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INTERNATIONAL STANDARD

NORME INTERNATIONALE

Electric strength of insulating materials – Test methods – Part 1: Tests at power frequencies

Rigidité diélectrique des matériaux isolants – Méthodes d'essai – Partie 1: Essais aux fréquences industrielles

IEC 60243-1:2013

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

ELECTRIC STRENGTH OF INSULATING MATERIALS – TEST METHODS –

Part 1: Tests at power frequencies

FOREWORD

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International Standard IEC 60243-1 has been prepared by technical committee 112: Evaluation and qualification of electrical insulating materials and systems.

This third edition cancels and replaces the second edition, published in 1998, and constitutes a technical revision.

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

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

FDIS	Report on voting
112/237/FDIS	112/248/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 the parts in the IEC 60243 series, published under the general title *Electric strength of insulating materials – Test methods,* can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site 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- withdrawn,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.

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.