method specified in IEC 60811-401 at an ageing temperature of 80 °C for a period of 7 h × 24 h.

For routine tests, a higher number of air changes than in the specified method is permitted.

7.2 Pressure test at high temperature

The object of this test is to determine the extent to which the cable sheath can withstand deformation when the cable subjected to moderately high temperatures undergoes mechanical pressure.

The pressure test shall be carried out in accordance with the method specified in IEC 60811-508 at a temperature of 80 °C.

7.3 Resistance to flame propagation

7.3.1 General

The object of this test is to determine the resistance to flame propagation of a cable or wire.

7.3.2 Wires

The test shall be carried out in accordance with the method specified in IEC 60332-2-2.

7.3.3 Cables

The test shall be carried out in accordance with the methods specified in IEC 60332-1-2 or IEC 60332-2-2.

7.4 Cold bend test

7.4.1 General

The object of this test is to determine the extent to which the cable or wire may be used after exposure to low temperature.

7.4.2 Insulation

Each wire to be tested shall be represented by two samples of suitable length taken from places separated by at least 1 m.

The cold bend test shall be carried out in accordance with the method specified in IEC 60811-504.

7.4.3 Sheath

Each sheath to be tested shall be represented by two pieces of completed cable of suitable length taken from places separated by at least 1 m.

The cold bend test shall be carried out in accordance with the method specified in IEC 60811-504.

The test temperature shall be given in the relevant specification.

7.5 Heat shock test

7.5.1 General

The object of this test is to determine the extent to which the insulation or the sheath withstands variations in temperature without sustaining damage.

7.5.2 Insulation

The heat shock test for insulation shall be carried out in accordance with the method specified in IEC 60811-509, except that each sample shall be wound helically for three complete

contiguous turns around a mandrel of diameter having a value, rounded off to the nearest whole diameter, of three times the mean overall diameter of the insulated conductor.

7.5.3 Sheath

The heat shock test for sheaths shall be carried out in accordance with the method specified in IEC 60811-509, except that each sample shall be a strip 4 mm wide cut from the sheath in the direction of the axis of the cable. The samples shall be wound helically for six complete contiguous turns round a mandrel of diameter as specified in Table 1.

Table 1 – Mandrel diameter according to mean thickness of sheath

Mean thickness of sheath mm	Mandrel diameter mm
Up to and including 1	5
≥ 1	10

7.6 Measurement of insulation shrinkage after overheating of conductor

The object of this test is to check the extent to which the insulation shrinks after overheating of the conductor.

The test shall be carried out in accordance with the method specified in IEC 60811-502. For wire of less than 1,5 mm diameter, the test sample shall be 100 mm ± 5 mm long with cleanly cut ends (without stripped ends).

Each test piece shall be heated at a temperature of 100 °C ± 2 °C for 1 h.

7.7 Combined shrinkage and heat shock test

This test only applies to insulations with an outer diameter less than 1,5 mm.

For routine tests, the combined test specified hereunder is accepted as an alternative to the group shrinkage test and the heat shock test. The two tests specified in 7.5 and 7.6 shall be considered as reference tests.

The object of this test is to determine the extent to which the insulation shrinks or withstands damage with variations in temperature. The test shall be carried out in accordance with the method specified in IEC 60811-509, except that each sample shall be wound helically for three complete contiguous turns around a mandrel of diameter having a value rounded off to the nearest whole millimetre of three times the mean overall diameter of the insulated conductor.

Also, the ends which shall be cleanly cut (without stripped ends) shall extend at right angles to the mandrel in opposite directions for a length of 50 mm.

The amount of shrinkage of the insulation from the conductor ends shall be measured and shall be recorded as a percentage of the tail length (50 mm).

7.8 Solder test on tinned conductors

For special applications, compliance shall be checked by the solder globule method specified in 4.8 of IEC 60068-2-20:1979.

This method applies when specified in the relevant specification.

Non-activated flux shall be used.

8 Electrical tests

8.1 Electrical resistance of conductors

The electrical resistance shall be measured on the finished cable or wire by means of a device capable of measuring accurately to within 0,5 % of the value to be determined.

The measured value, corrected proportionately to the length and expressed in ohm/kilometre, shall be referred to the standard temperature of 20 °C.

For copper conductors, the resistance shall be corrected to the standard temperature by multiplying the measured value by the factor k as follows:

$$k = \frac{1}{1 + 0{,}003\ 93(t - 20)}$$

where

t is the temperature in °C at which the measurement is made.

To correct the value proportionally to the length, the measured resistance shall be multiplied by the factor $(1/L)$, where L is the length of the cable in kilometres.

8.2 Dielectric strength

8.2.1 General

This test shall be carried out before the measurement of insulation resistance described in 8.3.

The dielectric strength of the insulation shall be checked on the finished cable or on a sample of wire. The test voltage may be either DC or AC. In the latter case, the waveform shall be approximately sinusoidal. The frequency shall be between 40 Hz and 60 Hz, and the voltage to be taken into consideration shall be expressed as an RMS value.

The value of the test voltage and the duration of application are specified in the relevant cable specifications.

A protective resistance of adequately high value shall be connected in the circuit supplying the test voltage to the sample under test.

8.2.2 Wires

a) Unscreened wires

The voltage test shall be carried out in accordance with the method specified in 2.3 of IEC 60227-2:1997.

b) Screened wires

The voltage test shall be carried out in accordance with the method specified in 2.2 of IEC 60227-2:1997.

8.2.3 Cables

The test shall be carried out on complete lengths of the finished cable in accordance with the method specified in IEC 60227-2.

The voltage shall be applied gradually at a rate not exceeding 1 kV/s and consecutively between any conductor and all others plus the screen, if any, connected to earth.

The full voltage shall be maintained for the specified period.

8.3 Insulation resistance

8.3.1 General

This measurement shall be made after the dielectric strength test described in 8.2. The insulation resistance shall be measured on the finished cable or on a sample of wire by means of a device capable of measuring to within 10 % of the value to be determined.

8.3.2 Wires

a) Unscreened wires

The insulation resistance test shall be carried out in accordance with the method specified in 2.4 of IEC 60227-2:1997.

b) Screened wires

The insulation resistance test shall be carried out in accordance with the method specified in 2.4 of IEC 60227-2:1997.

8.3.3 Cables

The measurement shall be carried out on complete lengths of the finished cable.

The insulation resistance shall be measured after a one-minute application of the test voltage between each conductor and all others plus the screen, if any, connected to earth.

The test shall be carried out at a minimum of 1 km in length. The test temperature shall be recorded.

8.4 Mutual capacitance

The mutual capacitance shall be measured on the finished cable by means of a device capable of measuring accurately to within 1 % of the value to be determined.

The measurement shall be carried out with alternating current at a frequency between 500 Hz and 2 000 Hz. If not specified differently in the respective detail specification, the test shall be carried out according to EN 50289-1-5.

No measurement shall be made on cables where the cabling element is a single wire.

For cables in pairs or triples, the mutual capacitance shall be measured on a certain number of elements between wire “a” and wire “b”, all the remaining conductors being connected together and to the screen, if any.

For cables in quads or quintuples, the mutual capacitance shall be measured on a certain number of elements between wire “a” and wire “b” and, if required, between wire “c” and wire “d”, all other conductors being connected together and to the screen, if any.

The measured capacitance shall be corrected proportionally to the length, and expressed in nanofarads per kilometre.

8.5 Capacitance unbalance (conductor to conductor)

The capacitance unbalance shall be measured on the finished cable by means of a device capable of measuring accurately to within 5 pF + 5 % of the value to be determined.

The measurement shall be carried out with alternating current at a frequency between 500 Hz and 2 000 Hz. If not specified differently in the respective detail specification, the test shall be carried out according to EN 50289-1-5.

For cables in pairs or triples, the capacitance unbalance shall be measured between different pairs; for cables in quads or quintuples, the capacitance unbalance shall be measured between the pairs a b of different cabling elements and, if required, between the two pairs a b and c d of the same element. Adjacent cabling elements shall be selected for at least two-thirds of the tests.

The capacitance unbalance shall be expressed in picofarads per 500 m length of cable.

If the tested cable has a length L other than 500 m, the measured value shall be multiplied by a correction factor of 500/L unless differently specified in the relevant cable specification.

Lengths of less than 100 m shall be considered as being equal to 100 m.

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

3, rue de Varembé
PO Box 131
CH-1211 Geneva 20
Switzerland

Tel: + 41 22 919 02 11
Fax: + 41 22 919 03 00
info@iec.ch
www.iec.ch