BS EN 60855-1:2017

BSI Standards Publication

Live working — Insulating foam-filled tubes and solid rods

Part 1: Tubes and rods of a circular cross-section

bsi.

National foreword

This British Standard is the UK implementation of EN 60855-1:2017. It is identical to IEC 60855-1:2016. It supersedes BS EN 60855:1997 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee PEL/78, Tools for live working.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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Live working - Insulating foam-filled tubes and solid rods - Part 1: Tubes and rods of a circular cross-section (IEC 60855-1:2016)

Travaux sous tension - Tubes isolants remplis de mousse et tiges isolantes pleines - Partie 1: Tubes et tiges de section circulaire
(IEC 60855-1:2016)

Arbeiten unter Spannung - Isolierende schaumgefüllte Rohre und massive Stäbe - Teil 1: Rohre und Stäbe mit kreisförmigem Querschnitt
(IEC 60855-1:2016)

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European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

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European foreword

The text of document 78/1147/FDIS, future edition 2 of IEC 60855-1, prepared by IEC/TC 78 "Live working" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 60855-1:2017.

The following dates are fixed:

• latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2017-08-10
• latest date by which the national standards conflicting with the document have to be withdrawn	(dow)	2020-02-10

This document supersedes EN 60855:1996.

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The text of the International Standard IEC 60855-1:2016 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following note has to be added for the standard indicated.

IEC 61477	NOTE	Harmonized as EN 61477.

Annex ZA
(normative)
Normative references to international publications with their corresponding European publications

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

NOTE 1 When an International Publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

NOTE 2 Up-to-date information on the latest versions of the European Standards listed in this annex is available here: www.cenelec.eu.

Publication	Year	Title	EN/HD	Year
IEC 60060-1	-	High-voltage test techniques -- Part 1: General definitions and test requirements	EN 60060-1	-
IEC 60060-2	-	High-voltage test techniques -- Part 2: Measuring systems	EN 60060-2	-
IEC 60212	2010	Standard conditions for use prior to and during the testing of solid electrical insulating materials	EN 60212	2011
IEC 61318	-	Live working - Conformity assessment applicable to tools, devices and equipment	EN 61318	-

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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LIVE WORKING – INSULATING FOAM-FILLED TUBES AND SOLID RODS –

Part 1: Tubes and rods of a circular cross-section

FOREWORD

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International Standard IEC 60855-1 has been prepared by technical committee 78: Live working.

This second edition cancels and replaces the first edition published in 2009. This edition constitutes a technical revision.

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

- reintroduction of specific diameters of foam-filled tubes and solid rods of circular cross-section with its tolerances;
- reintroduction of the dielectric tests before and after exposure to humidity, as included in IEC 60855-1:2009;
- specification of an alternative test (after exposure to immersion) in case of foam-filled tubes and solid rods having completed the production phase;
- review of phase angle maximum specified values;

- review of the wet test procedure and the improvement of the associated test arrangement.

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

FDIS	Report on voting
78/1147/FDIS	78/1156/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.

A list of all parts in the IEC 60855 series, published under the general title *Live working – Insulating foam-filled tubes and solid rods*, can be found on the IEC website.

Terms defined in Clause 3 are given in *italic* print throughout this standard.

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

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

INTRODUCTION

This part of IEC 60855 has been prepared in accordance with the requirements of IEC 61477.

The product covered by this part of IEC 60855 may have an impact on the environment during some or all stages of its life cycle. These impacts can range from slight to significant, be short-term or long-term, and occur at the global, regional or local level.

This part of IEC 60855 does not include requirements and test provisions for the manufacturers of the product, or recommendations to the users of the product for environmental improvement. However, all parties intervening in its design, manufacture, packaging, distribution, use, maintenance, repair, reuse, recovery and disposal are invited to take account of environmental considerations.

Technical committee 78 is considering the preparation of IEC 60855-2, which would cover foam-filled tubes and solid rods of cross-section other than circular.

LIVE WORKING – INSULATING FOAM-FILLED TUBES AND SOLID RODS –

Part 1: Tubes and rods of a circular cross-section

1 Scope

This part of IEC 60855 is applicable to *insulating foam-filled tube*s and solid rods, of a circular cross-section, made of synthetic materials with reinforced fibreglass and intended to be used in the manufacture and construction of tools, devices and equipment for carrying out live working on electrical systems operating at voltages above 1 kV.

Foam-filled tubes and solid rods of cross-section other than circular and/or made with material other than synthetic materials with reinforced fibreglass are not covered by this part of IEC 60855.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

IEC 60060-2, *High-voltage test techniques – Part 2: Measuring systems*

IEC 60212:2010, *Standard conditions for use prior to and during the testing of solid electrical insulating materials*

IEC 61318, *Live working – Conformity assessment applicable to tools, devices and equipment*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 61318 and the following apply.

3.1
foam
insulating material composed of closed cells, generally made of polyurethane, used to prevent the ingress and migration of moisture

Note 1 to entry: *Foam* is the inner support to manufacture the *foam*-filled tubes covered by this part of IEC 60855.

[SOURCE: IEC 60050-651:2014, 651-22-03, modified – The note has been changed to refer specifically to the *foam* filled tubes covered by this part of IEC 60855.]

3.2
insulating foam-filled tube
foam-filled tube
tube of uniform circular cross-section supplied in straight lengths, manufactured on a *foam* and constructed or formed of synthetic insulating rigid material with reinforced fibreglass

3.3
insulating solid rod
solid rod
solid product of uniform circular cross-section supplied in straight lengths, constructed or formed of synthetic insulating rigid reinforced material

[SOURCE: IEC 60050-651:2014, 651-22-04, modified – The term and its definition have been changed to refer specifically to *insulating solid rod*s covered by this part of IEC 60855.]

4 Requirements

4.1 Materials and design

Foam-filled tubes and solid rods shall be made of synthetic insulating material with reinforced fibreglass.

NOTE Yellow, orange and red are the preferred colours to indicate that the material has insulating properties.

If any coating is applied, it may be transparent or coloured.

The *foam* filling shall be bonded to the wall of the insulating tube, and neither the *foam* nor the bond shall be deteriorated during the tests, other than those tests which lead to destruction of the parts. The *foam* filling shall be free of voids, separations, cracks or other defects.

4.2 Electrical requirements

The material and the design of *foam*-filled tubes and solid rods shall have insulating properties.

The external surface of the *foam*-filled tubes and solid rods shall have hydrophobic properties.

4.3 Mechanical requirements

The material and the design of *foam*-filled tubes and solid rods shall have mechanical resistance properties.

4.4 Diameters of foam-filled tubes and solid rods

All measured diameters shall fall within the tolerance limits specified in Table 1.

Table 1 – Specified diameters

Item	External nominal diameter mm	Tolerance on external diameter mm
Solid rod	10	± 1
	15	± 1
Foam-filled tube	32	± 1
	39	± 1,1
	51	± 1,2
	64	± 1,3
	77	± 1,5

4.5 Marking

Embossed marking is prohibited.

The marking of each *foam*-filled tube and solid rod shall include the following information as a minimum:

- name or trademark of the manufacturer;
- external nominal diameter;
- date of manufacture (month and year) and identification number when available;
- number of the relevant IEC standard (IEC 60855-1).

Other characteristics or information not needed at the work location, like the year of publication of the standard, shall be associated to the product item by other means, such as coded information (bar codes, microchips, etc.) on the product or on its packaging.

The marking shall be clearly legible to a person with normal or corrected vision, without additional magnification. The marking shall be durable and shall not affect the electrical performance of *foam*-filled tubes and solid rods.

4.6 Packaging

The marking of each pack shall include the following information as a minimum:

- name or trademark of the manufacturer;
- external nominal diameter;
- date of manufacture (month and year) and identification number when available;
- number of the relevant IEC standard (IEC 60855-1).

The packaging should reduce abrasive or direct contact with other *foam*-filled tubes or solid rods or any surface that could damage the polished surface.

5 Tests

5.1 General

This part of IEC 60855 provides testing provisions to demonstrate that the *foam*-filled tubes and solid rods comply with the requirements of Clause 4. These testing provisions are primarily intended to be used for type testing for validation of the design input. Where relevant, alternative means (calculation, examination, tests, etc.), are specified within the test subclauses for the purpose of foam-filled tubes and solid rods having completed the production phase (see Annex B).

5.2 Type test conditions

5.2.1 General

To comply with this part of IEC 60855, the design of the product shall fulfil all the type tests listed in Table A.1.

The type tests shall be carried out following the order given in Table A.1.

Each test shall be carried out on each separate test piece in the relevant group.

Any test piece failing to pass any one of the tests mentioned in Annex A shall result in the design being rejected.

For all type tests, environmental conditions in the test room shall comply with the normal atmospheric conditions provided in Table 2 of IEC 60212:2010, at a temperature of between 15 °C and 35 °C, with a relative humidity between 25 % and 75 % (taking into account Note 4 of Table 2 of IEC 60212:2010).

Nevertheless, for the electrical test the atmospheric conditions shall be at temperature between 18 °C and 28 °C, with a relative humidity between 45 % and 75 %.

This part of IEC 60855 covers foam-filled tubes and solid rods for use at temperatures between –25 °C and +55 °C and at a relative humidity between 20 % and 93 %. For foam-filled tubes and solid rods intended to be used in unusual atmospheric conditions (higher or lower temperatures, higher relative humidity), the tests should be more restricting and be carried out in appropriate conditions.

Unless otherwise specified, for all type tests, the tolerance on the dimensions shall be ± 0,5 %.

When a visual check is specified, it shall be understood to be a visual check by a person with normal or corrected vision without additional magnification.

5.2.2 Groups and test pieces

The manufacturer shall supply lengths of foam-filled tubes and solid rods to provide the following groups of test pieces. For each test piece of every group the corresponding length shall be cut at least to 0,1 m from the end of the initial length of solid rod or foam-filled tube provided by the manufacturer.

Group 1: three test pieces of 0,3 m.

Group 2: three test pieces of 1,2 m.

Group 3: three test pieces of 2,5 m in case of foam-filled tube and 2 m in case of solid rod.

Group 4: three test pieces of 1,2 m.

Group 5: (for foam-filled tubes only): three test pieces of length equal to three times the external diameter ± 5 %.

Group 6: three test pieces of 2,5 m.

Group 7: three test pieces of (100 ± 5) mm.

One length of 2 m shall be kept as a reference specimen.

The equipment used to cut the test pieces shall not leave any trace of overheating on the cross-section. The cut shall be clean, showing no signs of tearing of the fibres and shall be made perpendicular to the axis of the foam-filled tube and solid rod.

5.3 Visual and dimensional checks

5.3.1 General

These checks shall be carried out to ensure that the general requirements are fulfilled and that the dimensions comply with the specifications.

5.3.2 Visual check

Initial lengths and test pieces shall be checked visually to verify the elements of marking, the packaging and to detect constructional defects.

There are two levels of inspection to detect constructional defects:

a) A first visual check shall be carried out on each of the initial lengths of foam-filled tube and solid rod provided by the manufacturer before the test pieces are cut from them. This is to detect any surface defects such as obviously faulty bonding between the fibre and the resin, voids underneath the varnish, foreign bodies, protrusions, dirt, bumps or scratches and absence of marks. Any defect shall result in rejection of the initial length.

b) A second visual check shall be carried out on each of the test pieces after they have been cut. This is to detect any internal defects around the visible part of the cross-section, and more particularly, any signs of detachment between the *foam* and the resin, and *foam* of poor quality (voids, cracks). Any such defect shall result in rejection of the test piece.

5.3.3 Dimensional check

The purpose of the dimensional check is to verify that diameters comply with the marking, and the tolerances comply with the requirements of 4.4.

The dimensional check shall be carried out on each of the initial lengths, before the test pieces are cut from them, at both ends and in the middle. The difference between any two measured diameters of a given length shall be less than 0,5 mm.

5.4 Electrical tests

5.4.1 General

Unless otherwise stated, tests shall be carried out using an AC power source at power frequency in accordance with the requirements given in IEC 60060-1. Measuring systems shall comply with IEC 60060-2 unless otherwise specified.

5.4.2 Dielectric test before and after exposure to humidity

5.4.2.1 Type test

5.4.2.1.1 General test conditions

Before the test, each test piece of 300 mm length shall be prepared by cleaning with isopropanol (CH_3-CH(OH)-CH_3) and then dried in air at room temperature for a period of not less than 15 min.

NOTE It is not the purpose of this part of IEC 60855 to ensure that any relevant legislation and any specific safety instructions regarding the use of isopropanol are fully observed.

The test pieces shall be lightly wiped with a clean dry lint-free cloth and the ends of the test pieces shall be covered with conductive adhesive tape.

Conditioning in a humid atmosphere is carried out in accordance with IEC 60212.

5.4.2.1.2 Measurements

The test assembly shall comply with Figures 1, 2, 3 and 4. The measuring apparatus shall not be less than 2 m from the high voltage source. All measuring leads, the shunt and the optional protective gap shall be shielded and earthed. The test piece shall be mounted at a minimum height of 1 m from the ground on an insulating support. A voltage of 100 kV rms at power frequency shall be applied between the electrodes for 1 min. The AC voltage shall be initially applied at a low value and gradually increased at a constant rate-of-rise of approximately 5 kV/s until the test voltage level is reached. The test period shall be considered to start at the instant the specified voltage is reached.

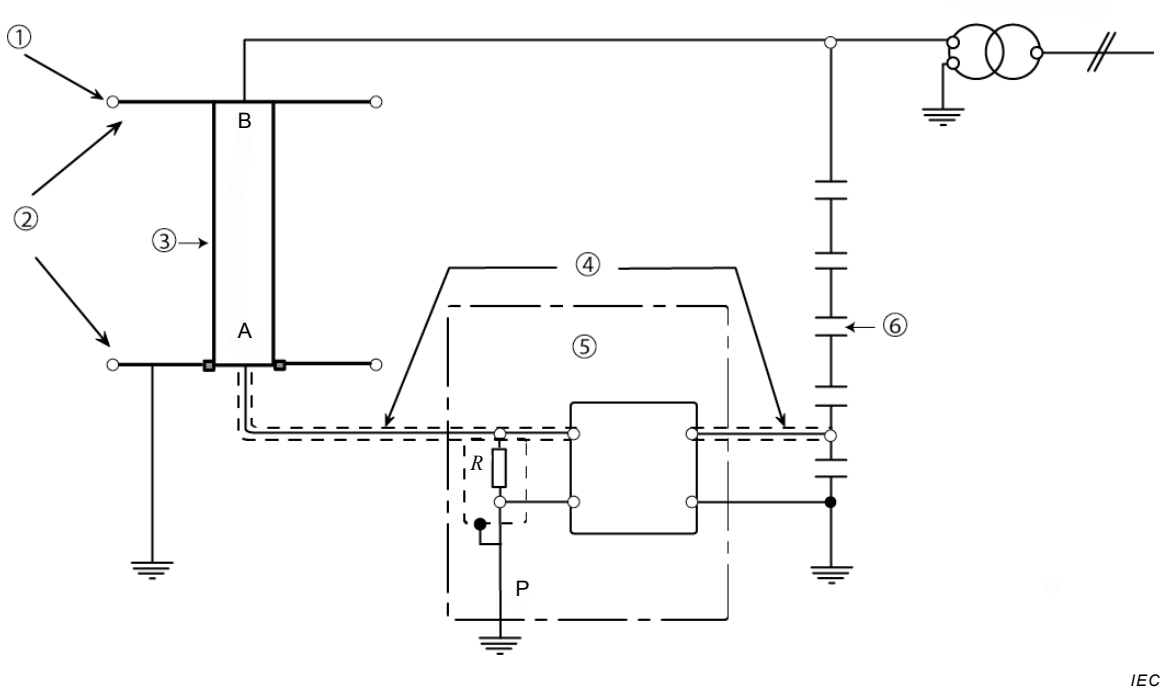
The current passing through the test piece shall be measured (the guard electrode on the earth side is directly connected to earth). The maximum current recorded during the test is called I.

The phase difference between current and voltage shall be measured as follows:

- current (earth end), by passing it through a known impedance;
- voltage (line end), by means of an appropriate divider.

The minimum phase angle recorded during the test is called φ.

Before installing the test piece in the test set-up, reference measurements with no test piece present shall be taken and the current and phase angle values recorded. The phase angle value shall be higher than 88°. This blank test will help verify the quality of the test set-up.

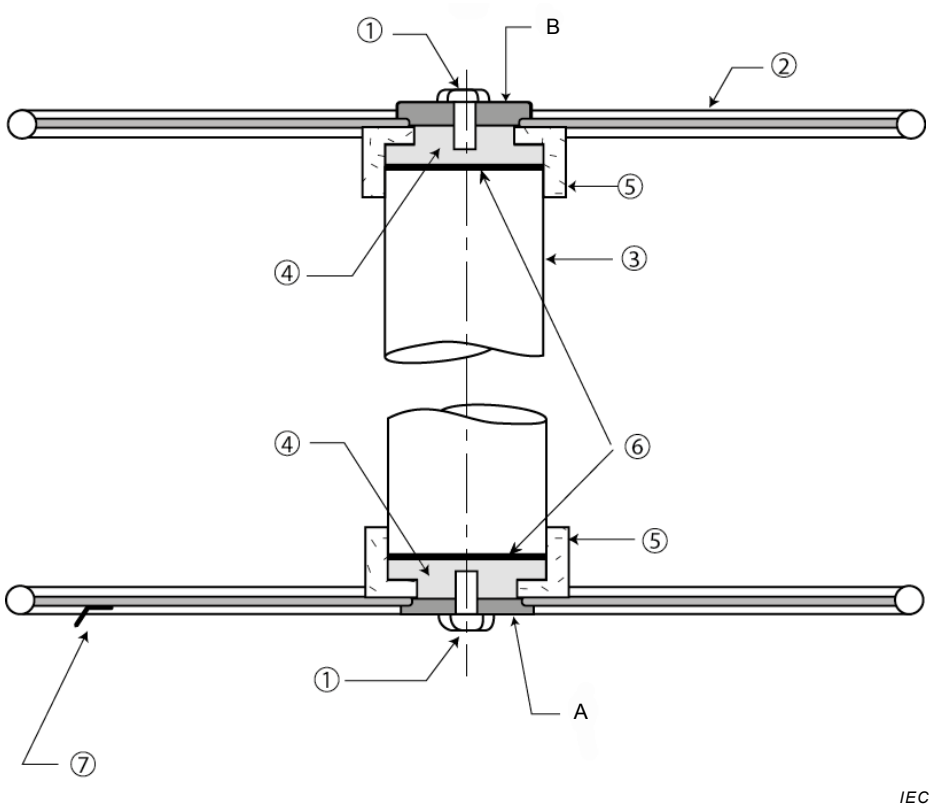


Key

1	continuous welded tube	4	screened leads
2	guard electrodes	5	measuring equipment
3	test piece	6	capacitive (or resistive) divider
A and B	See Figure 2.		
R	resistance between points A and P: $R \leq 10\ 000\ \Omega$		

The measurement zone is situated at least 2 m away from any high voltage source.

Figure 1 – Typical dielectric test arrangement



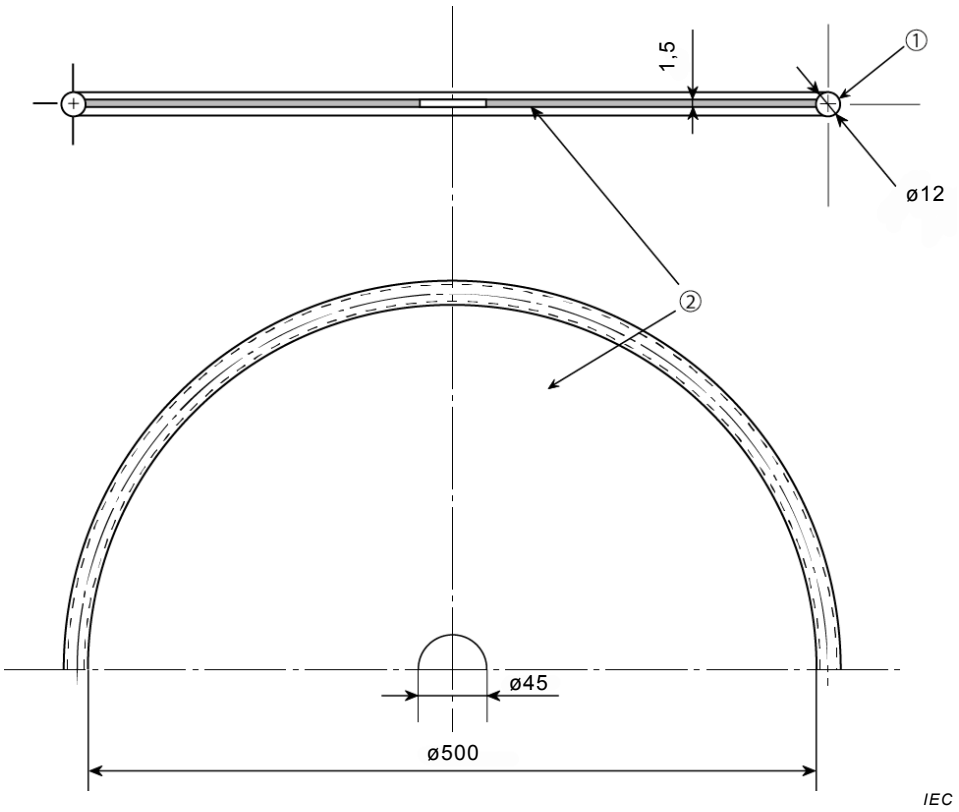
Key

A	insulating material	B	brass
1	socket for ∅ 4 mm banana plug	5	insulating support
2	guard electrode	6	contact maintained by conductive adhesive tape
3	test piece of 300 mm length	7	socket for ∅ 4 mm banana plug soldered on guard electrode
4	brass electrode		

Banana plugs may be replaced by other suitable electrical connectors.

Figure 2 – Assembly set-up of the test piece to the guard electrodes

Dimensions in millimetres



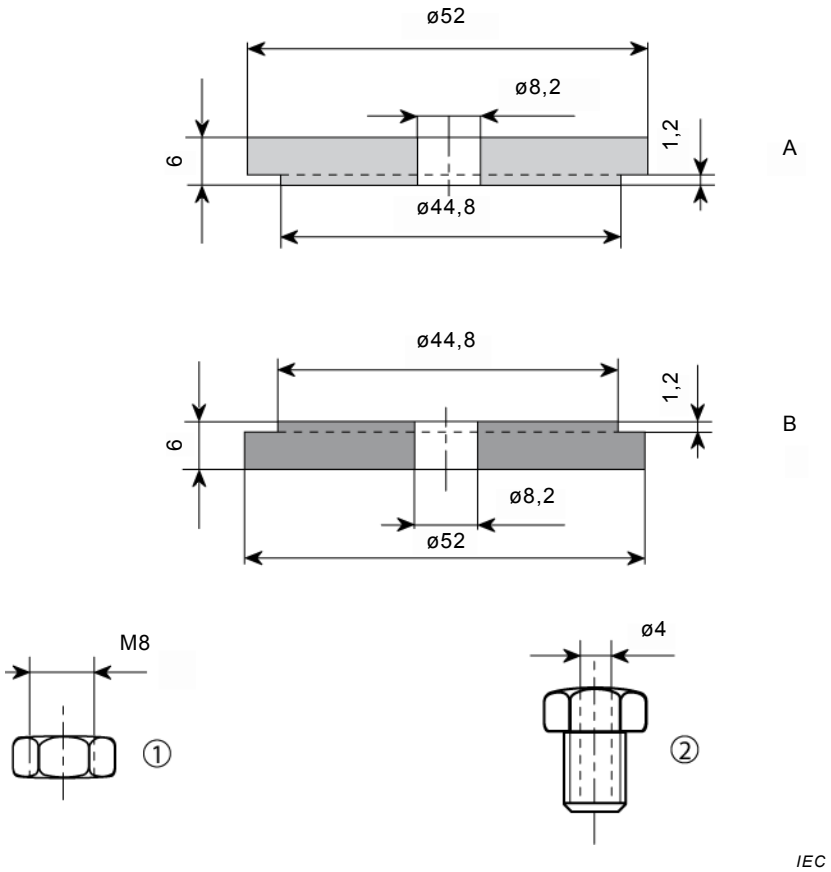
Key

1 copper tube soldered onto brass plate

2 brass plate

Figure 3a – Constructional drawing for guard electrodes (two required)

Dimensions in millimetres



Key

A insulating material

B brass

1 two M8 brass nuts for rods

2 two M8 × 10 brass screws with ∅ 4 mm holes for foam-filled tubes

Figure 3b – Constructional drawings for parts A and B

Figure 3 – Constructional drawings for guard electrodes and parts

Dimensions in millimetres

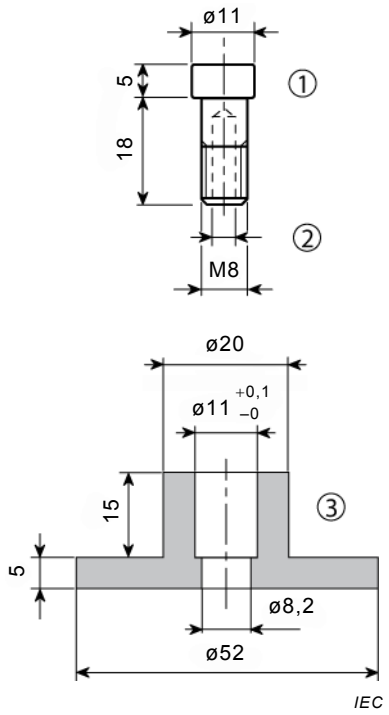


Figure 4a – For 10 mm diameter solid rod

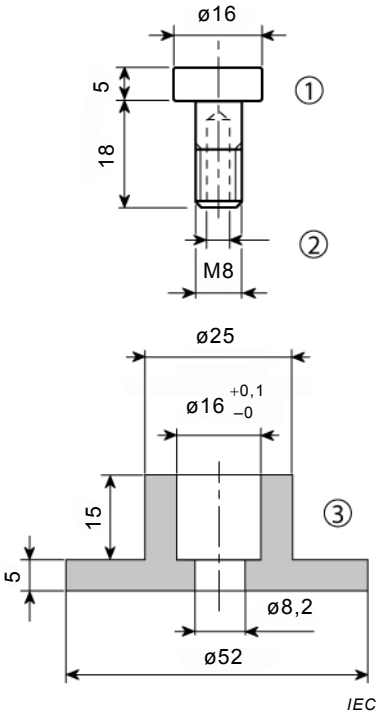


Figure 4b – For 15 mm diameter solid rod

Dimensions in millimetres

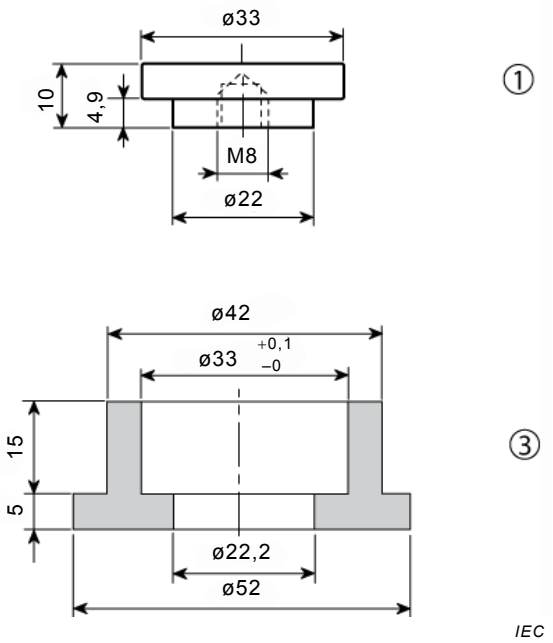


Figure 4c – For 32 mm diameter foam-filled tube

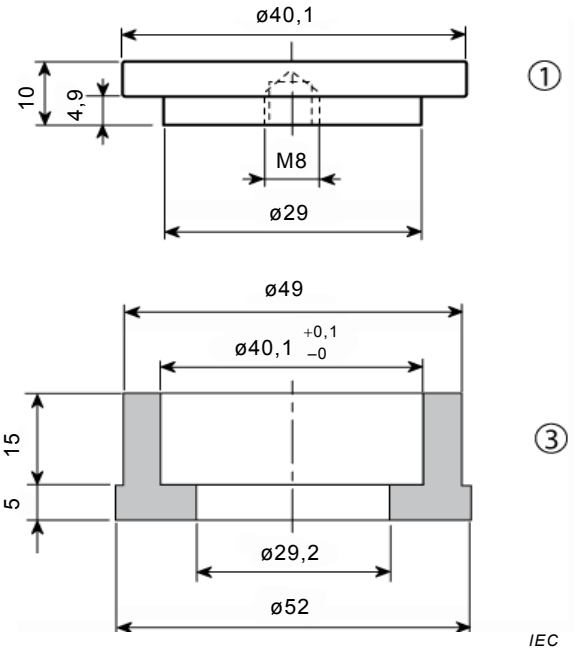


Figure 4d – For 39 mm diameter foam-filled tube

Dimensions in millimetres

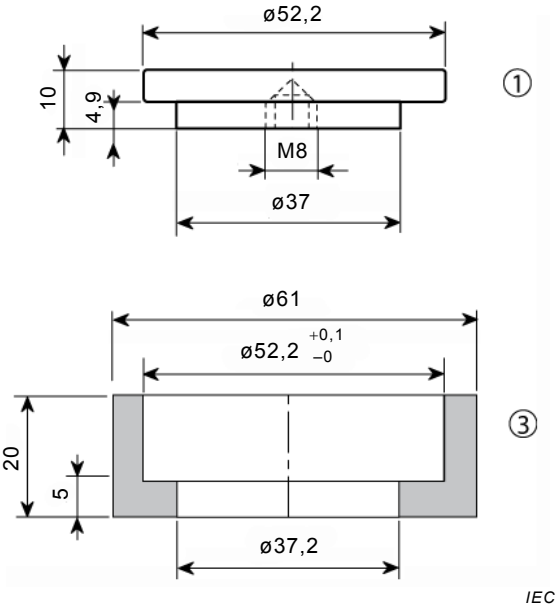


Figure 4e – For 51 mm diameter foam-filled tube

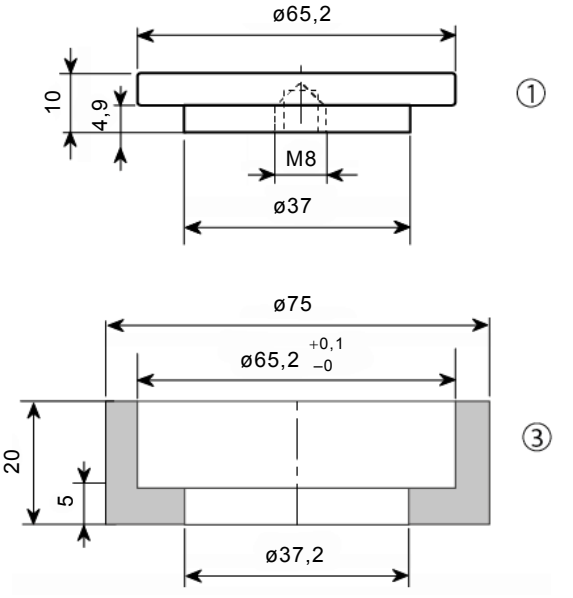


Figure 4f – For 64 mm diameter foam-filled tube

Dimensions in millimetres

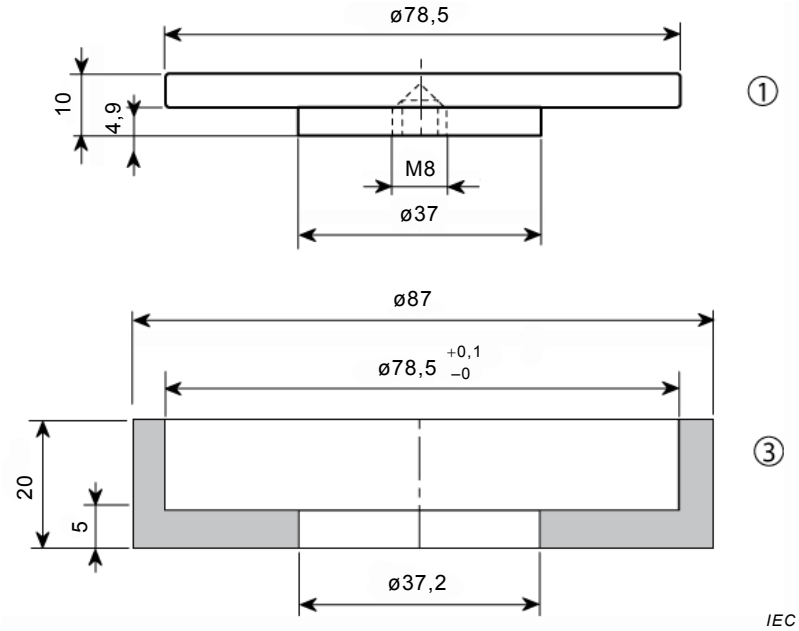


Figure 4g – For 77 mm diameter foam-filled tube

Key

1 brass electrode

2 ∅ 4 mm hole for banana plug

3 insulating support

Figure 4 – Drawings for guard electrode parts according to test piece diameters

5.4.2.1.3 Tests before exposure to humidity

After at least 24 h in the ambient atmosphere of the test area, the current I_1 is measured at an alternating voltage of 100 kV rms at power frequency applied between the electrodes for 1 min. The maximum current and the phase angle φ_1 between current and voltage are recorded.

5.4.2.1.4 Tests after exposure to humidity

The test pieces shall be placed for 168 h in a conditioning chamber and subjected to a temperature of 23 °C and a relative humidity of 93 % according to Table 2 of IEC 60212:2010.

At the end of this 168 h period, the test pieces shall remain in an atmosphere of 93 % relative humidity and be tested upon return to the ambient temperature of the test area. After the test pieces have been lightly wiped with a dry cloth, the current I_2 and phase angle φ_2 are measured under the same conditions as I_1 and φ_1.

The test piece shall be located in the same position in relation to earth; for both tests, the high voltage end shall remain the same.

5.4.2.1.5 Test results

Before exposure to humidity:

- the phase angle φ_1 measured shall be higher than 80°;
- the current I_1 measured shall not exceed the values given in Table 2.

Table 2 – Maximum current I_1 before exposure to humidity

Diameter (mm)	**Solid rod**		**Foam-filled tube**				
	10	15	32	39	51	64	77
Maximum current I_1 (μA rms)	10	10	10	12	15	20	25

The test shall be considered as passed if after exposure to humidity the current I_2 is lower than 2 I_1.

If I_2 is greater than 2 I_1, but lower than I_1 + 40 μA, the test shall also be considered as passed if the phase angle between voltage and current is higher than 50° for foam-filled tubes and 40° for solid rods.

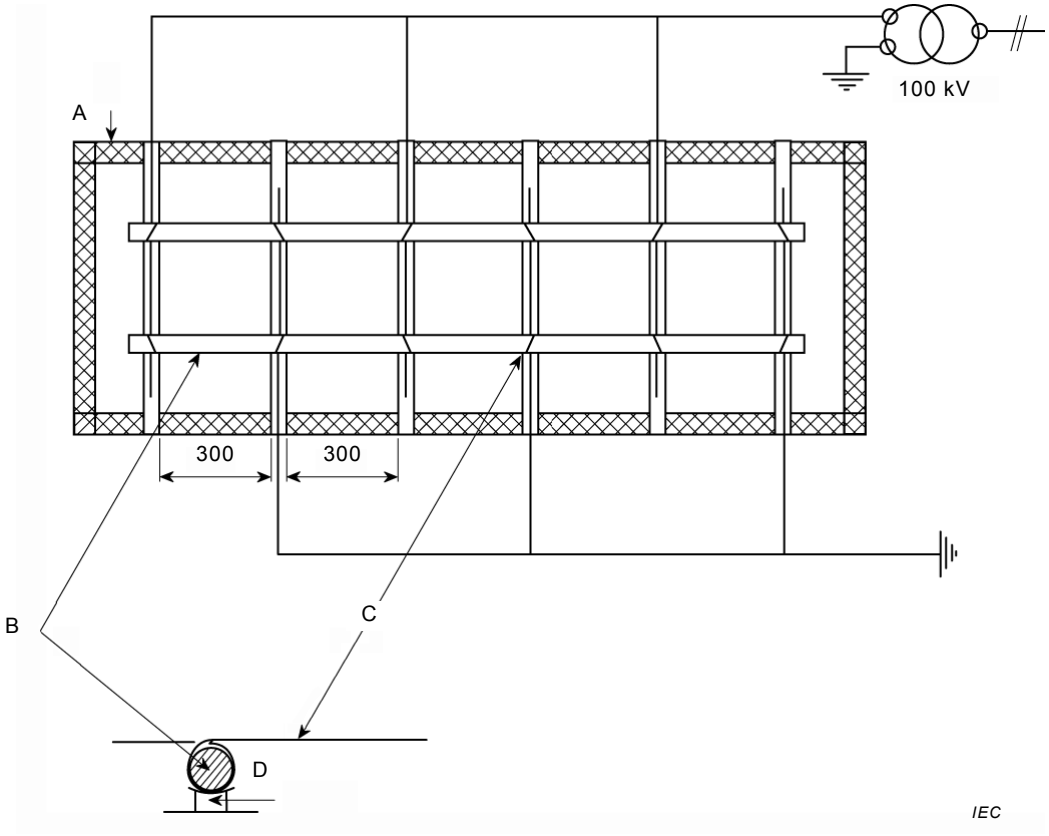
In no case shall I_2 be greater than I_1 + 40 μA.

5.4.2.2 Alternative tests in case of foam-filled tubes and solid rods having completed the production phase

5.4.2.2.1 Alternative dry test

An example of a suitable test arrangement is given in Figure 5.

Dimensions in millimetres



Key

A insulating table

B foam-filled tube or solid rod to be tested

C stranded wire electrodes not less than 5 mm width

D metallic support

Figure 5 – Alternative dielectric test under dry condition – Example of a typical test arrangement

The foam-filled tubes and solid rods shall be subjected to an alternating voltage of 100 kV rms at power frequency applied between electrodes 300 mm apart, for 1 min. The AC voltage shall be initially applied at a low value and gradually increased at a constant rate-of-rise of approximately 5 kV/s until the test voltage level is reached. The test period shall be considered to start at the instant the specified voltage is reached.

The test shall be considered as passed if the foam-filled tubes and solid rods fulfil the following:

- no flashover, no sparkover or puncture;
- no visual sign of tracking or erosion on the surface;
- no perceptible temperature rise of the foam-filled tube or solid rod estimated by bare hand.

5.4.2.2.2 Alternative test after exposure to immersion

At the production stage, it is not possible to perform the test of 5.4.2.1.4 which requires a long duration conditioning not compatible with the production stage.

The manufacturer shall perform the test as follows:

- the test set-up shall be the one of 5.4.2.1;
- the conditioning is carried out according to the following.

Before the test, each test piece of 300 mm length shall be prepared by cleaning with isopropanol (CH_3-CH(OH)-CH_3) and then dried in air at room temperature for a period of not less than 15 min.

The test pieces shall be conditioned by total immersion for 24 h in a tank of tap water with a minimum conductivity of 500 μS/cm corresponding to a maximum resistivity of 20 Ω·m, at 20 °C.

At the end of this conditioning period, the test pieces shall be lightly wiped with a clean dry lint-free cloth, and the ends of the test pieces covered with conducting adhesive tape. The test pieces shall be tested upon return to room temperature in the test area.

5.4.3 Wet test

5.4.3.1 Type test

5.4.3.1.1 General test conditions

Before the test, each test piece shall be prepared by cleaning with isopropanol (CH_3-CH(OH)-CH_3) and then dried in air at room temperature for a period of not less than 15 min.

The electrodes shall be made of an aluminium or copper soft wire 3 mm to 4 mm in diameter, encircling the test piece with three or four turns, as shown in Figure 6a. The electrodes shall be placed symmetrically on the test piece and spaced 1 m apart (see Figure 6b). The fixing support shall be placed at the lower part of the test piece. The high voltage electrode shall be placed at the upper end of the test piece.

The surface of the electrode should not be oxidized, and if a treatment against oxidization is applied, it should not modify the characteristics of the water streaming on the test piece.

The test assembly shall comply with Figure 6b. The test piece shall be inclined at an angle of 45° from the vertical. A voltage of 100 kV rms at power frequency shall be applied between the electrodes for 1 h. The AC voltage shall be initially applied at a low value and gradually increased at a constant rate-of-rise of approximately 5 kV/s until the test voltage level is reached. The test period shall be considered to start at the instant the specified voltage is reached.

5.4.3.1.2 Precipitation characteristics

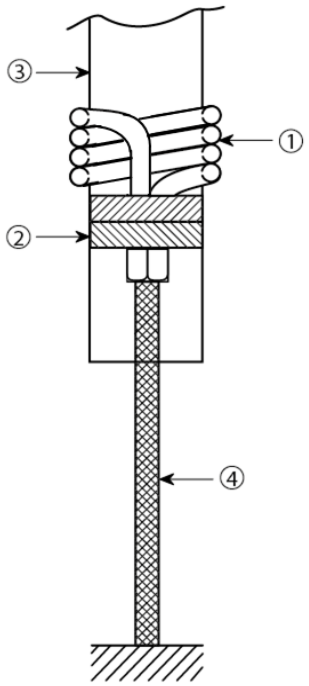
The wet test shall be carried out in accordance with the standard wet test procedure described in IEC 60060-1 except for the average and the beginning of the precipitation:

- average precipitation rate in vertical and horizontal directions: 1,0 mm/min to 1,5 mm/min;
- resistivity of collected water corrected to 20 °C: 100 Ω·m ± 15 Ω·m;
- precipitation shall commence immediately when the voltage is applied.

Precipitation shall be such that the water falling near the test piece shall be at a 90° angle to the test piece, as shown in Figure 6b.

The temperature of the water shall be similar to the temperature of the test area.

As the ambient temperature can change faster than the temperature of the water, when the temperature is measured a deviation of 3 °C is allowed.



Key

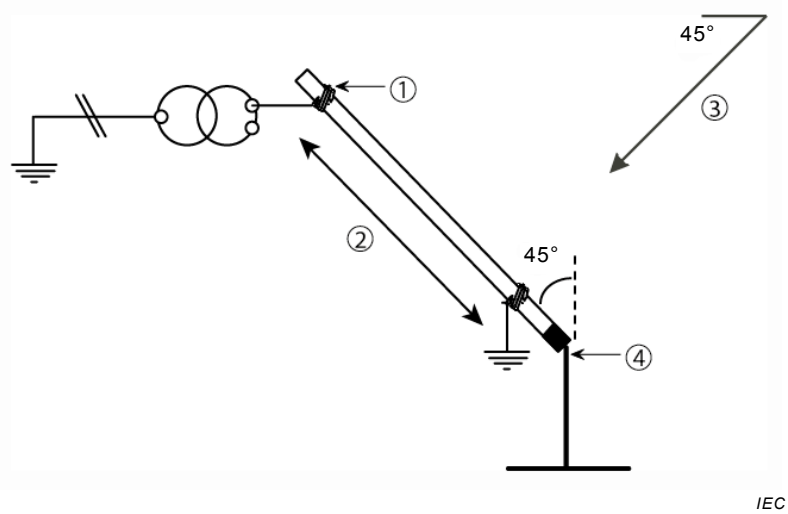
1 aluminium or copper soft tie wire; 3 to 4 turns, 3 mm to 4 mm diameter

2 electrode fixed by adhesive tape

3 test piece

4 earthing brass braid; 10 mm^2 cross area

Figure 6a – Details of electrode arrangement



Key

1 high voltage electrode

2 electrode spacing, 1 m

3 rain direction

4 1 m minimum height fixing support

Figure 6b – Typical test arrangement

Figure 6 – Wet test

5.4.3.1.3 Test results

The test shall be considered as passed if the following conditions are met:

- no flashover during the test;
- no sparkover or puncture;
- no visual sign of tracking or erosion on the surface;
- no temperature rise greater than 7 °C, relative to the initial test piece temperature, on any spot from 10 cm to the high voltage electrode to 10 cm from the earth electrode on the surface of the test piece at the end of the test period. The temperature measurement shall take place no more than 2 min after completion of the test.

An infrared camera can be used to measure the temperature of the surface. The camera should be calibrated for the test object prior to use.

5.4.3.2 Alternative means for insulating foam-filled tubes and solid rods having completed the production phase

There is no alternative test for checking the conformity with the associated requirement (for instance, some tests could be destructive). Nevertheless, the manufacturer shall prove that he has followed the same documented manufacturing procedure with identical components as for the type-tested product.

5.5 Mechanical tests

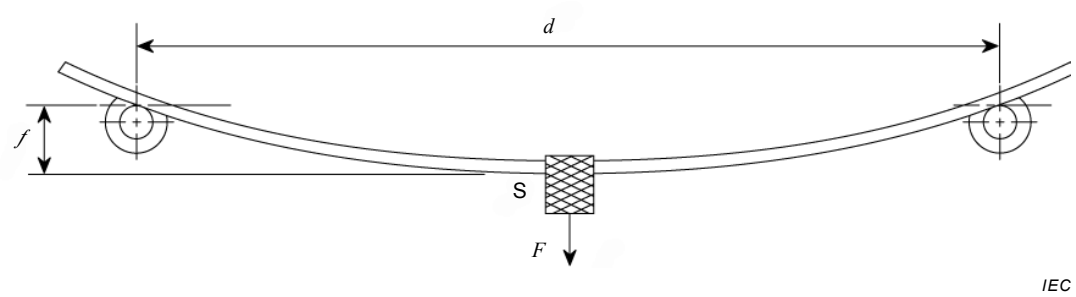
5.5.1 Bending test

5.5.1.1 Type test

A foam-filled tube 2,50 m long or a solid rod 2 m long shall be placed between two supports consisting of pulleys (Figure 7) with the following distance d between the axes:

- 0,50 m for solid rods;
- 1,50 m for 32 mm diameter foam-filled tubes;
- 2 m for 39 mm diameter foam-filled tubes or larger.

At the centre of the span, a vertical force F shall be applied to a leather or fabric strap, 50 mm ± 2,5 mm wide, which is placed on the foam-filled tube or solid rod.

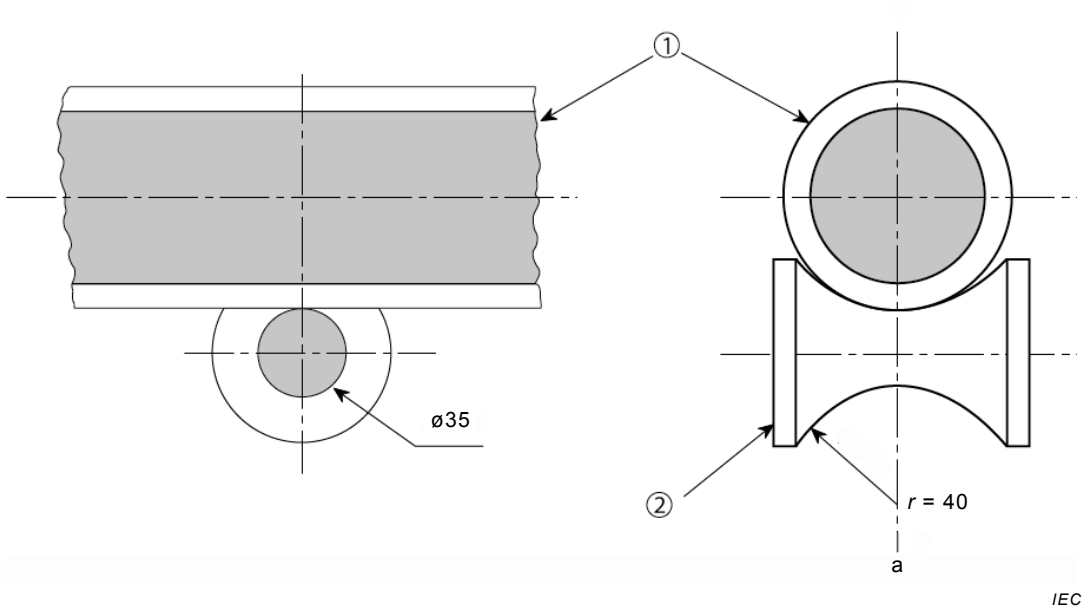


Key

S strap

Figure 7a – Bending test assembly

Dimensions in millimetres



Section a-a

Key

1 foam-filled tube under test

2 pulley

Figure 7b – Detail of supports

Figure 7 – Bending test

F_d is the force for which the elastic limit is not exceeded.

The applied force F shall be increased at a rate of (200 ± 50) N/s and the deflection shall be measured for the loads $\frac{F_d}{3}$, $\frac{2F_d}{3}$ and F_d, these having been maintained for 30 s.

The difference between the deflections measured for $\frac{F_d}{3}$ and $\frac{2F_d}{3}$ and for $\frac{2F_d}{3}$ and F_d, shall be less than the value of f indicated in Table 3.

This force shall then be removed progressively and, 1 min after the force has been removed, the residual deflection shall be measured; this shall not exceed 6 % of the deflection measured during application of the force F_d for foam-filled tubes, and 1 mm for solid rods.

The foam-filled tubes and solid rods shall then be rotated through 90°, 180° and 270°, and the test repeated for each position. For the same load, the deflection f shall not vary by more than 15 %.

The measured deflection produced by force F_d shall be compared with that for the previous test. With the foam-filled tube and solid rod in the plane for which the total deflection was the greatest, the force shall then be reapplied and progressively increased under the same conditions as above, up to the value F_r, which is then maintained for 30 s. There shall be no sign of failure.

The test shall be continued until the test piece breaks and the actual breaking load is recorded for information.

Table 3 gives the values of F_d, f and F_r for foam-filled tubes and solid rods of specific diameters.

Table 3 – Values of F_d, f and F_r for bending test

External diameter of foam-filled tube or solid rod		Distance between supports d	F_d	f	F_r	Length of test piece
mm		m	N	mm	N	m
Solid rods	10	0,5	270	20	540	2
	15	0,5	1 350	15	2 700	2
Foam-filled tubes	32	1,5	1 100	35	2 150	2,5
	39	2	1 500	50	2 950	2,5
	51	2	3 250	45	6 450	2,5
	64	2	5 500	35	11 000	2,5
	77	2	11 650	30	23 250	2,5

5.5.1.2 Alternative bending test for insulating foam-filled tubes and solid rods having completed the production phase

There is no alternative test for checking the conformity with the associated requirement (for instance, this test could be destructive). Nevertheless, the manufacturer shall prove that he has followed the same documented manufacturing procedure with identical components as for the type-tested product.

In addition, the manufacturer shall perform a test according to 5.5.1.1 except for the measurement of F_r. Only f shall be measured.

5.5.2 Torsion test

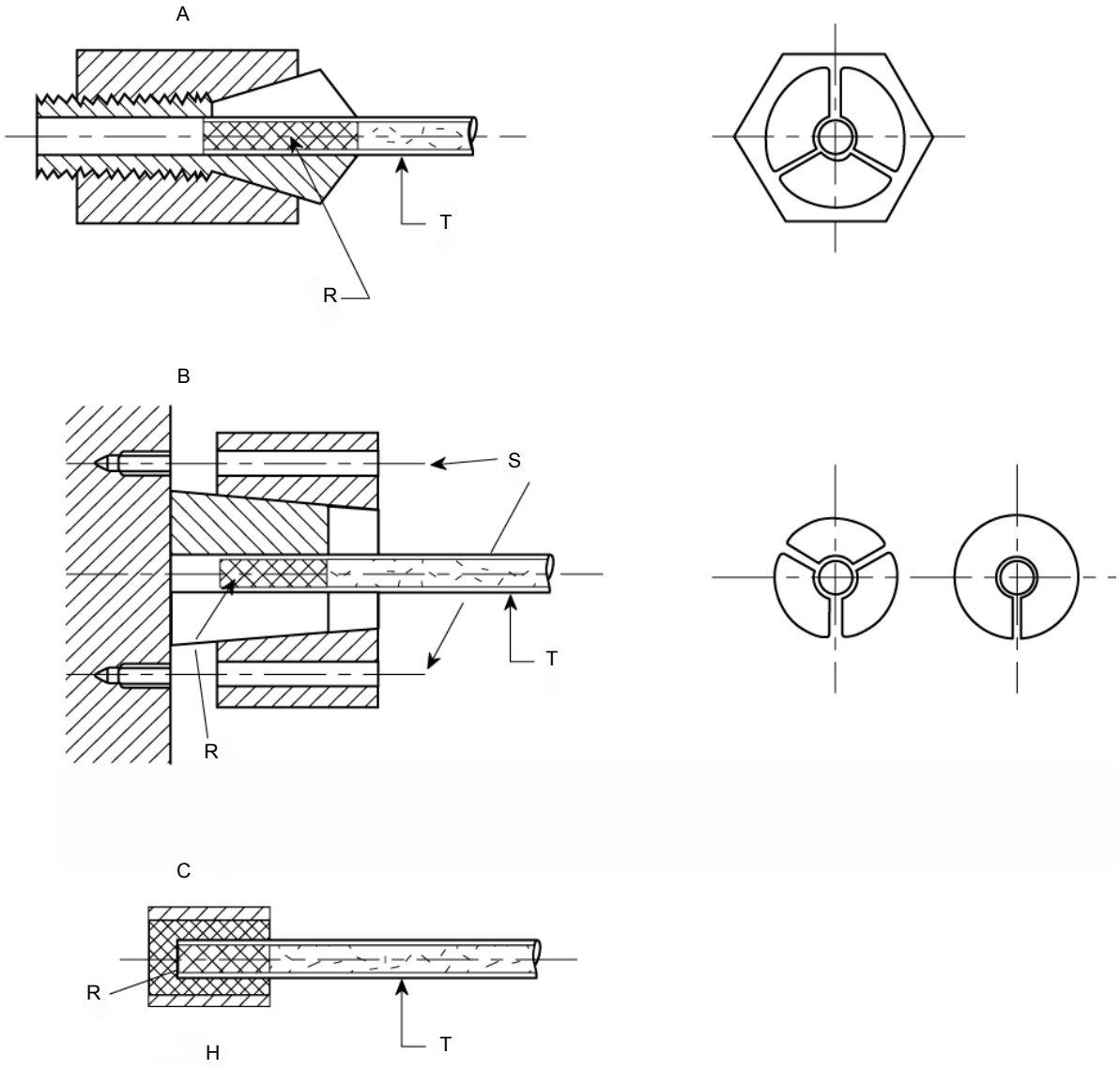
The test piece shall be subjected to a torsion test over a length of 1 m (between collets or terminations). Figure 8 shows suitable alternative methods of fixing the ends of the test pieces for this test.

A linear torque shall be applied progressively at a rate of not more than (5 ± 2) N·m/s up to the value C_d, which is the torque for which neither audible nor visible defects are observed. At this value, the angular deflection measured after a 30 s application of the torque shall be less than the corresponding angle a_d (see Table 4).

The torque shall then be removed and, after 1 min, the residual angle of deflection shall be measured. This shall be less than 1 % of a_d for solid rods, and 1° for foam-filled tubes.

An increasing torque shall then be reapplied, as above, up to a value C_r and shall be maintained for 30 s. There shall be no sign of failure.

The test shall be continued until the test piece breaks, for information purposes.



Key

A	test piece gripped in spring collet	H	housing suitable for gripping in mandrel
B	test piece gripped by taper mandrel	S	screws
C	termination potted in resin	T	test piece
R	resin		

Figure 8 – Torsion test – Examples for fixing foam-filled tube and solid rod

Table 4 – Values of C_d, a_d and C_r for torsion test

External diameter of foam-filled tube and solid rod mm		C_d N·m	a_d degrees	C_r N·m
Solid rods	10	4,5	150	9
	15	13,5	180	27
Foam-filled tubes	32	40	35	80
	39	80	40	160
	51	120	12	240
	64	320	12	640
	77	600	8	1 200

5.5.3 Crushing test on insulating foam-filled tube

The length of each test piece shall be equal to three times the external diameter. The test piece shall be placed between two smooth, flat, parallel, rigid plates and compressed (see Figure 9). The length of the plates shall be at least equal to the test piece length plus 20 mm. The distance between plates shall then be continuously decreased at a constant speed of 2 mm/min.

The force F applied to the test piece shall be recorded versus time.

Two values of F are to be considered:

a) $F = F_d$: minimum value of F where first linearity is lost. This corresponds to a loss of $\Delta F \geq 0{,}01\ F_d$;

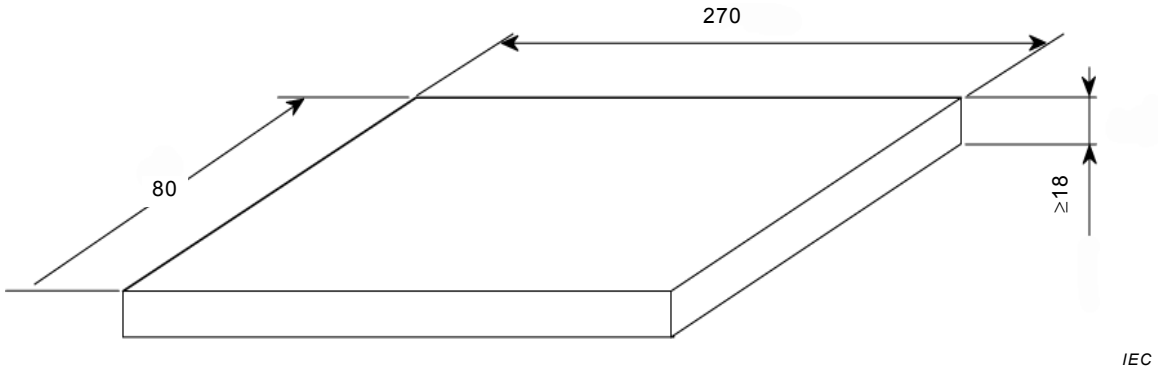
b) $F = F_r$: maximum value of F recorded during the three first minutes of test (displacement $\leq$ 6 mm).

F_d and F_r measured values shall be higher than the values specified in Table 5.

Table 5 – Values of F_d and F_r for crushing test

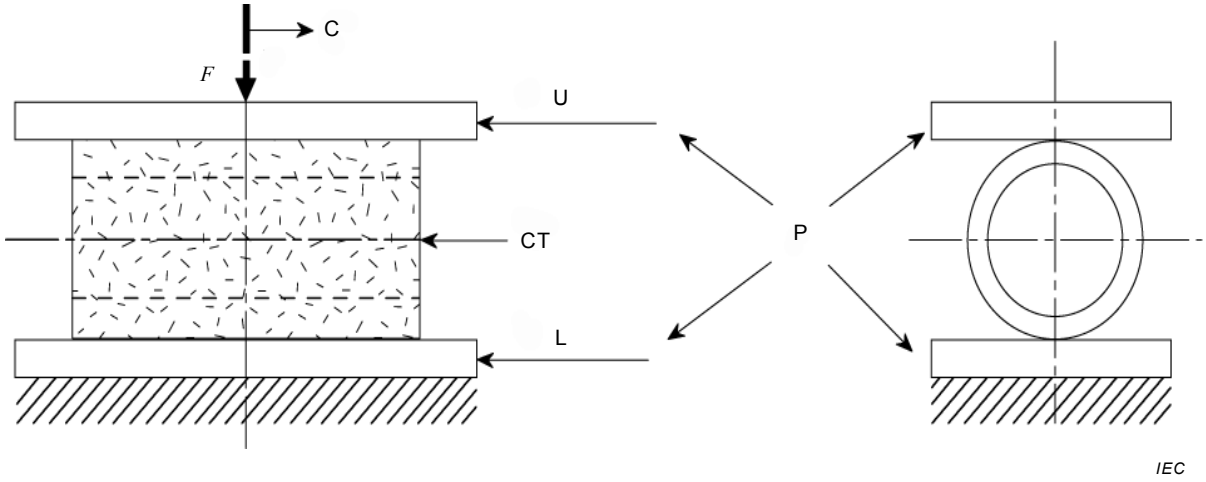
Nominal diameter of foam-filled tube mm	32	39	51	64	77
F_d (N)	700	1 650	3 000	3 400	7 000
F_r (N)	1 400	3 300	6 000	6 800	14 000

Dimensions in millimetres



NOTE Young's modulus of material $E \geq 2{,}2 \times 10^{11}$ N/m^2.

Figure 9a – Two crushing plates



Key

C	centred	U	upper plate
CT	centred test piece	L	lower plate
P	plates		

Upper-plate stability shall be ensured by displacing down application point of force F, with the help of stirrups.

Figure 9b – Test mounting

Figure 9 – Crushing test

5.5.4 Electrical test after mechanical ageing

5.5.4.1 Bending ageing test

The test consists of subjecting each test piece to a total of 4 000 bending cycles under the test conditions described in 5.5.1. The force F_d indicated in Table 3 shall be applied at the midpoint of the test piece, to give 1 000 bending cycles in each of four directions, 90° apart.

The frequency of application of the load shall be between one and two cycles per minute. The test piece shall be rotated through 90° after each 1 000 bending cycles.

The test shall be considered as passed if, after 4 000 cycles, the test piece shows no signs of deterioration, localized or otherwise, nor any permanent set, during a visual check.

5.5.4.2 Dielectric test after mechanical ageing

Two 300 mm new test pieces shall be cut from each half of the three test pieces having undergone the 4 000 cycles bending test. These six new test pieces shall be tested before and after exposure to humidity as described in 5.4.2.1.

The test shall be considered as passed if the results are in accordance with 5.4.2.1.5.

5.5.5 Dye penetration test

The three test pieces shall be totally immersed in a container filled with aqueous dye solution. The dye shall be selected in accordance with occupational health and environmental requirements.

NOTE IEC 60855:1985 specified a solution of fuschine. For health considerations, efforts have been made by TC78 to identify a replacement and comparative dye penetration tests have been carried out, using various dyes. These tests indicate that the choice of the dye does not affect significantly the characterization of foam-filled tubes and solid rods. In practice however, eosine ($C_{60}H_6Br_4Na_2O_5$) proves to be particularly convenient. The concentration of the eosine is about 1 % to 2 % in distilled water.

The container with the immersed test pieces shall be placed in a vacuum chamber at a pressure of less than 6 500 Pa (about 50 Torr). After 1 h, the pressure shall be released and the test pieces shall be removed from the solution.

In order to avoid dye solution spreading from the test piece ends during cutting, the test pieces shall be dried for 24 h at a temperature of about 35 °C before cutting them.

After drying, the test pieces shall be cut 5 mm from each end. The new test pieces thus obtained shall be slit lengthways.

The test shall be considered as passed if there is no sign of solution dye penetration in either the *foam*, at the junction of the *foam* and the insulating tube, or in the solid rod.

5.5.6 Durability of marking

This test is carried out on the markings of three initial lengths of foam-filled tube and solid rod provided by the manufacturer, before the test pieces are cut from them.

The markings shall be rubbed vigorously for 1 min with a clean cloth soaked in water, then with a clean cloth soaked in isopropanol (CH_3-CH(OH)-CH_3).

The test shall be considered as passed if the markings are still legible and the characters do not run or smear.

NOTE This test does not apply to the marking of the packaging.

6 Conformity assessment of foam-filled tubes and solid rods having completed the production phase

For conducting the conformity assessment during the production phase, IEC 61318 shall be used in conjunction with this part of IEC 60855.

Annex B developed from a risk analysis on the performance of the foam-filled tubes and solid rods provides the classification of defects and identifies the associated tests applicable in case of production follow-up.

7 Modifications

Any modification of the design of foam-filled tubes and solid rods that affects the performance of the product shall require the type tests to be repeated, in whole or in part, as well as a change in the reference literature. If the modification of a characteristic does not modify the requirements which are checked through a certain test, it is not necessary to repeat this test.

Annex A
(normative)

Plan of carrying out of the type tests

The numbers given in the different test groups of Table A.1 indicate the order in which the tests shall be carried out. Within a group, tests with the same sequential number may be performed in the order that is most convenient.

Table A.1 – Chronological order of the type tests

Type tests	Subclause		Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7
	Requirements	Tests							
Dimensional check [a]	4.4	5.3.3	1	1	1	1	1	1	1
Durability of marking [b]	4.5	5.5.6	1	1	1	1	1	1	1
Visual check [c]	4.1 4.5 4.6	5.3.2	2	2	2	2	2	2	2
Dielectric test before and after exposure to humidity	4.2	5.4.2.1	3						
Wet test	4.2	5.4.3		3					
Bending test	4.3	5.5.1.1			3				
Torsion test	4.3	5.5.2				3			
Crushing test on foam-filled tube	4.3	5.5.3					3		
Bending ageing test	4.3	5.5.4.1						3	
Dielectric test after mechanical ageing	4.3	5.5.4.2						4	
Dye penetration test	4.2	5.5.5							3

[a] This check is carried out on the initial lengths of solid rod and/or foam-filled tube provided by the manufacturer, before the test pieces are cut off.

[b] This check is carried out on the markings of 3 initial lengths of solid rod and/or foam-filled tube provided by the manufacturer, before the test pieces are cut from them.

[c] This check is carried out on the initial lengths of solid rod and/or foam-filled tube provided by the manufacturer, before the test pieces are cut off, then on the test pieces after cutting.

Annex B
(normative)

Classification of defects and associated requirements and tests

Annex B was developed to address the level of defects of foam-filled tubes and solid rods (critical, major or minor) in a consistent manner (see IEC 61318). For each requirement identified in Table B.1, both the type of defect and the associated test are specified.

Table B.1 – Classification of defects and associated requirements and tests

Requirements		Type of defects			Tests
		Critical	Major	Minor	
4.1	Material and design	X			5.3.2[a]
4.2	Dielectric strength before exposure to humidity	X			5.4.2.2.1
	Dielectric strength after exposure to humidity		X		5.4.2.2.2
	Dielectric strength of external surface	X			5.4.3.2
4.3	Mechanical: bending	X			5.5.1.2
	Mechanical: torsion		X		5.5.2
	Mechanical: crushing		X		5.5.3
4.4	Tolerance requirements on external diameter	X			5.3.3
4.5	Marking: – absence of marking – incorrect marking – durability of marking	 X 	 X 	 X	 5.3.2 5.3.2 5.5.6

[a] This check is carried out on the initial lengths of solid rod and/or foam-filled tube provided by the manufacturer, before the test pieces are cut off.

Bibliography

IEC 60050-651:2014, *International Electrotechnical Vocabulary – Part 651: Live working* (available at: www.electropedia.org)

IEC 61477, *Live working – Minimum requirements for the utilization of tools, devices and equipment*

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