BS EN 60243-1:2013

BSI Standards Publication

Electric strength of insulating materials — Test methods

Part 1: Tests at power frequencies

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National foreword

This British Standard is the UK implementation of EN 60243-1:2013. It is identical to IEC 60243-1:2013. It supersedes BS EN 60243-1:1998 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee GEL/112, Evaluation and qualification of electrical insulating materials and systems.

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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English version

Electric strength of insulating materials - Test methods - Part 1: Tests at power frequencies
(IEC 60243-1:2013)

Rigidité diélectrique des matériaux isolants - Méthodes d'essai - Partie 1: Essais aux fréquences industrielles
(CEI 60243-1:2013)

Elektrische Durchschlagfestigkeit von isolierenden Werkstoffen - Prüfverfahren - Teil 1: Prüfungen bei technischen Frequenzen
(IEC 60243-1:2013)

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European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
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Foreword

The text of document 112/237/FDIS, future edition 3 of IEC 60243-1, prepared by IEC/TC 112 "Evaluation and qualification of electrical insulating materials and systems" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 60243-1:2013.

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)	2014-01-30
• latest date by which the national standards conflicting with the document have to be withdrawn	(dow)	2016-04-30

This document supersedes EN 60243-1:1998.

EN 60243-1:2013 includes the following significant technical changes with respect to EN 60243-1:1998:

The significant technical change with respect to the previous edition is that the current version now includes an option for testing elastomeric materials.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CENELEC [and/or CEN] shall not be held responsible for identifying any or all such patent rights.

Endorsement notice

The text of the International Standard IEC 60243-1:2013 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 60674-2 NOTE Harmonised as EN 60674-2.

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 When an international publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

Publication	Year	Title	EN/HD	Year
IEC 60212	-	Standard conditions for use prior to and during the testing of solid electrical insulating materials	EN 60212	-
IEC 60296	-	Fluids for electrotechnical applications - Unused mineral insulating oils for transformers and switchgear	EN 60296	-
IEC 60455-2	-	Resin based reactive compounds used for electrical insulation - Part 2: Methods of test	EN 60455-2	-
IEC 60464-2	-	Varnishes used for electrical insulation - Part 2: Methods of test	EN 60464-2	-
IEC 60684-2	-	Flexible insulating sleeving - Part 2: Methods of test	EN 60684-2	-
IEC 60836	-	Specifications for unused silicone insulating liquids for electrotechnical purposes	EN 60836	-
IEC 61099	-	Insulating liquids - Specifications for unused synthetic organic esters for electrical purposes	EN 61099	-
ISO 293	-	Plastics - Compression moulding of test specimens of thermoplastic materials	EN ISO 293	-
ISO 294-1	-	Plastics - Injection moulding of test specimens of thermoplastic materials - Part 1: General principles, and moulding of multipurpose and bar test specimens	EN ISO 294-1	-
ISO 294-3	-	Plastics - Injection moulding of test specimens of thermoplastic materials - Part 3: Small plates	EN ISO 294-3	-
ISO 295	-	Plastics - Compression moulding of test specimens of thermosetting materials	EN ISO 295	-
ISO 10724	Series	Plastics - Injection moulding of test specimens of thermosetting powder moulding compounds (PMCs)	EN ISO 10724	Series

CONTENTS

ELECTRIC STRENGTH OF INSULATING MATERIALS – TEST METHODS –

Part 1: Tests at power frequencies

1 Scope

This part of IEC 60243 provides test methods for the determination of short-time electric strength of solid insulating materials at power frequencies between 48 Hz and 62 Hz.

This standard does not cover the testing of liquids and gases, although these are specified and used as impregnates or surrounding media for the solid insulating materials being tested.

NOTE Methods for the determination of breakdown voltages along the surfaces of solid insulating materials are included.

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 60212, *Standard conditions for use prior to and during the testing of solid electical insulating materials*

IEC 60296, *Fluids for electrotechnical applications – Unused mineral insulating oils for transformers and switchgear*

IEC 60455-2, *Specification for solventless polymerizable resinous compounds used for electrical insulation – Part 2: Methods of test*

IEC 60464-2, *Varnishes used for electrical insulation – Part 2: Methods of test*

IEC 60684-2, *Flexible insulating sleeving – Part 2: Methods of test*

IEC 60836, *Specifications for unused silicone insulating liquids for electrotechnical purposes*

IEC 61099, *Insulating liquids – Specifications for unused synthetic organic esters for electrical purposes*

ISO 293, *Plastics – Compression moulding of test specimens of thermoplastic materials*

ISO 294-1, *Plastics – Injection moulding of test specimens of thermoplastic materials – Part 1: General principles, and moulding of multipurpose and bar test specimens*

ISO 294-3, *Plastics – Injection moulding of test specimens of thermoplastic materials – Part 3: Small plates*

ISO 295, *Plastics – Compression moulding of test specimens of thermosetting materials*

ISO 10724 (all parts), *Plastics – Injection moulding of test specimens of thermosetting powder moulding compounds (PMCs)*

3 Terms and definitions

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

3.1
electric breakdown
severe loss of the insulating properties of test specimens while exposed to electric stress, which causes the current in the test circuit to operate an appropriate circuit-breaker

Note 1 to entry: Breakdown is often caused by partial discharges in the gas or liquid medium surrounding the test specimen and the electrodes which puncture the specimen beyond the periphery of the smaller electrode (or of both electrodes, if of equal diameter).

3.2
flashover
loss of the insulating properties of the gas or liquid medium surrounding a test specimen and electrodes while exposed to electric stress, which causes the current in the test circuit to operate an appropriate circuit-breaker

Note 1 to entry: The presence of carbonized channels or punctures through the specimen distinguishes tests where breakdown occurred, from others where flashover occurred.

3.3
breakdown voltage

3.3.1
< tests with continuously rising voltage > voltage at which a specimen suffers breakdown under the prescribed test conditions

3.3.2
< step-by-step tests > highest voltage which a specimen withstands without breakdown for the duration of the time at that voltage level

3.4
electric strength
quotient of the breakdown voltage and the distance between the electrodes between which the voltage is applied under the prescribed test conditions

Note 1 to entry: The distance between the test electrodes is determined as specified in 5.5, unless otherwise specified.

4 Significance of the test

Electric strength test results obtained in accordance with this standard are useful for detecting changes or deviations from normal characteristics resulting from processing variables, ageing conditions or other manufacturing or environmental situations. However, they are not intended for use in evaluating the behaviour of insulating materials in an actual application.

Measured values of the electric strength of a material may be affected by many factors, including:

a) Condition of test specimens
   1) the thickness and homogeneity of the specimen and the presence of mechanical strain;
   2) previous conditioning of the specimens, in particular drying and impregnation procedures;

3) the presence of gaseous inclusions, moisture or other contamination.

b) Test conditions

1) the frequency, waveform and rate of rise or time of application of the voltage;
2) the ambient temperature, pressure and humidity;
3) the configuration, the dimensions, and thermal conductivity of the test electrodes;
4) the electrical and thermal characteristics of the surrounding medium.

The effects of all these factors shall be considered when investigating materials for which no experience exists. This standard defines particular conditions which give rapid discrimination between materials and which can be used for quality control and similar purposes.

The results given by different methods are not directly comparable but each may provide information on relative electric strengths of materials. The electric strength of most materials decreases as the thickness of the specimen between the electrodes increases and as the time of voltage application increases.

The measured electric strength of most materials is significantly affected by the intensity and the duration of surface discharges prior to breakdown. For designs which are free from partial discharges up to the test voltage, it is very important to know the electric strength without discharges prior to breakdown. However, the methods in this standard are generally not suitable for providing this information.

Materials with high electric strength will not necessarily resist long-term degradation processes such as heat, erosion or chemical deterioration by partial discharges, or electrochemical deterioration in the presence of moisture, all of which may cause failure in service at much lower stress.

5 Electrodes and specimens

5.1 General

The metal electrodes shall be maintained smooth, clean and free from defects at all times. Electrode arrangements for tests on boards and sheets perpendicular to the surface are shown in Figure 1.

NOTE This maintenance becomes more important when thin specimens are being tested. Stainless steel electrodes e.g. minimize electrode damage at breakdown.

The leads to the electrodes shall not tilt or otherwise move the electrodes, nor affect the pressure on the specimen, nor appreciably affect the electric field configuration in the neighbourhood of the specimen.

When very thin films (for example <5 μm thick) are to be tested, the standards for those materials shall specify the electrodes and special procedures for handling and specimen preparation.

5.2 Tests perpendicular to the surface of non-laminated materials and normal to laminate of laminated materials

5.2.1 Boards and sheet materials, including pressboards, papers, fabrics and films

5.2.1.1 Unequal electrodes

The electrodes shall consist of two metal cylinders with the edges rounded to give a radius of (3 ± 0,2) mm. One electrode shall be (25 ± 1) mm in diameter and approximately 25 mm high. The other electrode shall be (75 ± 1) mm in diameter and approximately 15 mm high. These two electrodes shall be arranged coaxially within 2 mm as in Figure 1a.

NOTE Radii for surface not in contact with the electrode are not critical with respect to test results but should avoid partial discharges in the surrounding medium.

5.2.1.2 Equal diameter electrodes

If a fixture is employed, which accurately aligns upper and lower electrodes within 1,0 mm, the diameter of the lower electrode may be reduced to (25 ± 1) mm, the diameters of the two electrodes differing by no more than 0,2 mm. The results obtained will not necessarily be the same as those obtained with the unequal electrodes of 5.2.1.1.

5.2.1.3 Sphere and plate electrodes

The electrodes shall consist of a metal sphere and a metal plate (see Figure 1c). The upper electrode shall be a sphere of (20 ± 1) mm in diameter and the lower one is a metal plate of (25 ± 1) mm in diameter with the edge rounded to give a radius of 2.5 mm. The discrepancy of the central axes between upper and lower electrodes shall be within 1 mm.

5.2.1.4 Tests on thick sample

When specified, boards and sheets over 3 mm thick shall be reduced by machining on one side to (3 ± 0,2) mm and then tested with the high-potential electrode on the non-machined surface.

When it is necessary in order to avoid flashover or because of limitations of available equipment, specimens may be prepared by machining to smaller thicknesses as needed.

5.2.2 Tapes, films and narrow strips

The electrodes shall consist of two metal rods, each (6 ± 0,1) mm in diameter, mounted vertically one above the other in a jig so that the specimen is held between the faces of the ends of the rods.

The upper and lower electrodes shall be coaxial within 0,1 mm. The ends of the electrodes shall form planes at right angles to their axes, with edge radii of (1 ± 0,2) mm. The upper electrode shall have a mass of (50 ± 2) g and shall move freely in the vertical direction in the jig.

Figure 2 shows an appropriate arrangement. If specimens are to be tested while extended, they shall be clamped in a frame holding them in the required position relative to the assembly shown in Figure 2. Wrapping one end of the specimen around a rotatable rod is one convenient way of achieving the required extension.

To prevent flashover around the edges of narrow tapes, the test specimen may be clamped using strips of film or other thin dielectric material overlapping the edges of the tape. Alternatively, gaskets that surround the electrodes may be used, provided that there is an annular space between electrode and gasket of 1 mm to 2 mm. The distance between the bottom electrode and the specimen (before the top electrode comes in contact with the specimen) shall be less than 0,1 mm.

NOTE For testing films see IEC 60674-2.

5.2.3 Flexible tubing and sleeving

To be tested according to IEC 60684-2.

5.2.4 Rigid tubes (having an internal diameter up to and including 100 mm)

The outer electrode shall consist of a band of metal foil (25 ± 1) mm wide. The inner electrode is a closely fitting internal conductor, e.g. rod, tube, metal foil or a packing of metal spheres

0,75 mm to 2 mm in diameter, making good contact with the inner surface. In each case, the ends of the inner electrode shall extend for at least 25 mm beyond the ends of the outer electrode.

Where no adverse effect will result, petroleum jelly may be used for attaching the foil to the inner and outer surfaces.

5.2.5 Tubes and hollow cylinders (having an internal diameter greater than 100 mm)

The outer electrode shall be a band of metal foil (75 ± 1) mm wide and the inner electrode, a disk of metal foil (25 ± 1) mm in diameter, flexible enough to conform with the curvature of the cylinder. The arrangement is shown in Figure 3.

5.2.6 Cast and moulded materials

5.2.6.1 Cast materials

Make test pieces and test according to IEC 60455-2.

5.2.6.2 Moulded materials

5.2.6.2.1 General

Use a pair of spherical electrodes, each (20 ± 0,1) mm in diameter, arranged on a common axis which is normal to the plane of the test specimen (see Figure 4) or, in case of elastomers, unequal electrodes according to 5.2.1.3 (see Figure 1c) .

5.2.6.2.2 Thermosets

Use test specimens of (1,0 ± 0,1) mm thickness, compression moulded in accordance with ISO 295; or injection moulded in accordance with the ISO 10724 series with lateral dimensions which are sufficient to prevent flashover (see 5.4).

If it is not possible to use specimens of (1,0 ± 0,1) mm thickness, specimens with a thickness of (2,0 ± 0,2) mm shall be used.

5.2.6.2.3 Thermoplastics

Use test specimens injection moulded in accordance with ISO 294-1 and ISO 294-3, ISO mould type D1 60 mm × 60 mm × 1 mm. If these dimensions are insufficient to prevent flashover (see 5.4) or if compression moulded test specimens are stipulated by the standard for the relevant material, use plates at least 100 mm in diameter and (1,0 ± 0,1) mm thick, compression moulded in accordance with ISO 293.

For the conditions of injection or compression moulding, see the standard for the relevant material. If there is no applicable material standard, the conditions shall be agreed between the interested parties.

5.2.6.2.4 Elastomers

Use test specimens of (1,0 ± 0,1) mm thickness with sufficient lateral dimensions to prevent flashover (see 5.4), moulded under standard conditions. If there is no effective standard the processing conditions shall be agreed between the interested parties.

As electrode arrangement, unequal electrodes according 5.2.1.3 (see Figure 1c) shall be used. In the case of elastomers of low hardness, e.g. silicone rubbers, a suitable casting material shall be used as embedding material or surrounding medium, respectively.

5.2.7 Shaped solid pieces

For shaped insulating specimens which do not have sufficient contact with the electrode's flat contact surface, the opposing identical spherical electrodes shall be used (see Figure 5). Commonly used electrodes for tests of this nature have diameters of 12,5 mm or 20 mm.

5.2.8 Varnishes

To be tested according to IEC 60464-2.

5.2.9 Filling compounds

The electrodes shall consist of two metal spheres, each 12,5 mm to 13 mm in diameter, arranged horizontally along the same axis (1 ± 0,1) mm apart, unless otherwise specified, and embedded in the compound. Care shall be taken to avoid cavities, particularly between the electrodes. As values obtained with the different electrode spacing are not directly comparable, the gap length shall be detailed in the specification for the compound and mentioned in the test report.

5.3 Tests parallel to the surface of non-laminated materials and parallel to the laminate of laminated materials

5.3.1 General

If it is not necessary to differentiate between failure by puncture of the specimen and failure across its surface, the electrodes of 5.3.2 or 5.3.3 may be used, those of 5.3.2 being preferred.

When the prevention of surface failure is required, the electrodes of 5.3.3 shall be used.

5.3.2 Parallel plate electrodes

5.3.2.1 Boards and sheets

For tests on boards and sheets, the test specimen shall be of the thickness of the material to be tested and rectangular, (100 ± 2) mm long and (25 ± 0,2) mm wide. The long edges shall be cut as parallel planes at right angles to the surface of the material. The test specimen is placed with the 25 mm width between parallel metal plates, not less than 10 mm thick, forming the electrodes between which the voltage shall be applied. For thin materials, two or three test specimens are used suitably placed (i.e. with their long edges at a convenient angle) to support the upper electrode. The electrodes shall be of sufficient size to overlap the edges of the test specimens by not less than 15 mm and care shall be taken to ensure good contact over the whole area of those edges. The edges of the electrodes shall be suitably rounded (3 mm to 5 mm) to avoid breakdown from edge to edge of the electrodes (see Figure 6).

If breakdown cannot be obtained with available equipment, the width of the specimens may be reduced to (15 ± 0,2) mm or (10 ± 0,2) mm. Such reduction of specimen width shall be specifically recorded in the test report.

This type of electrode is suitable only for tests on rigid materials at least 1,5 mm thick.

5.3.2.2 Tubes and cylinders

For tests on tubes and cylinders, the test specimen shall be a complete ring or a 100 mm circumferential portion of a ring of (25 ± 0,2)mm axial length. Both edges of the specimen shall be finished as parallel planes at right angles to the axis of the tube or cylinder. The specimen is tested between parallel plates as described in 5.3.2.1 for boards and sheets. Where necessary to support the upper electrode, two or three specimens are used. The electrodes shall be of sufficient size to overlap the edges of the specimens by not less than

15 mm and care shall be taken to ensure good contact over the whole area of the edges of the specimens.

5.3.3 Taper pin electrodes

Two parallel holes are drilled perpendicularly to the surface, with centres (25 ± 1) mm apart and of such a diameter that, after reaming with a reamer having a taper of approximately 2 %, the diameter of each hole at the larger end is not less than 4,5 mm and not greater than 5,5 mm.

The holes shall be drilled completely through the specimen or, in the case of large tubes, through one wall only, and shall be reamed throughout their full length.

When the specimens are drilled and reamed, the material adjacent to the holes shall not be damaged, e.g. split, broken or charred, in any way.

The taper pins used as electrodes shall have a taper of (2 ± 0,02) % and shall be pressed, not hammered into the holes so that they fit tightly and extend on each side of the test specimen by not less than 2 mm (see Figure 7, 7a and 7b).

This type of electrode is suitable only for tests on rigid materials at least 1,5 mm thick.

5.3.4 Parallel cylindrical electrodes

For tests on specimens of high electric strength and which are more than 15 mm thick, specimens 100 mm × 50 mm shall be cut and two holes drilled as shown in Figure 8 so that each is not more than 0,1 mm greater in diameter than each cylindrical electrode which shall be (6 ± 0,1) mm in diameter and have hemispherical ends. The base of each hole is hemispherical to mate with the end of the electrode, so that the gap between the end of the electrode and the base of the hole will not exceed 0,05 mm at any point. If not otherwise specified in the material specification, the holes shall be (10 ± 1) mm apart, edge-to-edge, throughout their length and extend to within (2,25 ± 0,25) mm of the surface opposite that through which they are drilled. Two alternative forms of vented electrodes are shown in Figure 8. When electrodes with slots are used, these slots shall be diametrically opposed to the gap between the electrodes.

5.4 Test specimens

In addition to the information concerning specimens given in the preceding subclauses, the following general points shall be noted.

In the preparation of test specimens from solid materials, care shall be taken that the surfaces in contact with the electrodes are parallel and as flat and smooth as the material allows.

For tests made perpendicularly to the surface of the material, test specimens need only be of sufficient area to prevent flashover under the conditions of test.

In tests made perpendicularly to the surface of the material, the results on specimens of different thicknesses are not directly comparable (see Clause 4).

5.5 Distance between electrodes

The value to be used in calculating the electric strength shall be one of the following, as specified for the material under test:

a) nominal thickness or distance between electrodes (use this value unless otherwise specified);

b) average thickness of the test specimen or distance between electrodes for tests parallel to the surface;

c) thickness or distance between electrodes measured immediately adjacent to the breakdown on each test specimen.

6 Conditioning before tests

The electric strength of insulating materials varies with temperature and moisture content. Where a specification is available for the material to be tested, this shall be followed. Otherwise, specimens shall be conditioned for not less than 24 h at (23 ± 2) °C, (50 ± 5) % relative humidity, that is, the standard ambient atmosphere of IEC 60212, unless other conditions are agreed upon.

7 Surrounding medium

7.1 General

Materials shall be tested in a surrounding medium selected to prevent flashover. Suitable materials may be transformer oil according to IEC 60296, silicone fluid according to IEC 60836 or ester fluid according to IEC 61099 or appropriate casting material. The surrounding medium shall not have significant interaction with the material under test, e.g. by causing swelling, during the time of testing.

Specimens having relatively low breakdown values may be tested in air, particularly if the tests are to be made at elevated temperature. Even at moderate test voltages, discharges at the edges of the electrodes may have significant effects on the test values.

If it is intended that the tests evaluate the behaviour of a material in another medium, that medium may be used.

Select a medium which has minimum deleterious effect on the material under test.

The effect of the ambient medium on the results may be great, particularly in the case of absorbent materials such as paper and pressboard, and it is essential that procedures for specimen preparation define fully all necessary steps (e.g. drying and impregnation), and the condition of the ambient medium during test.

Sufficient time shall be allowed for the specimen and the electrodes to attain the required temperature, but some materials may be affected by prolonged exposure to high temperatures.

7.2 Tests in air at elevated temperature

Tests in air at elevated temperature may be made in any well-designed oven of sufficient size to accommodate the test specimen and the electrodes without flashover occurring during the tests. Some means of circulating the air within the oven shall be provided so that a substantially uniform temperature within ±2 K of the specified temperature is maintained around the test specimen, and with a thermometer, thermocouple or other means for measuring the temperature as near the point of test as practicable.

7.3 Tests in liquids

When tests are conducted in an insulating liquid, it is necessary to ensure adequate electric strength of the liquid to avoid flashover. Specimens tested in liquids which have a higher relative permittivity than transformer oil may show a higher dielectric strength than when tested in transformer oil. Contamination which reduces the electric strength of the oil or other liquid may also increase the measured electric strength of test specimens.

Tests at elevated temperature may be made either in a container of liquid in an oven (see 7.1) or in a thermostatically controlled bath using the insulating liquid for heat transfer. In this case, suitable means for circulating the liquid, so that the temperature is substantially uniform and maintained within ±2 K of the specified temperature around the test specimen, shall be provided.

7.4 Tests in solid materials

For plate-shaped specimens of soft elastomers, a suitable casting material shall be used, which preferably cures at room temperature and has a permittivity similar to the tested elastomer. During the casting, voids shall be avoided, particularly in the volume between the cylindrical electrode and test plate by a vacuum treatment. The casting material shall have a sufficient adhesion at the electrodes and the surface of the test plate.

For silicone elastomers this can be silicone rubber of low viscosity (room temperature vulcanizing two components)

8 Electrical apparatus

8.1 Voltage source

The test voltage shall be obtained from a step-up transformer supplied from a variable sinusoidal low-voltage source. The transformer, its voltage source and the associated controls shall have the following properties.

The ratio of crest to root-mean-square (r.m.s.) test voltage shall be equal to $\sqrt{2}$ ±5 % (1,34...1,48), with the test specimen in the circuit, at all voltages up to and including the breakdown voltage.

The power rating of the source shall be sufficient to meet the requirements above until electric breakdown occurs. For most materials, using electrodes as recommended, an output current capacity of 40 mA is usually adequate. The power rating for most tests will vary from 0,5 kVA, for testing low-capacitance specimens at voltages up to 10 kV, to 5 kVA for voltages up to 100 kV.

The controls on the variable low-voltage source shall be capable of varying the test voltage smoothly, uniformly and without overshoots. When applying voltage in accordance with Clause 8, the incremental increase produced, e.g. by a variable autotransformer, shall not exceed 2 % of the expected breakdown voltage.

Motor-driven controls are preferable for making short-time or rapid-rise tests.

To protect the voltage source from damage, it shall be equipped with a device which disconnects the power supply within a few cycles on breakdown of the specimen. It may consist of a current-sensitive element in the HV supply to the electrodes.

To restrict damage by current or voltage surges at breakdown, it is desirable to include a resistor with a suitable value in series with the electrodes. The value of the resistor will depend on the damage which can be tolerated on the electrodes.

The use of a very high valued resistor may result in breakdown voltages which are higher than those obtained with a lower valued resistor.

8.2 Voltage measurement

The voltage values are recorded in equivalent r.m.s. values. It is preferable to use a peak-reading voltmeter and divide the reading by $\sqrt{2}$. The overall error of the voltage-measuring circuit shall not exceed 5 % of the measured value, including the error due to the response time of the voltmeter. The response-time induced error shall not be greater than 1 % of the breakdown voltage at any rate of rise used.

A voltmeter complying with the above requirements shall be used to measure the voltage applied to the electrodes. It shall preferably be connected directly to them, or via a potential divider or a potential transformer. If a potential winding on the step-up transformer is used for measurement, the accuracy of indication of the voltage applied to the electrodes shall be unaffected by the loading of the step-up transformer and the series resistor.

It is desirable for the reading that the maximum applied test voltage be retained on the voltmeter after breakdown so that the breakdown voltage can be accurately read and recorded, but the indicator shall not be sensitive to transients which can occur at breakdown.

9 Procedure

The document calling for the test shall state the following:

a) specimen to be tested;
b) method for measurement of specimen thickness (if not nominal);
c) any treatment or conditioning prior to test;
d) number of specimens, if other than five;
e) temperature of test;
f) surrounding medium;
g) electrodes to be used;
h) mode of increase of voltage;
i) whether the result is to be reported as electric strength or breakdown voltage.

Electrodes complying with Clause 5 shall be applied to the specimen in such a manner that damage to the specimen is avoided. Using apparatus providing a voltage complying with Clause 8, a voltage is applied between the electrodes and increased in accordance with 10.1 to 10.5. It is observed whether specimens suffer breakdown or flashover (see Clause 11).

10 Mode of increase of voltage

10.1 Short-time (rapid-rise) test

The voltage shall be raised from zero at a uniform rate until breakdown occurs.

A rate of rise shall be selected for the material under test which will cause breakdown most commonly to occur between 10 s and 20 s. For materials which differ considerably in their breakdown voltage, some samples may fail outside these limits. It is satisfactory if the majority of breakdowns occur between 10 s and 20 s.

Other rates of voltage rise that meet the breakdown time criteria mentioned above may also be used, when agreed to by all parties.

The rate of rise shall be chosen from the following:

100 V/s; 200 V/s; 500 V/s; 1 000 V/s; 2 000 V/s; 5 000 V/s; etc.

For a broad spectrum of materials, a commonly used rate of rise is 500 V/s. For moulded materials, a rate of rise of 2 000 V/s is recommended to obtain comparable data in accordance with IEC 60296.

For multipoint data presented as a ratio of non-exposed vs exposed specimens (such as long term thermal aging), identical rates of rise shall be used for all specimens from both sets.

10.2 20 s step-by-step test

A voltage at 40 % of the probable short-time breakdown voltage shall be applied to the specimen. If the probable short-time value is not known, it shall be obtained in accordance with the method in 10.1.

If the test specimen withstands this voltage for 20 s without failure, the voltage shall be increased in incremental steps as defined in Table 1. Each increased voltage shall be immediately and successively applied for 20 s until failure occurs.

Table 1 – Increments of voltage increase (kilovolts, peak / $\sqrt{2}$)

When start voltage (kV) is	Increment kV
1,0 or less	10 % of start voltage
Over 1,0 to 2,0	0,1
Over 2,0 to 5,0	0,2
Over 5,0 to 10,0	0,5
Over 10 to 20	1,0
Over 20 to 50	2,0
Over 50 to 100	5,0
Over 100 to 200	10,0
Over 200	20,0

When specified, smaller voltage increments may be used. In such cases, higher starting voltages are permissible, but breakdown shall not occur in less than 120 s.

The increases of voltage shall be made as quickly as possible and without any transient overvoltage, and the time spent in raising the voltage shall be included in the period of 20 s at the higher voltage.

If breakdown occurs in less than six levels from the start of the test, a further five specimens shall be tested, using a lower starting voltage.

The electric strength shall be based on the highest nominal voltage which is withstood for 20 s without breakdown.

10.3 Slow rate-of-rise test (120 s... 240 s)

The voltage shall be raised from 40 % of the probable short-time breakdown voltage at a uniform rate such that breakdown occurs between 120 s and 240 s. For materials which differ considerably in their breakdown voltage, some samples may fail outside these limits. It is satisfactory if the majority of breakdowns occur between 120 s and 240 s. The rate of rise of voltage shall be initially selected from the following:

2 V/s; 5 V/s; 10 V/s; 20 V/s; 50 V/s; 100 V/s; 200 V/s; 500 V/s; 1 000 V/s; etc.

Other rates of voltage rise that meet the breakdown time criteria mentioned above may also be used, when agreed to by all parties.

10.4 60 s step-by-step test

Unless otherwise specified, the test shall be carried out in accordance with 10.2 but with a step duration of 60 s.

10.5 Very slow rate-of-rise test (300 s... 600 s)

Unless otherwise specified, this test is carried out in accordance with 10.3 but with breakdowns occurring between 300 s and 600 s with a rate of rise of voltage selected from the following:

1 V/s; 2 V/s; 5 V/s; 10 V/s; 20 V/s; 50 V/s; 100 V/s; 200 V/s; etc.

NOTE The slow rate-of-rise tests of 120 s...240 s in 10.3, and 300 s...600 s in 10.5 produce approximately the same results as the 20 s (see 10.2) or 60 s (see 10.4) step-by-step tests. They are more convenient than the step-by-step tests when using modern automated equipment and they are included to enable such equipment to be used.

Other rates of voltage rise that meet the breakdown time criteria mentioned above may also be used, when agreed to by all parties.

10.6 Proof tests

When it is required to apply a predetermined proof voltage for the purpose of a proof or withstand test, the voltage shall be raised to the required value as rapidly as possible, consistent with its accurate attainment without any transient overvoltage. This voltage is then maintained at the required value for the duration of the specified time.

11 Criterion of breakdown

Electric breakdown is accompanied by an increase of current flowing in the circuit and by a decrease of voltage across the specimen. The increased current may trip a circuit-breaker or blow a fuse. However, tripping of a circuit-breaker may sometimes be influenced by flashover, specimen charging current, leakage or partial discharge currents, equipment magnetizing current or malfunctioning. It is therefore essential that the circuit-breaker is well coordinated with the characteristics of the test equipment and the material under test otherwise the circuit-breaker may operate without breakdown of the specimen, or fail to operate when breakdown has occurred and thus not provide a positive criterion of breakdown. Even under the best conditions, premature breakdowns in the ambient medium may occur, and observations shall be made to detect them during tests. If breakdowns in the ambient medium are observed, they shall be reported.

For materials for which the sensitivity of the fault-detecting circuit is of particular significance, the standard for that material shall so specify.

Where tests are made perpendicularly to the surface of a material, there is usually no doubt when breakdown has occurred and subsequent visual inspection readily shows the actual breakdown channel, whether this is filled with carbon or not.

If in tests parallel to the surface it is required that failure by puncture and failure across the surface are differentiated (see 5.3), this can be done by examination of the specimen or in some cases by reapplying a voltage less than that of the first apparent breakdown. A convenient practice that has been found is the reapplication of half the breakdown voltage, followed by increasing the voltage until failure is reached by the same procedure as in the first test.

12 Number of tests

Unless otherwise specified, five tests shall be conducted and the electric strength or breakdown voltage determined from the median of the test results. If any test result deviates by more than 15 % from the median, five additional tests shall be made. The electric strength or breakdown voltage shall then be determined from the median of the 10 results.

When tests are made for purposes other than routine quality control, larger numbers of specimens will be necessary depending on the variability of the material and the statistical analysis to be applied.

Refer to Annex A for references which may be useful for determining the number of tests needed and the interpretation of data for other than routine quality control tests.

13 Report

Unless otherwise specified, the report shall include the following:

a) a complete identification of the material tested, a description of the specimens and their method of preparation;

b) the median of the electric strengths in kilovolts/millimetres and/or breakdown voltages in kilovolts;

c) the thickness of each test specimen (see 5.4);

d) the surrounding medium during the test and its properties;

e) the electrode system;

f) the mode of application of the voltage and the frequency;

g) the individual values of electric strengths in kV/mm and/or breakdown voltage in kV;

h) the temperature, pressure and humidity during tests in air or other gas; or the temperature of the surrounding medium when this is a liquid;

i) the conditioning treatment before test;

j) an indication of the type and position of breakdown.

When the shortest statement of results is required, the first six items and the lowest and highest values shall be included.

Dimensions in millimetres

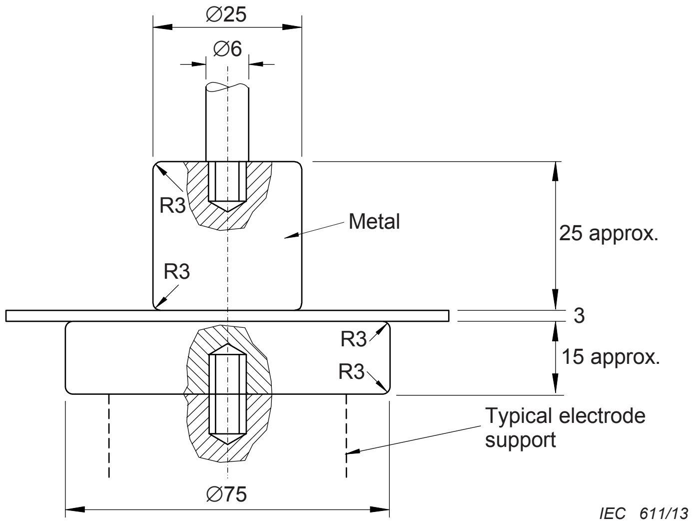


Figure 1a – Unequal electrodes

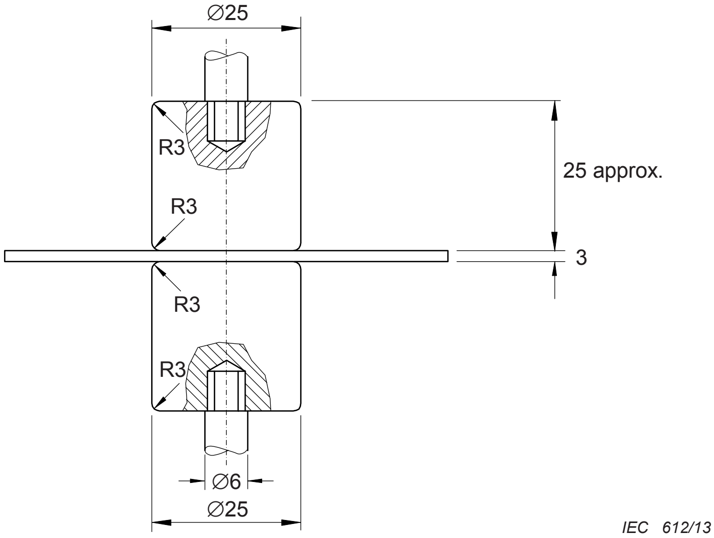


Figure 1b – Equal diameter electrodes

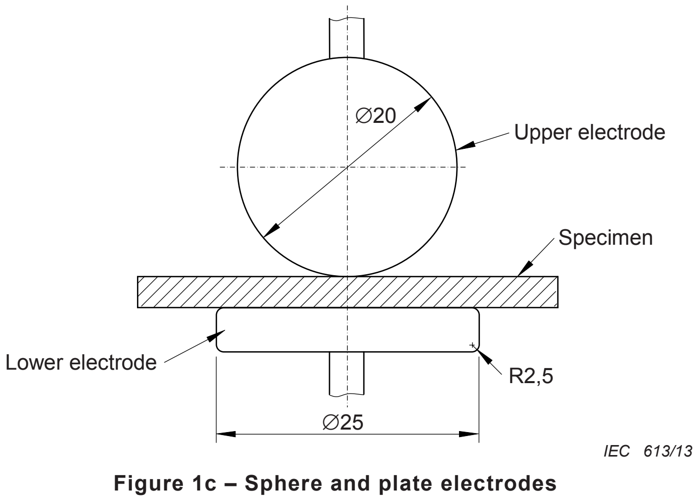
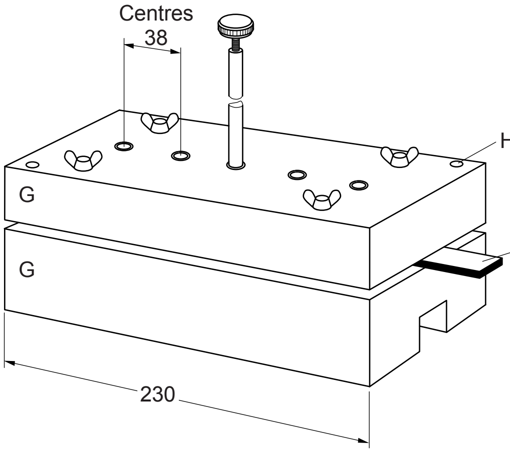


Figure 1c – Sphere and plate electrodes

All tolerances for linear measures ± 1 mm for radius ± 2 mm

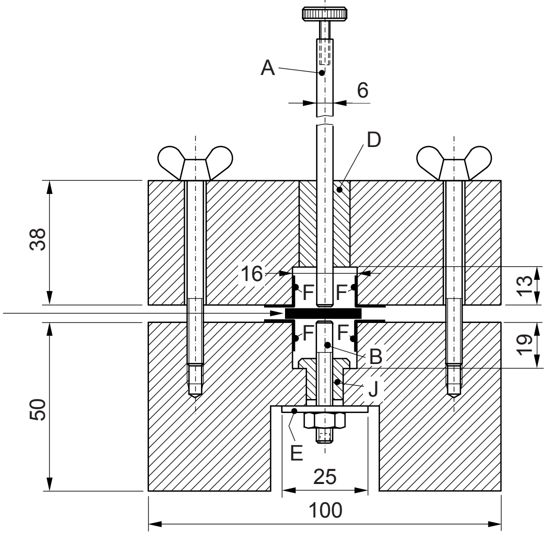
Figure 1 – Electrode arrangements for tests on boards and sheets perpendicular to the surface

Dimensions in millimetres



IEC 614/13

Figure 2a – General arrangement of apparatus



IEC 615/13

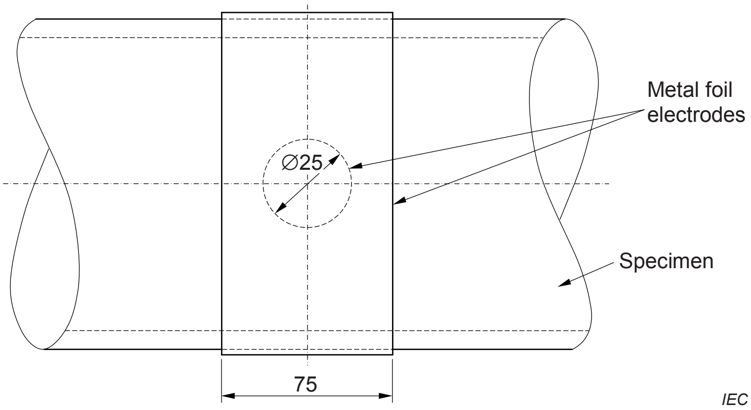
Figure 2b – Section of apparatus through electrodes with top slightly raised

Key

A upper electrode to be an easy fit in bush D
B lower electrode
C specimen under test
D brass bush with inside diameter just sufficient to clear 6 mm rod
E brass strip 25 mm wide connecting all lower electrodes
F pieces of film overlapping edges or specimen
G blocks of suitable insulating material, for example a paper filled laminate
H dowel hole
J brass bushing with internal thread

Figure 2 – Typical example of electrode arrangement for tests on tapes perpendicular to the surface (see 5.2.2)

Dimensions in millimetres



IEC 616/13

Figure 3 – Electrode arrangement for tests perpendicular to the surface on tubes and cylinders with internal diameter greater than 100 mm

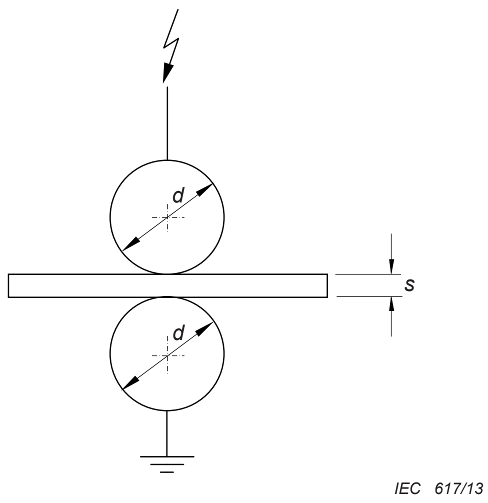


Figure 4 – Electrode arrangement for tests on casting and moulding materials (diameter of the spherical electrodes: *d* = (20 ± 0,1) mm)

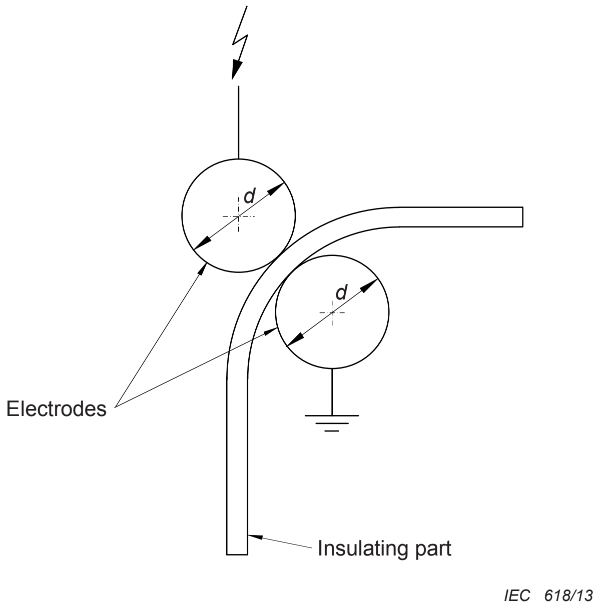


Figure 5 – Electrode arrangement for test on shaped insulating parts (see 5.2.7)

Dimensions in millimetres

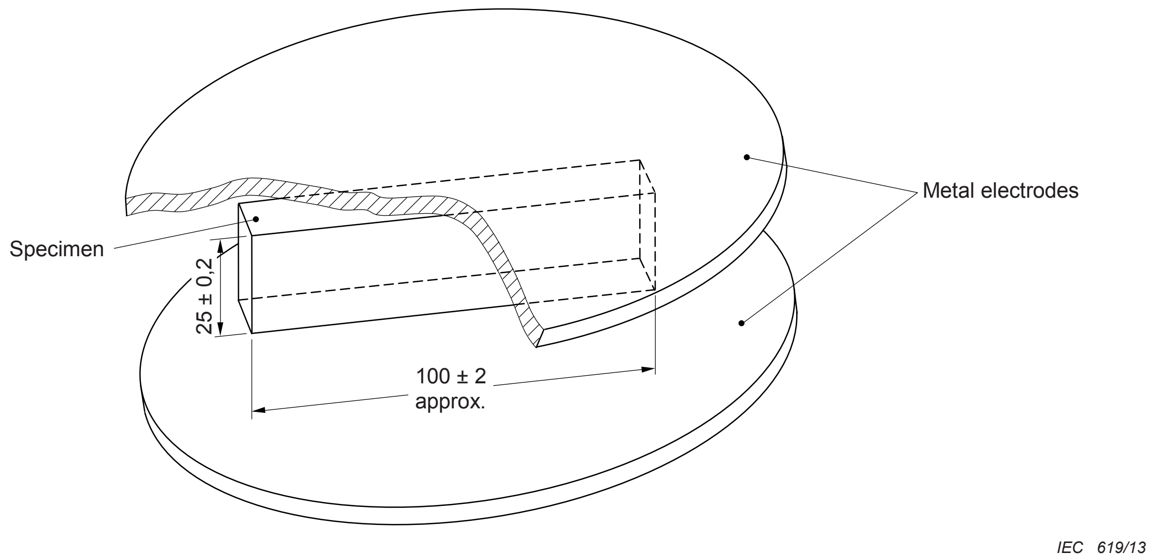


Figure 6 – Electrode arrangement for tests parallel to the surface (and along the laminae, if present)

Dimensions in millimetres

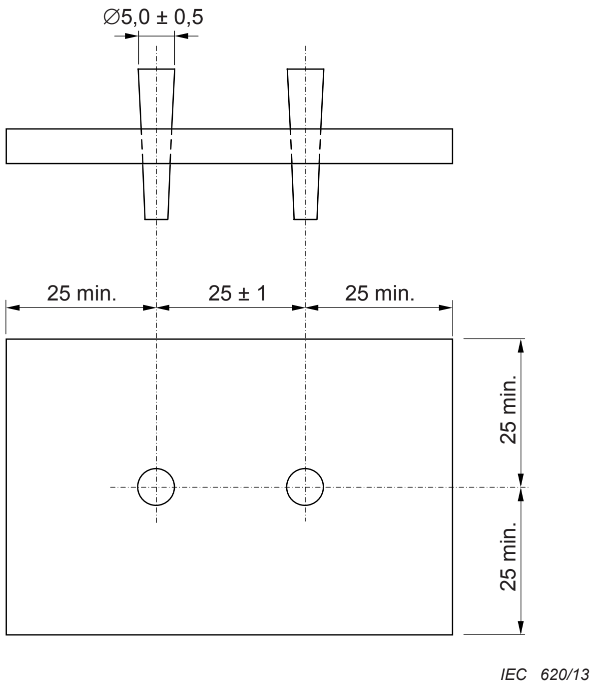


Figure 7a – Plate specimen with taper pin electrodes

Dimensions in millimetres

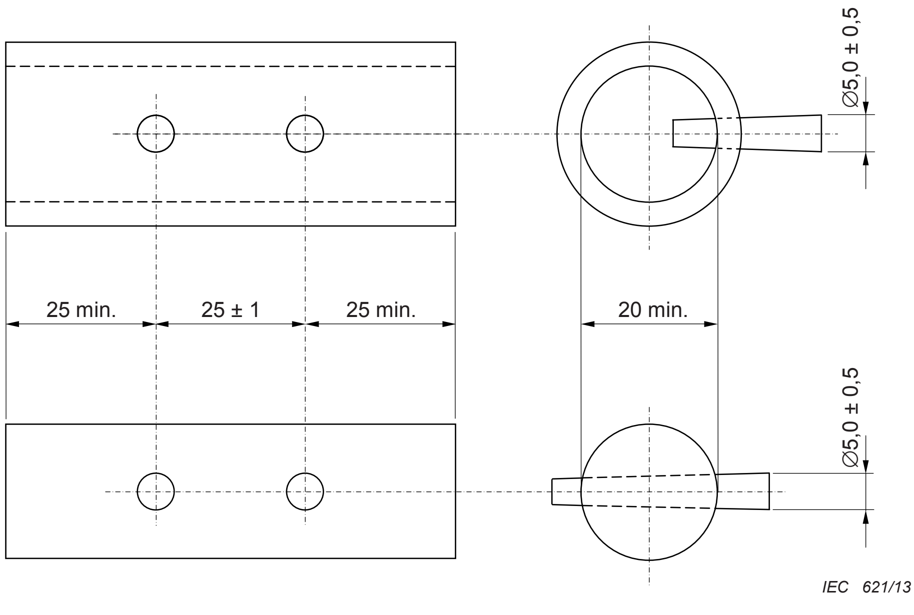


Figure 7b – Tube or rod specimens with taper pin electrodes

Figure 7 – Electrode arrangement for tests parallel to the surface (and along the laminae if present)

Dimensions in millimetres

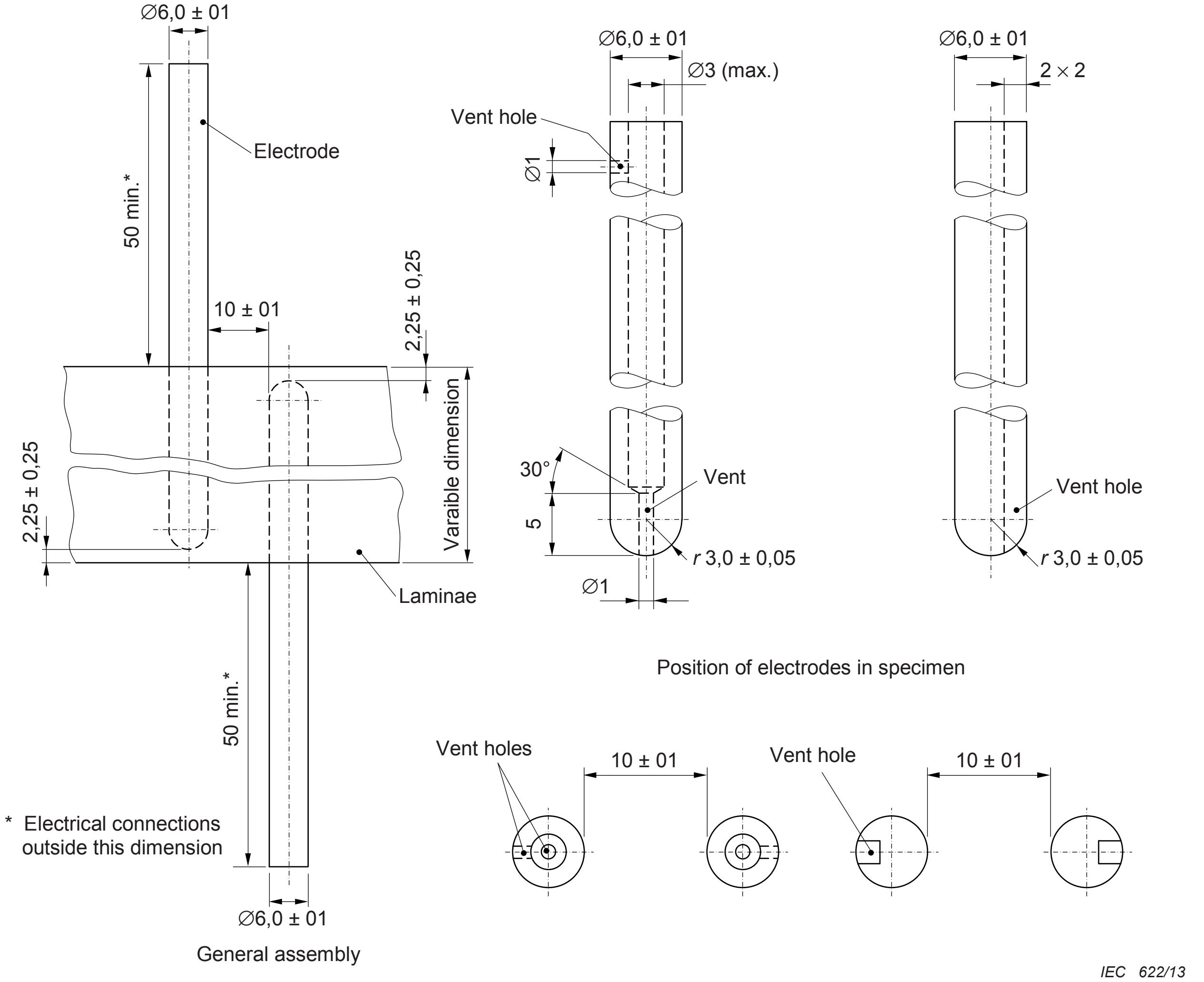


Figure 8 – Arrangement for tests parallel to the laminae for boards more than 15 mm thick with parallel cylindrical electrodes (see 5.3.4)

Annex A
(informative)

Treatment of experimental data

For routine testing, the procedure given in Clause 12 is ordinarily adequate for analysis and reporting of data. However, many research studies require more information about the response of materials to electric stress, so that larger numbers of specimens and more involved evaluation of test results may be needed.

Procedures for designing test procedures in such cases and for analysing the resultant data have been published. Some of these are shown in the Bibliography.

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