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colour inside

Insulating materials – Industrial rigid laminated sheets based on thermosetting resins for electrical purposes –
Part 2: Methods of test

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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INSULATING MATERIALS –
INDUSTRIAL RIGID LAMINATED SHEETS BASED ON THERMOSETTING RESINS FOR ELECTRICAL PURPOSES –

Part 2: Methods of test

FOREWORD

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This redline version of the official IEC Standard allows the user to identify the changes made to the previous edition IEC 60893-2:2003. A vertical bar appears in the margin wherever a change has been made. Additions are in green text, deletions are in strikethrough red text.

IEC 60893-2 has been prepared by IEC technical committee 15: Solid electrical insulating materials. It is an International Standard.

This third edition cancels and replaces the second edition published in 2003. This edition constitutes a technical revision.

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

a) removal of reference to withdrawn specification IEC 60167:1964;
b) inclusion of reference to IEC 62631-3-3:2015, which supersedes IEC 60167:1964. Details in 6.3 have been updated accordingly. The actual performance of the test has not changed;
c) normative references have been updated.

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

Draft	Report on voting
15/1017/FDIS	15/1023/RVD

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

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

A list of all parts in the IEC 60893 series, published under the general title *Insulating materials – Industrial rigid laminated sheets based on thermosetting resins for electrical purposes*, can be found on the IEC website.

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

- reconfirmed,
- withdrawn, or
- revised.

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INTRODUCTION

This document is one of a series which deals with industrial rigid laminated sheets based on thermosetting resins for electrical purposes.

This series consists of four parts:

- Part 1: Definitions, designations and general requirements (IEC 60893-1);
- Part 2: Methods of test (IEC 60893-2);
- Part 3: Specifications for individual materials (IEC 60893-3);
- Part 4: Typical values (IEC TR 60893-4).

INSULATING MATERIALS – INDUSTRIAL RIGID LAMINATED SHEETS BASED ON THERMOSETTING RESINS FOR ELECTRICAL PURPOSES –

Part 2: Methods of test

1 Scope

This part of IEC 60893 describes methods of test for the materials defined in IEC 60893-1 (referred to also as Part 1).

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60112, *Method for ~~determining the comparative and the proof tracking indices of solid insulating materials under moist conditions~~ the determination of the proof and the comparative tracking indices of solid insulating materials*

~~IEC 60167:1964, *Methods of test for the determination of the insulation resistance of solid insulating materials*~~

IEC 60212:~~1971~~2010, *Standard conditions for use prior to and during the testing of solid electrical insulating materials*

IEC 60216-1:~~2001~~2013, *Electrical insulating materials – ~~Properties of~~ Thermal endurance properties – Part 1: Ageing procedures and evaluation of test results*

IEC 60243-1:~~1998~~2013, *Electric strength of ~~solid~~ insulating materials – Test methods – Part 1: Tests at power frequencies*

~~IEC 60250:1969, *Recommended methods for the determination of the permittivity and dielectric dissipation factor of electrical insulating materials at power, audio and radio frequencies including metre wavelengths*~~

IEC 60296:~~1982~~2012[1], *~~Specification for unused mineral insulating oils for transformers and switchgear~~ Fluids for electrotechnical applications – Unused mineral insulating oils for transformers and switchgear*

IEC 60587:~~1984~~2007[2], *~~Test method for evaluating resistance to tracking and erosion of electrical insulating materials used under severe ambient conditions~~ Electrical insulating materials used under severe ambient conditions – Test methods for evaluating resistance to tracking and erosion*

1 A fifth edition of this standard has been published in 2020.

2 A fourth edition of this standard has been published in 2022.

IEC 60695-11-10:19992013, *Fire hazard testing – Part 11-10: Test flames – 50 W horizontal and vertical flame test methods*

IEC 60893-1, *Insulating materials – Industrial rigid laminated sheets based on thermosetting resins for electrical purposes – Part 1: Definitions, designations and general requirements*[3]

IEC 60893-3 (all parts -3), *Insulating materials – Industrial rigid laminated sheets based on thermosetting resins for electrical purposes – Part 3: Specifications for individual materials*

IEC TR 60893-4:2003, *Insulating materials – Industrial rigid laminated sheets based on thermosetting resins for electrical purposes – Part 4: Typical values*

IEC 62631-3-3:2015, *Dielectric and resistive properties of solid insulating materials – Part 3-3: Determination of resistive properties (DC methods) – Insulation resistance*

ISO 62:19992008, *Plastics – Determination of water absorption*

ISO 178:20012010[4], *Plastics – Determination of flexural properties*

ISO 179-1:2000[5], *Plastics – Determination of Charpy impact properties – Part 1: Non-instrumented impact test*

ISO 179-2:1997[6], *Plastics – Determination of Charpy impact properties – Part 2: Instrumented impact test*

ISO 180:2000[7], *Plastics – Determination of Izod impact strength*

ISO 527-1:19932012[8], *Plastics – Determination of tensile properties – Part 1: General principles*

ISO 527-4:1997[9], *Plastics – Determination of tensile properties – Part 4: Test conditions for isotropic and orthotropic fibre-reinforced plastic composites*

ISO 604:2002, *Plastics – Determination of compressive properties*

~~ISO 1183:1987, *Plastics – Methods for determining the density and relative density of non-cellular plastics*~~

ISO 1183-1:2012[10], *Plastics – Methods for determining the density of non-cellular plastics – Part 1: Immersion method, liquid pyknometer method and titration method*

~~3 Use edition 2 when published.~~

4 A sixth edition of this standard has been published in 2019.

5 A third edition of this standard has been published in 2023.

6 A second edition of this standard has been published in 2020.

7 A fifth edition of this standard has been published in 2023.

8 A third edition of this standard has been published in 2019.

9 A third edition of this standard has been published in 2023.

10 A third edition of this standard has been published in 2019.

ISO 3611:~~1978~~2010[11], ~~*Micrometer callipers for external measurement*~~ *Geometrical product specifications (GPS) – Dimensional measuring equipment: Micrometers for external measurements – Design and metrological characteristics*

3 Terms and definitions

No terms and definitions are listed in this document.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- IEC Electropedia: available at https://www.electropedia.org/
- ISO Online browsing platform: available at https://www.iso.org/obp

4 Conditioning of test specimens

Unless otherwise specified, test specimens shall be conditioned for at least 24 h in standard atmosphere B according to IEC 60212:2010 (temperature ~~23 °C ± 2 K~~ 23 ± 2 °C, relative humidity (50 ± 5) %).

Unless otherwise specified, each specimen shall be tested in the conditioning atmosphere and at the conditioning temperature, or the tests shall commence within 3 min of removal of each test specimen from the conditioning atmosphere.

Where testing at an elevated temperature is required in one of the specification sheets of IEC 60893-3, test specimens shall be conditioned for 1 h at that elevated temperature immediately before testing.

5 Dimensions

5.1 Thickness

5.1.1 General

Any method which enables the thickness of the laminated sheet to be measured at an appropriate number of points may be used, provided that the equipment used and the method of measurement are capable of a precision of 0,01 mm or better.

The following reference method has been shown to be suitable and shall be used in cases of dispute.

5.1.2 Test apparatus for reference method

In case of dispute, an external screw type micrometer in accordance with ISO 3611 having faces with diameters between 6 mm and 8 mm shall be used.

5.1.3 Procedure for reference method

Measure the thickness of the rigid laminated sheet as delivered to the nearest 0,01 mm at eight points, two along each edge but not less than 20 mm from the edge.

[11] A third edition of this standard has been published in 2023.

5.1.4 Results

Report the maximum and minimum measured values and the arithmetic mean of all measured values in mm.

5.2 Flatness

5.2.1 General

This test is applicable to all sheets having a thickness of 3 mm or greater.

5.2.2 Test specimens

The test specimen shall be the whole sheet or panel under test in the 'as received' condition.

5.2.3 Test method

When any sheet of nominal thickness 3,0 mm or more is placed without restraint, concave side up, on a flat surface, the departure at any point of the upper surface of the sheet from a light straight edge 1 000 mm or 500 mm in length, laid in any direction upon it, shall not exceed the value given in the relevant sheet of IEC 60893-3 appropriate to the material, its thickness and length of straight edge. The mass of the 1 000 mm straight edge shall not exceed 800 g, and the mass of the 500 mm straight edge shall not exceed 400 g.

5.2.4 Results

Report the maximum measured deviation from flatness in mm.

~~NOTE~~ In cases where the sheet deviates from flatness in two directions, is saddle-shaped, measure both deviations and report the highest.

6 Mechanical tests

6.1 Flexural strength

6.1.1 General

The flexural strength is defined as the flexural stress at rupture. It shall be determined by the method specified in ISO 178. Method A shall be used.

6.1.2 Test specimens

Cut the test specimens from the sheet to be tested with their major axes parallel to the sides of the sheet. Test five test specimens in each direction, except for types with fibres aligned mainly in the same direction. In such cases, cut five specimens only, with their long axis parallel to the direction of the fibres.

If the nominal thickness of the sheet to be tested is more than 10 mm (20 mm in the case of types PF WV), reduce the thickness of the test specimens to 10 mm (20 mm in the case of PF WV).

When it is necessary to reduce the thickness of a test specimen, machine it, leaving one face of the sheet intact. In such cases, test specimens shall be tested with the original surface of the sheet in contact with the two supports.

6.1.3 Test method

The test shall be carried out with the load applied perpendicular to the plane of the laminations. The test speed shall be 5 mm/min with a tolerance of ±20 %.

6.1.4 Results

Report the arithmetic mean of the results for each direction in MPa. Take the lower of the two mean values as the minimum flexural strength of the sheet under test, except in cases where the reinforcing fibres run mainly in one direction. In such cases, take the mean value obtained in this direction.

6.2 Modulus of elasticity in flexure

6.2.1 General

The following test method shall be used in order to determine the modulus of elasticity in flexure.

6.2.2 Test specimens

The specimens shall be in the same form as described for the flexural strength test described in 6.1.2 above.

6.2.3 Test method

Modulus of elasticity shall be determined by the method specified in ISO 178.

6.2.4 Results

Results shall be expressed in MPa.

6.3 Compressive strength

6.3.1 General

The following test method shall be used in order to determine the compressive strength.

6.3.2 Test specimens

Specimens shall be cut from the sheet under test as described in ISO 604.

6.3.3 Test method

Compressive strength shall be determined by the method specified in ISO 604 with the load applied perpendicular to the plane of the laminations.

6.3.4 Results

Results shall be expressed in MPa.

6.4 Impact strength

6.4.1 General

This test is only applicable to sheets of nominal thickness equal to or greater than 5 mm.

6.4.2 Charpy Impact strength

6.4.2.1 Test specimens

Test specimens shall be cut from the sheet under test in accordance with Figure 1 a). Five specimens, with a thickness between 5 mm and 10 mm, shall be tested in each direction, except for types with fibres aligned mainly in the same direction. In such cases, cut five specimens only, with their longitudinal axis parallel to the direction of the fibres.

If the nominal thickness of the sheet to be tested is greater than 10 mm, reduce the thickness of the test specimen to 10 mm by machining equal amounts from both faces of the sheet.

6.4.2.2 Test method

The Charpy impact strength shall be determined in the edgewise direction as described by the method given in ISO 179-1 and ISO 179-2 except that the specimens shall be as described above, and the span shall be 70 mm. The material shall be tested with the major axes in each direction parallel to the sides of the sheet, except in the case of materials whose fibres lie mainly in the same direction. For these materials only specimens with their longitudinal axis parallel to the direction of the fibres shall be tested.

6.4.2.3 Results

Report the arithmetic mean of the results for each direction in kJ/m^2. Take the lower of the two mean values as the minimum Charpy impact strength of the sheet under test, except in cases where the reinforcing fibres run mainly in one direction. In such cases, take the mean value obtained in this direction.

6.4.3 Izod impact strength

6.4.3.1 Test specimens

The dimensions of the specimens shall be as described in Figure 1 b). Five specimens, with a thickness between 5 mm and 10 mm, shall be tested in each direction, except for types with fibres aligned mainly in the same direction. In such cases, cut five specimens only, with their longitudinal axis parallel to the direction of the fibres.

If the nominal thickness of the sheet to be tested is greater than 10 mm, reduce the thickness of the test specimen to 10 mm by machining equal amounts from both faces of the sheet.

6.4.3.2 Test method

The Izod impact strength shall be determined in the edgewise direction as described by the method given in ISO 180. The material shall be tested with the major axes in each direction parallel to the sides of the sheet, except in the case of materials whose fibres lie mainly in the same direction. For these materials only, specimens with their longitudinal axis parallel to the direction of the fibres shall be tested.

6.4.3.3 Results

Report the arithmetic mean of the results for each direction in kJ/m^2. Take the lower of the two mean values as the minimum Izod impact strength of the sheet under test, except in cases where the reinforcing fibres run mainly in one direction. In such cases, take the mean value obtained in this direction.

6.5 Shear strength parallel to laminations

6.5.1 General

The shear strength parallel to laminations test provides data that gives an indication of the degree of bonding or adhesion between laminations. The test is only applicable to sheets of nominal thickness greater than 5 mm.

6.5.2 Test specimens

Rectangular test specimens are cut with the following dimensions:

Length 20 mm ± 0,1 mm

Width and thickness $5\,^{0}_{-0,15}$ mm

Cut the test specimens from the sheet to be tested with their major axes parallel to the sides of the sheet. Prepare five sets of test specimens for each direction, each set of specimens comprising two pieces.

The two specimens in each pair shall have widths (dimension along the laminations orthogonal to the length) identical within 0,01 mm.

6.5.3 Test method

Two test specimens are simultaneously subjected to shearing stress in the device shown in Figure 2.

The test specimens shall be arranged so that the shearing stress acts in a plane parallel to the laminations. The relative rate of movement of the cross head of the testing machine shall be 2 mm/min with a tolerance of ±20 %.

6.5.4 Results

Calculate the shear strength by dividing the shear force through the total shear plane area of 2 × 100 mm^2.

Report the arithmetic mean value of the results for each direction in MPa and take the lower of the two mean values as the parallel shearing strength of the sheet under test.

6.6 Tensile strength

6.6.1 General

Tensile strength defined as tensile stress at maximum load shall be determined by the method specified in ISO 527-4, in conjunction with ISO 527-1.

6.6.2 Test specimens

Specimens shall be cut from the sheet under test with the major axis in each direction parallel to the sides of the sheet. Five specimens of nominal thickness between 1,5 mm and 10,0 mm shall be prepared from each direction according to type 1 of ISO 527-4, except in the case of materials whose fibres lie mainly in the same direction. For these materials, only specimens with their longitudinal axis parallel to the direction of the fibres shall be tested.

If the sheet to be tested is more than 10 mm thick, reduce the thickness of the test specimens to 10 mm by machining equal amounts from each face.

6.6.3 Test method

Carry out the test as described in ISO 527-4. The rate of separation of the jaws of the testing machine shall be 5 mm/min with a tolerance of ±20 %.

6.6.4 Results

Report the arithmetic mean of the results for each direction in MPa. Take the lower of the two mean values as the minimum tensile strength of the sheet under test, except in cases where the reinforcing fibres run mainly in one direction. In such cases, take the mean value obtained in this direction.

7 Electrical tests

7.1 Electric strength and breakdown voltage

7.1.1 General

Electric strength and breakdown voltage shall be determined by the methods specified in IEC 60243-1, which describes both the step-by-step and 60 s proof tests. Either test method may be used. Unless otherwise specified the test shall be carried out at ~~90 °C ± 2 K~~ 90 ± 2 °C in mineral oil as described in IEC 60296:2012, which is reasonably free from decomposition products. Immerse the specimens in oil maintained at that temperature for not less than 0,5 h and not more than 1 h immediately before test.

7.1.2 Test specimens

For electric strength, test three specimens normal to laminations. For breakdown voltage, test three specimens parallel to the laminations.

Test specimens shall be cut from the sheet under test. Specimen dimensions shall be as described in IEC 60243-1.

7.1.3 Test method

7.1.3.1 General

Test the material using either the 20 s step-by-step test as described in 10.2 of IEC 60243-1:2013, or using the 60 s proof test as described in 10.6 of IEC 60243-1:2013.

7.1.3.2 Electric strength perpendicular to laminations

For thicknesses not greater than 3 mm, the material shall be tested perpendicular to the laminations. The upper electrode shall be 25 mm in diameter and the lower electrode shall be 75 mm in diameter according to IEC 60243-1.

~~NOTE~~ This test is usually not required for thicknesses above 3 mm, in the Part 3 series. When it is required, reduce the thickness of the specimens to 3 mm by machining one face according to 5.2.1.4 of IEC 60243-1:2013, and use the requirement of the 3 mm thickness.

7.1.3.3 Breakdown voltage parallel to laminations

For thicknesses above 3 mm and less than or equal to 10 mm, the material shall be tested edgewise in accordance with 5.3.3 of IEC 60243-1:2013 (taper pin electrodes) or with 5.3.2.1 of IEC 60243-1:2013, (parallel plate electrodes), and for thicknesses above 10 mm in accordance with 5.3.2.1 of IEC 60243-1:2013 (parallel plate electrodes). For types with their fibres mainly in the same direction the test shall be carried out in the fibre direction.

7.1.3.4 Results

For each of the above tests, the arithmetic mean of the test results shall be taken as the result. The minimum value shall also be reported. Results of the electric strength perpendicular to lamination test shall be reported in kV/mm, and the results of the breakdown voltage test parallel to laminations, shall be reported in kV.

7.2 Permittivity and dissipation factor

7.2.1 General requirements

Permittivity and dissipation factor may be determined by any one of the three methods given in 7.2.2. Unless otherwise indicated in the relevant clauses of IEC TR 60893-4, the specimens shall be conditioned for (96 ± 1) h in air at a temperature of ~~105 °C ± 5 K~~ 105 ± 5 °C with a relative humidity of less than 20 % (dry hot standard atmosphere according to IEC 60212:2010). At the end of this time, allow the specimens to cool to room temperature in a desiccator. Apply the electrodes, and/or otherwise make the measurements within 10 min of removal of each specimen from the desiccator.

Where intimate electrodes are required, silver paint shall be painted centrally on the test specimen. Conducting rubber, evaporated and sputtered electrodes shall not be used.

Unless otherwise specified, measurements shall be made at a temperature of ~~23 °C ± 2 K~~ 23 ± 2 °C at a power frequency between 48 Hz and 62 Hz or at a radio frequency of 1 MHz.

To ensure that the specimens, the electrodes and the immersion fluid are in thermal equilibrium with their environment during the measurement, they should all be kept at the measurement temperature for not less than 0,5 h immediately before the measurement. The test voltage shall be high enough to provide the required sensitivity, but low enough to avoid dielectric heating and discharges at the edges of the electrodes.

In all three methods, the test shall be carried out on two test specimens unless otherwise specified. At all times, the specimens shall be handled with stainless steel flat-faced forceps to minimize the likelihood of damage or contamination.

The average of the two determinations shall be taken as the result.

Reference to IEC 60250:1969 [1][12] should be made for additional guidance and clarification.

NOTE ~~1~~ In total, the three methods described ~~may~~can be used for sheet materials in the thickness range 0,3 mm to 12,0 mm, dependent upon the design of the specimen holders and electrodes, but the precision of each method is influenced by specimen dimensions and properties.

~~NOTE 2 Reference to IEC 60250 should be made for additional guidance and clarification.~~

7.2.2 Methods

Method A – A direct measuring method utilizing intimate electrodes

Method B – An air substitution technique without intimate electrodes

Method C – A two-fluid immersion technique without intimate electrodes

Method A is suitable for sheet materials of permittivity up to 10,0 and dissipation factors greater than 50 × 10^{-6}, having thicknesses in the range 0,3 mm to 12,0 mm, dependent upon the design of the specimen holders. Method A requires an accurate knowledge of the specimen thickness and may be used in all cases when this information is available. See 7.2.3.

Method B is suitable for sheet materials of permittivity up to 10,0 but ~~may~~ can lack sufficient precision for materials of dissipation factor below 250 × 10^{-6}. Method B requires an accurate knowledge of the specimen thickness and may be used in place of method A when this information is available. Dependent upon the design of the specimen holders, specimens with thicknesses in the range 0,3 mm to 12,0 mm can be tested.

Method C is suitable for materials of permittivity up to 10,0 but may show a lack of precision for materials of dissipation factor below 250 × 10^{-6}. If the thickness is not sufficiently accurately known, method C may be used subject to the limitation that the method requires use of an inert liquid of approximately the same permittivity as the specimen.

[12] Numbers in square brackets refer to the Bibliography.

The immersion method, C, is capable of better precision for permittivity for sheet materials of thickness 0,3 mm to 1,0 mm and has the advantage that accurate knowledge of the specimen thickness is not required, but it is not suitable for materials with an open cell structure.

7.2.3 Principles of the methods

In the methods described, the electrode assembly is an integral part of the specimen holder into which the specimen is placed. In method A, backing electrodes make contact with the intimate electrodes and the properties of the specimen are measured with the specimen in the form of a simple capacitor. The specific advantage of method A is that measurements may be made at elevated temperatures, limited only by the thermal properties of the specimen.

In Methods B and C, the specimen and appropriate insulating fluid(s) are introduced into the specimen holder, the capacitance and dissipation factor of the assembly being measured. Such systems introduce smaller errors in measurement than those using intimately applied electrodes, and facilitate the easier provision of guard electrodes that minimize electric field distortions and stray capacitances.

Suitable electrode systems for each of the methods are described in 7.2.5.2, 7.2.6.2 and 7.2.7.2. Suitable measuring instruments are described in 7.2.4.

~~NOTE~~ The permittivity and dissipation factor of a dielectric ~~may~~ can change considerably with frequency, temperature and relative humidity. Accordingly, the measured values should only be taken to indicate the dielectric properties of the specimen under conditions similar to those used for the test.

7.2.4 Measuring instruments

Instruments of adequate sensitivity shall be used. Minimum detectable changes in capacitance of 0,3 fF(= 0,3 × 10^{-15} F) and minimum detectable changes in dissipation factor of 0,000 01 (= 10 × 10^{-6}) have been found to be acceptable.

NOTE 1 A variety of modes of output is offered by commercial measuring equipment. Some of the more sophisticated offer a variety of outputs from the same instrument thus enabling the user to select the appropriate output. This standard assumes that the output is in the form of capacitance (C, in pF) and dissipation factor (tanδ). See Annex A for conversion of other forms of output to this format.

NOTE 2 The electrode systems described in methods A, B and C are of three terminal 'guarded' design. This practically eliminates the influence of stray electric fields at the electrode edges and removes the need for 'edge capacitance' corrections.

~~NOTE 3 Care should be taken to ensure that~~ All measuring leads ~~are~~ should be screened and kept as short as possible, consistent with the instrument manufacturer's instructions.

Some types of instruments require a 'short' and 'open' circuit calibration. The 'short circuit' should be established between the electrodes of the electrode system, in the position that the specimen would occupy. Care should be taken to ensure that the short circuit used is of low resistance and inductance and that it does not damage the surfaces of the electrodes. It is essential also to ensure the micrometer zero is not altered. A smooth-edged U-shaped piece of springy metal is suitable for use as a short circuit. The 'open' circuit is established by disconnection of the electrodes at the end of the cables farthest from the capacitance meter, so that allowance is again made for the effect of the measuring leads. Reference should be made to the manufacturer's instructions to determine whether it is necessary to link the outer connections of the coaxial cables during this calibration and whether the error introduced by omission of the electrode system is small and may be ignored. In any case it is preferable to use a three terminal measuring instrument, for example with 'high', 'low' and 'guard' connections.

~~NOTE 4~~ Many commercial instruments are now based on measurement of current, voltage and phase angle. These instruments are commonly of four (or five) terminal design. Reference should be made to the manufacturer's instructions concerning the preferred mode of connecting a three terminal electrode system to such an instrument.

7.2.5 Method A: Direct measurement technique

7.2.5.1 Principle

After measurement of the specimen thickness, intimate electrodes are painted on to the specimen that is then inserted into the guarded specimen holder and placed between the backing electrodes. The separation of the backing electrodes is reduced until they make contact with the intimate electrodes. Measurements of the specimen capacitance and dissipation factor are made.

The permittivity of the test material is calculated from the measured capacitance and thickness. The dissipation factor is usually read directly from the measuring instrument.

7.2.5.2 Electrode system

The electrode system shall be of rigid mechanical design and of sufficient thermal capacity so that rapid changes in ambient temperature do not significantly affect its dimensions. It shall comprise a circular measuring electrode surrounded by a concentric coplanar guard electrode, and a movable electrode whose separation from the measuring electrode is controlled by a spring-loaded arrangement with a screw thread. Rotation of the screw drive mechanism allows the spring-loaded electrodes to close on to the intimate electrodes. The screw rotation should not be transmitted to the electrode.

Figure 3 illustrates a possible construction and means of connection to a three terminal measuring instrument.

~~NOTE~~ For connection to instruments having four or more terminals, reference should be made to the manufacturer's instructions.

7.2.5.3 Test specimens

The test piece shall be essentially flat and uniform in thickness and shall extend beyond the unguarded electrode by at least 2 mm. Wherever possible, test specimens shall be used as recommended by the manufacturer of the electrode system. For the electrode system shown the test piece shall be either:

a) a flat circular sheet (61 ± 1) mm in diameter, or

b) a flat square sheet, 60 mm × 60 mm is sufficient but a rectangular sheet (61 ± 1) mm by (100 ± 1) mm is preferred to ease test specimen handling.

The thickness at any point shall not vary by more than 1 % from the mean value.

~~NOTE~~ If possible, it is recommended that the specimen be of the same thickness and prepared by the same process as the electrical insulating material under evaluation. If it is necessary to reduce its thickness, ~~take care to ensure that~~ its surfaces ~~are~~ shall not be contaminated during the process.

The maximum tolerance deviation from a straight edge placed along a diameter or diagonal on the concave side, shall be less than 10 % of the thickness.

7.2.5.4 Determination of test piece thickness

Determine the test piece thickness with a micrometer conforming to 5.1.1. Measure four values of thickness at points equally spaced around the periphery of the test piece, and a fifth value centrally. Calculate the arithmetic mean thickness of each test piece as t.

7.2.5.5 Application of electrodes

Apply the silver paint electrodes using a masking technique and following the manufacturer's instructions. The outer diameter of the guarded electrode should be as specified by the manufacturer of the measuring instrument and should be larger than the corresponding backing electrode. The inner diameter of the guard electrode should be correspondingly smaller than the backing guard electrode.

The outer diameter of the unguarded electrode should be approximately the same as the diameter of the unguarded backing electrode.

7.2.5.6 Measurement of capacitance and dissipation factor

Place the specimen into the specimen holder and close the backing electrodes until they make contact with the intimate electrodes on the specimen, ensuring that the intimate electrodes align with the backing system.

Measure and record the specimen capacitance, dissipation factor, test frequency and humidity.

Repeat the measurements on a second specimen.

7.2.5.7 Calculations

Calculate the effective area of the test piece in cm^2:

$$A = \left(\frac{\pi}{4}\right)(d_1 + g)^2 \tag{1}$$

and the (relative) permittivity

$$\varepsilon_r = \frac{3{,}6\pi C t}{A} \tag{2}$$

where

C is the measured capacitance in pF;

t is the test piece thickness in cm;

d_1 is the diameter of guarded electrode in cm;

g is the width of gap between the guard and guarded electrodes in cm;

A is the effective electrode area in ~~m^2~~ cm^2.

Determine the dissipation factor from the instrument reading.

Calculate the permittivity and the dissipation factor as the average from the two determinations.

7.2.5.8 Results

Record the result, the test frequency, temperature and humidity.

7.2.6 Method B: Air substitution technique

7.2.6.1 Principle

The test piece is inserted into a guarded electrode system in which the electrode separation is variable. Small air gaps are left between the sample and electrodes to ensure that the test piece is not mechanically stressed. The capacitance and dissipation factor of the assembly are measured.

The test piece is removed, and the electrode separation adjusted to give a capacitance reading which is the same as the value measured with the specimen in place. The electrode movement and the new value of dissipation factor are measured.

The permittivity and dissipation factor of the test material are calculated, as shown in 7.2.6.7, from the test piece thickness, the change in electrode spacing and the change in observed values of dissipation factor.

7.2.6.2 Electrode system

The electrode system shall be of rigid mechanical design and of sufficient thermal capacity so that rapid changes in ambient temperature do not significantly affect its dimensions. The system shall comprise a circular measuring electrode surrounded by a concentric coplanar guard electrode, and a movable electrode whose separation from the measuring electrode is controlled by a micrometer head. The precision of the micrometer shall be 0,01 mm. Rotation of the drive mechanism should not be transmitted to the electrode.

The electrode surfaces shall be flat and shall remain substantially parallel at all times.

Figure 4 illustrates a possible construction and means of connection to a three terminal measuring instrument.

~~NOTE 1~~ For connection to instruments with four or more terminals, reference should be made to the manufacturer's instructions.

~~NOTE 2~~ A more precise means of determining the changes in electrode spacing, e.g. a displacement transducer, which will not disturb the electric field between the electrodes, ~~may~~ can be introduced.

7.2.6.3 Test specimens

The test piece shall be approximately flat and uniform in thickness and shall extend beyond the unguarded electrode by at least 2 mm. Wherever possible, test specimens shall be used as recommended by the manufacturer of the electrode system. For the electrode system shown, the test piece shall be either:

a) a flat circular sheet (61 ± 1) mm in diameter, or
b) a flat square sheet, 60 mm × 60 mm is sufficient but a rectangular sheet (61 ± 1) mm by (100 ± 1) mm is preferred to ease test specimen handling.

The thickness shall be in the range appropriate for the specific test specimen holder. In most cases this will be between 0,3 mm and 12,0 mm. The thickness at any point shall not vary by more than 1 % from the mean value t, measured according to 7.2.6.4.

~~NOTE~~ If possible, it is recommended that the specimen be of the same thickness and prepared by the same process as the electrical insulating material under evaluation. If it is necessary to reduce its thickness ~~take care to ensure that~~, its surfaces ~~are~~ shall not be contaminated during the process.

The maximum tolerance deviation from a straight edge placed along a diameter or diagonal shall be less than 10 % of the thickness.

7.2.6.4 Determination of test piece thickness

Determine the test piece thickness with a micrometer conforming to 5.1.1. Measure four values of thickness at points equally spaced around the periphery of the test piece, and a fifth value centrally. Calculate the arithmetic mean thickness of each test piece as t.

7.2.6.5 Measurement of capacitance and dissipation factor

Insert the test piece between the electrodes and decrease the electrode gap until the upper electrode just fails to touch the test piece.

~~NOTE~~ Turn the micrometer screw until the upper electrode just touches the test piece, then turn the micrometer screw in the reverse direction until no resistance is felt against a small lateral movement of the sample.

Measure the capacitance and dissipation factor.

Record the value of the dissipation factor as tan δ_1, and the electrode spacing as m_1. Remove the test piece and decrease the electrode gap until the capacitance is returned to the original value. Record the new value of the dissipation factor as tan δ_2 and the electrode spacing as m_2.

Repeat this procedure for a further test piece.

Record the frequency, temperature and relative humidity at which the measurements were made.

Calculate the values of permittivity and dissipation factor for each set of measurements as shown in 7.2.6.7.

Calculate the means of these values as the permittivity and dissipation factor of the material under test.

7.2.6.6 Symbols

tan δ_1 is the dissipation factor of electrode assembly with test piece present;

tan δ_2 is the dissipation factor of electrode assembly without test piece;

Δtan δ = (tan δ_1 – tan δ_2);

m_1 is the micrometer reading with test piece present, in mm;

m_2 is the micrometer reading without test piece, in mm;

Δm = $(m_1 - m_2)$ in mm;

t is the specimen thickness in mm;

tan δ is the dissipation factor of material;

ε_r is the (relative) permittivity of material.

7.2.6.7 Calculation of permittivity and dissipation factor

Permittivity:

Calculate the (relative) permittivity

$$\varepsilon_r = \frac{t}{t - \Delta m} \quad (3)$$

Dissipation factor:

Calculate the dissipation factor

$$\tan\delta = \Delta \tan\delta \left(\frac{m_2}{t - \Delta m} \right) \quad (4)$$

7.2.6.8 Expression of results

The result shall be the arithmetic mean of the determinations on individual test specimens. Record all of the individual values.

7.2.7 Method C: Two fluid immersion technique

7.2.7.1 Principle

As with method B, the electrode spacing is only slightly greater than the test piece thickness. Although, in principle, either or both of the fluids used in this method may be liquids or gases, this standard permits only the use of a gas (usually air) as the first fluid, and a liquid as the second fluid.

The test piece is inserted into a guarded electrode system, the electrode spacing adjusted, the test piece removed and the capacitance and dissipation factor measured. The test piece is replaced and the capacitance and dissipation factor of the electrode system are re-measured. After removal of the test piece, the space between the electrodes is filled with the immersion liquid and the capacitance and dissipation factor measured. The test piece is inserted and the capacitance and dissipation factor re-measured. The permittivity and dissipation factor of the test material are calculated as shown in 7.2.7.8.

7.2.7.2 Electrode system

The electrode system shall be of rigid mechanical design and of sufficient thermal capacity so that rapid changes in ambient temperature do not significantly affect its dimensions. The system shall comprise a circular measuring electrode surrounded by a concentric coplanar guard electrode, and a moveable electrode, the separation of which from the measuring electrode is controlled by a micrometer head. The drive mechanism shall be linked with the electrodes so that the electrode does not rotate with the drive mechanism. Both electrodes shall be mounted vertically so that air bubbles dragged into the liquid with the specimen may escape.

The electrode surfaces shall be flat and shall remain substantially parallel at all times.

Figure 5 illustrates a possible construction and means of connection to a three terminal measuring instrument.

~~NOTE 1~~ For connection to instruments with four or more terminals, reference should be made to the manufacturer's instructions.

NOTE ~~2~~ The temperature of this cell ~~may~~ can be controlled to ±0,1 ~~K~~ °C by a liquid circulation system.

NOTE 3 The electrodes are preferably made from stainless steel. If they are made from brass, then all metal parts must shall be plated with hard bright gold having a minimum thickness of 10 µm.

7.2.7.3 Immersion fluids

Suitable liquids of known permittivity values are listed in Annex B (see Table B.1). Liquids which affect the properties of the test material, whether by swelling or by any other interaction shall not be used. The immersion fluid shall not be reused if the value of the dissipation factor of the cell fluid changes from its original value by more than 2 % or 10 × 10^{-6}, whichever is the greater.

NOTE Silicone fluid of viscosity 1 × 10^{-6} m^2/s to 2 × 10^{-6} m^2/s (1 cSt to 2 cSt) is satisfactory for use with many plastic materials, e.g. the polyolefins PE, PTFE, PET and polycarbonates. Cyclohexane is an acceptable fluid for use with PTFE. Perfluorinated liquids are excellent as they do not interact with most organic polymers. The liquid shall not be reused if the value of the dissipation factor of the cell fluid has changed by more than 2 % or 10 × 10^{-6}, whichever is the greater.

7.2.7.4 Test specimens

For the electrode system shown, the test piece shall be a rectangular sheet (61 ± 1) mm × (100 ± 1) mm. The thickness shall be between 0,3 mm and 1,0 mm.

NOTE The precise specimen thickness is not required. However, it may can be measured and used for comparison with that derived from the electrical measurements as a cross-check on the procedure. Wherever possible, specimens should be used as prepared by the manufacturer. However, if it is necessary to reduce their thickness, take care that the surfaces are shall not be contaminated during the process.

7.2.7.5 Preparation of test cell

Prepare a cell by rinsing several times with warm de-ionized water and then rinse with acetone. Dry the cell at 50 °C and allow to cool to the measuring temperature (see 7.2.1). After allowing at least 1 h for stabilization, the dissipation factor shall be less than (10 × 10^{-6}). Ensure that the electrode assembly, the liquids and the test piece in the desiccator, are in thermal equilibrium at the measuring temperature to within ±0,1 K °C before commencing a test. Adjust the electrode spacing so that the specimen occupies at least 80 % of the gap but without filling the gap completely so that it may can be easily moved in and out.

7.2.7.6 Measurement of capacitance and dissipation factor

Connect the leads to the cell and follow the manufacturer's instructions as to the initial bridge calibration. Record the values of capacitance and dissipation factor as C_1 and tan δ_1 with air between the electrodes.

Insert the specimen into the air-filled cell. Record the values of capacitance and dissipation factor as C_2 and tan δ_2. Record the cell temperature to ±0,1 K °C.

NOTE 1 It is essential that The temperature of the test specimen and fluid temperatures are shall be very close to that of the guard block.

Remove the specimen from the cell and fill the cell with the fluid chosen. Measure the capacitance and dissipation factor and record the values as C_3 and tan δ_3.

Insert the specimen into the cell. Measure the capacitance and dissipation factor and record the values as C_4 and tan δ_4.

Remove the specimen from the cell after this measurement and repeat the procedure for a further test piece.

Calculate the values of permittivity and dissipation factor for each set of measurements as shown in 7.2.7.8.

Calculate the mean values of permittivity and material dissipation factor. Record the frequency, temperature and relative humidity at which measurements are made.

~~NOTE 2~~ For routine measurements, the following sequence, as shown in Table 1, ~~may~~ can be found more convenient, but in cases of dispute, the sequence of measurements given in the main text shall be used:

Table 1 – Sequence employed for routine measurements

Test specimen	Fluid	Use reading as
None	Air	$(C_1)_1$ $(C_1)_2$
1	Air	$(C_2)_1$
2	Air	$(C_2)_2$
None	Liquid	$(C_3)_1$ $(C_3)_2$
1	Liquid	$(C_4)_1$
2	Liquid	$(C_4)_2$
None	Liquid	$(C_3)_3$

7.2.7.7 Symbols

C_1 is the cell capacitance with air alone in pF;

C_2 is the cell capacitance with specimen in air in pF;

C_3 is the cell capacitance with fluid alone in pF;

C_4 is the cell capacitance with specimen in fluid in pF;

ΔC_A = $(C_2 - C_1)$ in pF;

ΔC_F = $(C_4 - C_3)$ in pF;

tan δ is the dissipation factor of specimen;

~~$\tan \delta_1$~~ D_1 is the dissipation factor of cell in air;

~~$\tan \delta_2$~~ D_2 is the dissipation factor with specimen in air;

~~$\Delta \tan \delta_A = (\tan \delta_2 - \tan \delta_1)$;~~

ΔD_A = $(D_2 - D_1)$;

A is the effective electrode area in m^2;

ε_0 is the electric constant 8,8542 pF × m^{-1}.

7.2.7.8 Calculation of permittivity and dissipation factor

Permittivity:

Calculate the (relative) permittivity

$$\varepsilon_r = 1 + \frac{C_4 \Delta C_A (C_3 - C_1)}{C_1 (C_4 \Delta C_A - C_2 \Delta C_F)} \tag{5}$$

Dissipation factor:

Calculate the dissipation factor from

$$\tan \delta = \frac{C_5 \Delta D_A}{\Delta C_A} \tag{6}$$

where

$$C_5 = \frac{C_2 C_4 (C_3 - C_1)}{(C_4 \Delta C_A - C_2 \Delta C_F)} \tag{7}$$

NOTE The calculated specimen thickness, t, is given by:

$$t = \frac{\varepsilon_r \varepsilon_0 A}{C_5} \tag{8}$$

This ~~may~~ can be compared with the measured thickness as an accuracy check.

7.2.7.9 Expression of results

The result shall be the mean of the determinations on individual specimens. Record also the individual values.

7.2.8 Test report

The following information shall be included in the test report:

a) reference to this standard and test method used, i.e. IEC 60893-2, Method A, B, or C;
b) type or designation of the insulating material and the form in which it was delivered;
c) method of fabrication of the specimen;
d) specimen thickness and information concerning the surface treatment (if any) at the electrode contact areas of the specimens;
e) method and duration of conditioning of the specimens if not as specified;
f) measuring instrument;
g) electrode and specimen dimensions if not as specified;
h) temperature and relative humidity during the test;
i) test voltage;
j) test frequency;
k) relative permittivity ε_r: arithmetic mean value, individual values;

l) dielectric dissipation factor (tan δ): arithmetic mean value, individual values;

m) date of test;

n) any unusual features noticed during the test.

7.3 Insulation resistance after immersion in water

7.3.1 General

Insulation resistance shall be determined using the method with taper pin electrodes, as specified in ~~IEC 60167~~ IEC 62631-3-3 and modified as described below. This test is applicable only to sheets of nominal thickness up to 25 mm inclusive.

7.3.2 Test specimens

Test specimens shall be cut from the sheet under test. Dimensions of the specimens shall be as described in ~~IEC 60167~~ IEC 62631-3-3:2015, Figure 1 a).

The holes in the test specimens shall be drilled with a suitable drill and then reamed with a taper pin reamer so that the diameter of each hole at the larger end is not less than 4,5 mm and not greater than 5,5 mm.

The material shall be tested with major axes in each direction, parallel to the sides of the sheet. Two specimens shall be tested in each direction. The thickness of the specimen shall be the thickness of the sheet under test.

7.3.3 Test method

Dry the test specimens in an oven at a temperature of ~~50 °C ± 2 K~~ 50 ± 2 °C for (24 ± 1) h and then immerse them in distilled or de-ionized water for (24 ± 1) h at a temperature of ~~23 °C ± 2 K~~ 23 ± 2 °C. At the end of this time, remove the test specimens from the water and remove the surface moisture by wiping with a clean dry cloth, absorbent paper or filter paper and insert the electrodes. Measure the insulation resistance at ~~25 °C ± 10 K~~ 25 ± 10 °C in an atmosphere of not more than 75 % relative humidity. Complete each measurement within 1,5 min to 2 min after removal from the water.

When it is possible to demonstrate that it does not affect the results, other drying conditions may be used (for example, drying for 1 h ± 5 min at ~~105 °C ± 5 K~~ 105 ± 5 °C) but in case of dispute, the specified method shall be used.

The applied voltage shall be 500 ± 10 V.

7.3.4 Results

Calculate the arithmetic mean of the measured values in each direction in MΩ and take the lower of the two arithmetic means as the insulation resistance after water immersion of the sheet under test.

7.4 Comparative and proof tracking indices

7.4.1 General

Test in accordance with IEC 60112.

7.4.2 Test specimens

Test specimens shall be cut from the sheet under test and shall be not less than 15 mm × 15 mm × the thickness of the sheet under test. The specimen thickness shall be equal or greater than 3 mm, which can be accomplished by stacking materials if necessary.

7.4.3 Test method

Comparative and proof tracking indices shall be determined by the method specified in IEC 60112. Test solution A shall be used.

7.4.4 Results

In the case of the Proof Tracking Index test, report pass or fail at the specified voltage as described in IEC 60112, and the thickness of the specimens tested. In the case of Comparative Tracking Index, report the value determined and the thickness of the specimens tested.

7.5 Tracking and erosion resistance

7.5.1 General

Test in accordance with IEC 60587.

7.5.2 Test specimens

Test specimens shall be cut from the sheet under test and shall be 50 mm × 120 mm × thickness of the sheet under test.

7.5.3 Test method

Tracking and erosion resistance shall be determined in accordance with IEC 60587 using the method specified in the relevant sheet of IEC 60893-3.

7.5.4 Results

Report pass or fail at the specified voltage as described in IEC 60587. Report also the thickness of the specimen tested.

8 Thermal tests

8.1 Thermal endurance

8.1.1 General

Thermal endurance shall be determined by the method specified in IEC 60216-1, and the relevant test specifications (i.e. IEC 60216-1 and ISO 178).

8.1.2 Test specimens

Specimens shall be cut from the sheet under test and their dimensions shall be as described in 6.1.2.

8.1.3 Test method

The ageing procedure used shall be as described in 5.5 and 5.6 of IEC 60216-1:2013. Unless otherwise specified, thermal endurance shall be determined using flexural strength as the distinguishing property (see 6.1) with 50 % reduction of the initial value as the end-point. Tests shall be carried out at ~~23 °C ± 5 K~~ 23 ± 5 °C.

8.1.4 Results

The thermal endurance shall be expressed, as described in 6.2 of IEC 60216-1:2013, with the temperature index at 20 000 h.

8.2 Flammability

8.2.1 General

Flammability shall be determined according to one of the methods given in IEC 60695-11-10, as specified in the relevant sheet of IEC 60893-3.

8.2.2 Test specimens

Specimens shall be cut from the sheet under test and their dimensions shall be as described in IEC 60695-11-10. Ensure that the specimens are free from dust or contamination.

8.2.3 Test method

Carry out the tests in accordance with the relevant clause of IEC 60695-11-10.

8.2.4 Results

Report the assigned classification in accordance with IEC 60695-11-10.

9 Other tests

9.1 Density

9.1.1 General

The following test method shall be used in order to determine the density.

9.1.2 Test specimens

Specimens shall be cut from the sheet under test as described in ISO 1183-1.

9.1.3 Test method

Density shall be determined using method A specified in ISO 1183-1.

9.1.4 Results

Results shall be expressed in g/cm^3.

9.2 Water absorption

9.2.1 General

Water absorption shall be determined in accordance with method 1 (6.2) of ISO 62:2008 and as modified below.

9.2.2 Test specimens

Three specimens shall be tested. The specimen dimensions shall be (50 ± 1) mm × (50 ± 1) mm × the thickness of the sheet under test except in cases where the nominal thickness of the sheet under test is greater than 25 mm. In such cases, the thickness of the test specimens shall be reduced to 22,5 mm ± 0,3 mm by machining one face only to a relatively smooth finish.

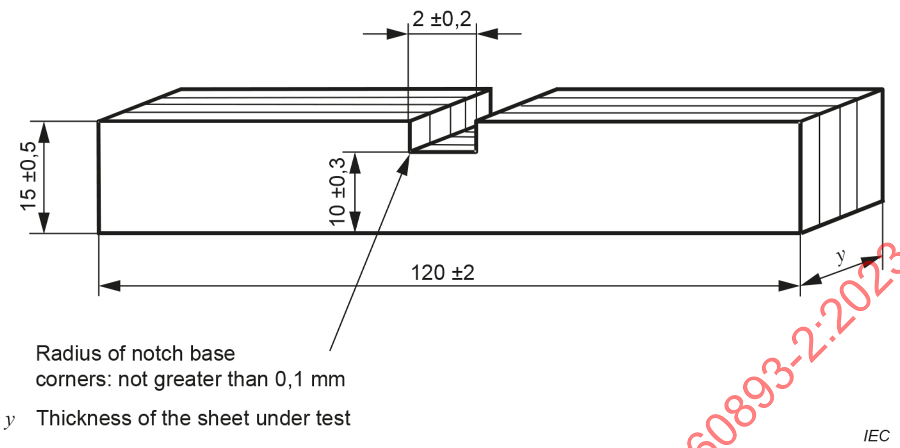
9.2.3 Test method

The test shall be performed as described in 6.2 of ISO 62:2008, maintaining the distilled or de-ionised water at ~~23 °C ± 0,5 K~~ 23 ± 0,5 °C.

9.2.4 Results

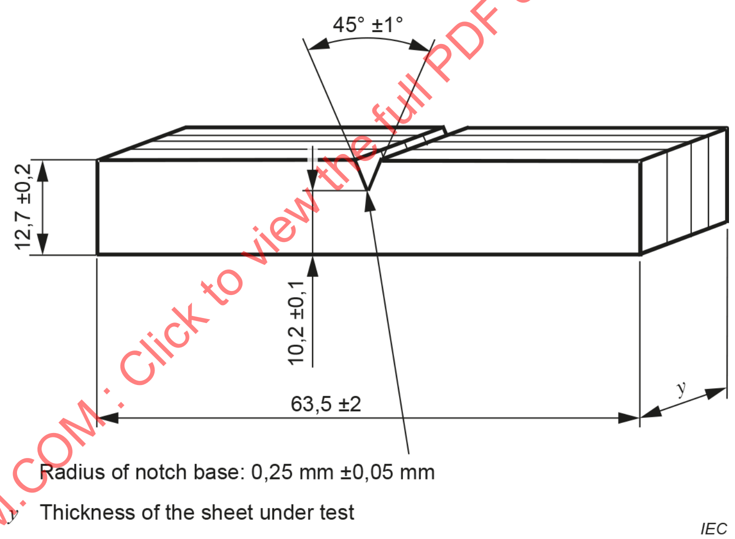
Results shall be expressed in mg in accordance with Clause 7 of ISO 62:2008. The arithmetic mean of the three results shall be reported as the water absorption.

Dimensions in millimetres



a) Test specimen for Charpy impact strength test

Dimensions in millimetres



b) Test specimen for Izod impact strength test

Figure 1 – Test specimens for impact strength test

Dimensions in millimetres

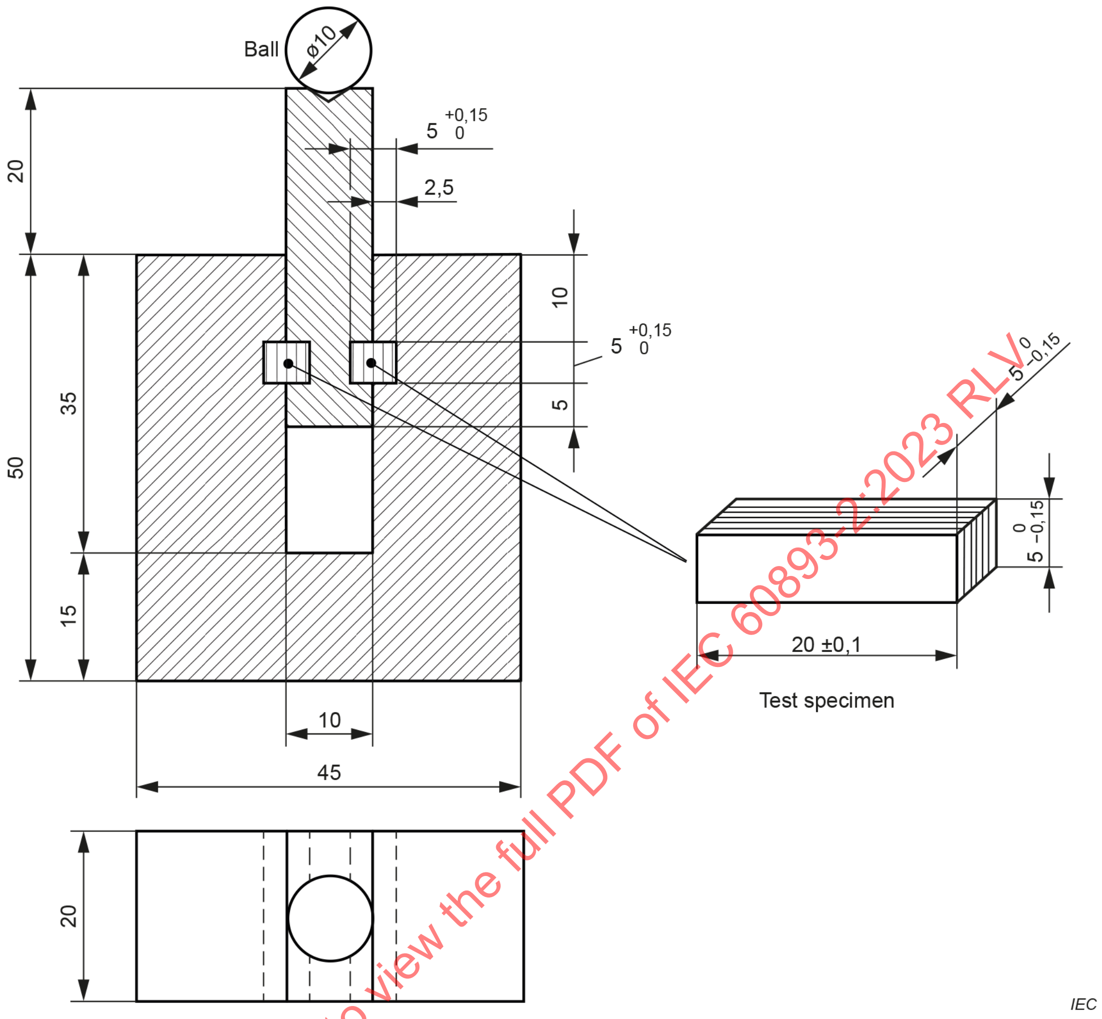


Figure 2 – Device for testing parallel shearing strength

Dimensions in millimetres

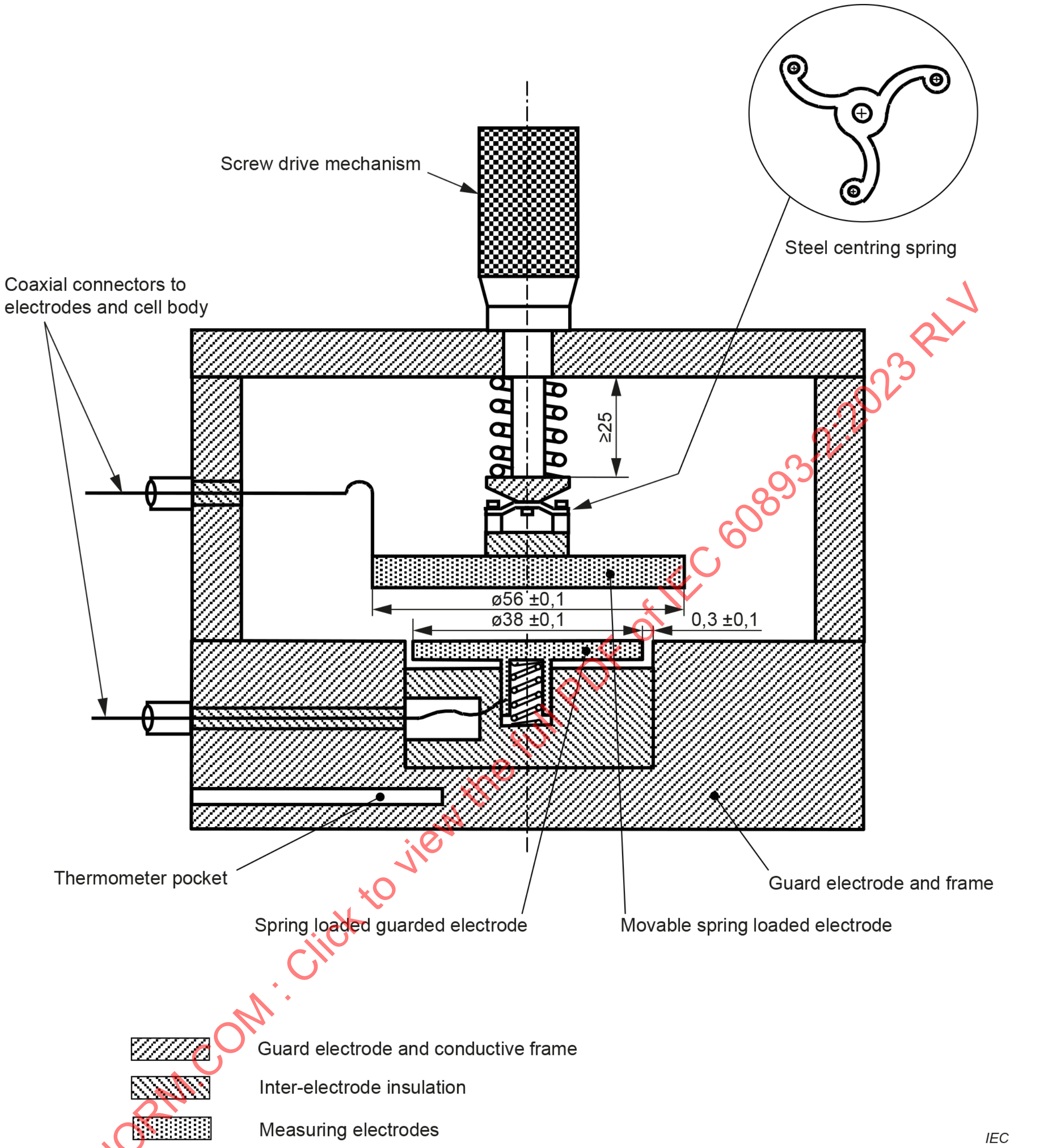


Figure 3 – Example of electrode system for method A

Dimensions in millimetres

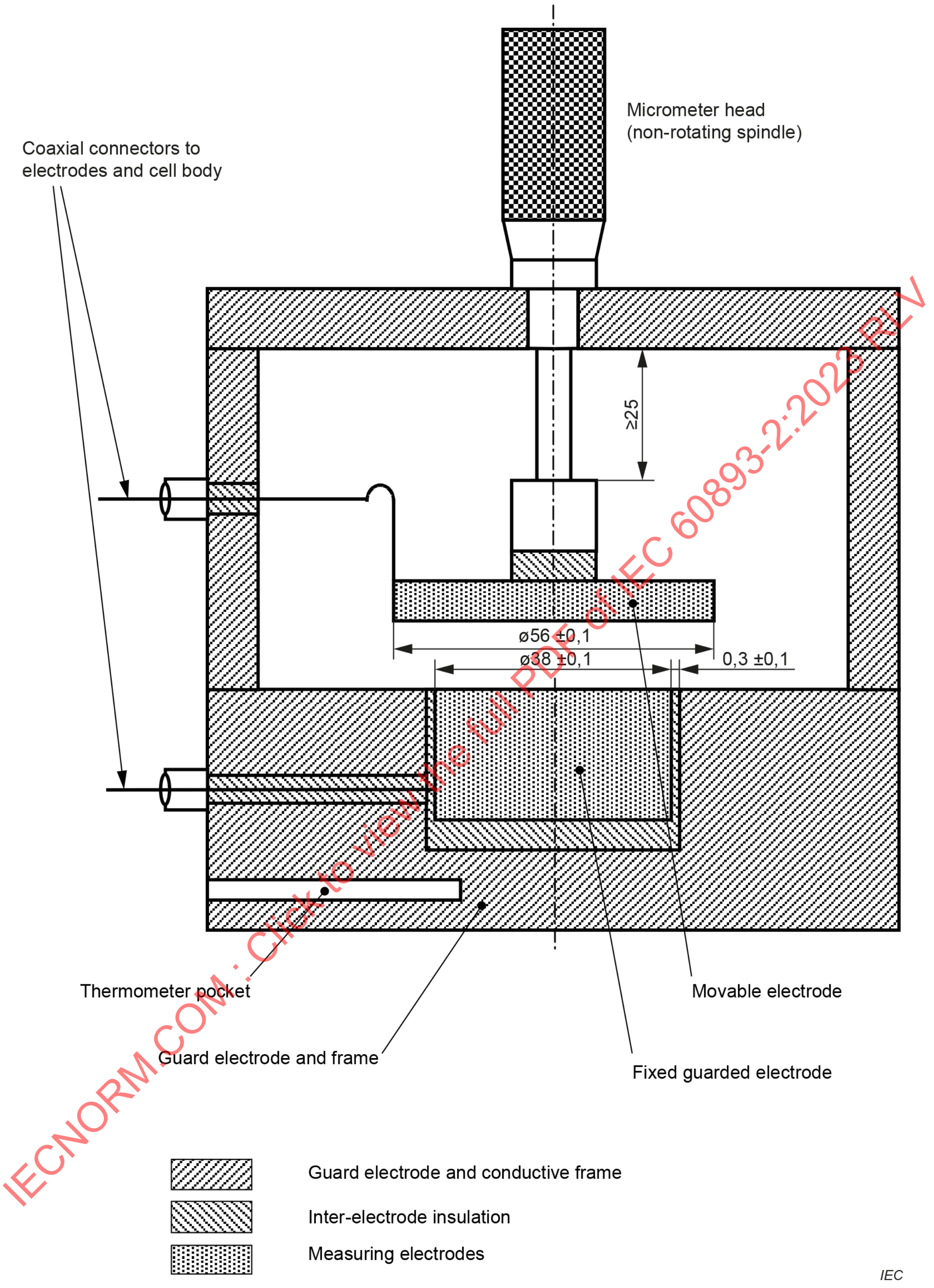


Figure 4 – Example of electrode system for method B

Dimensions in millimetres

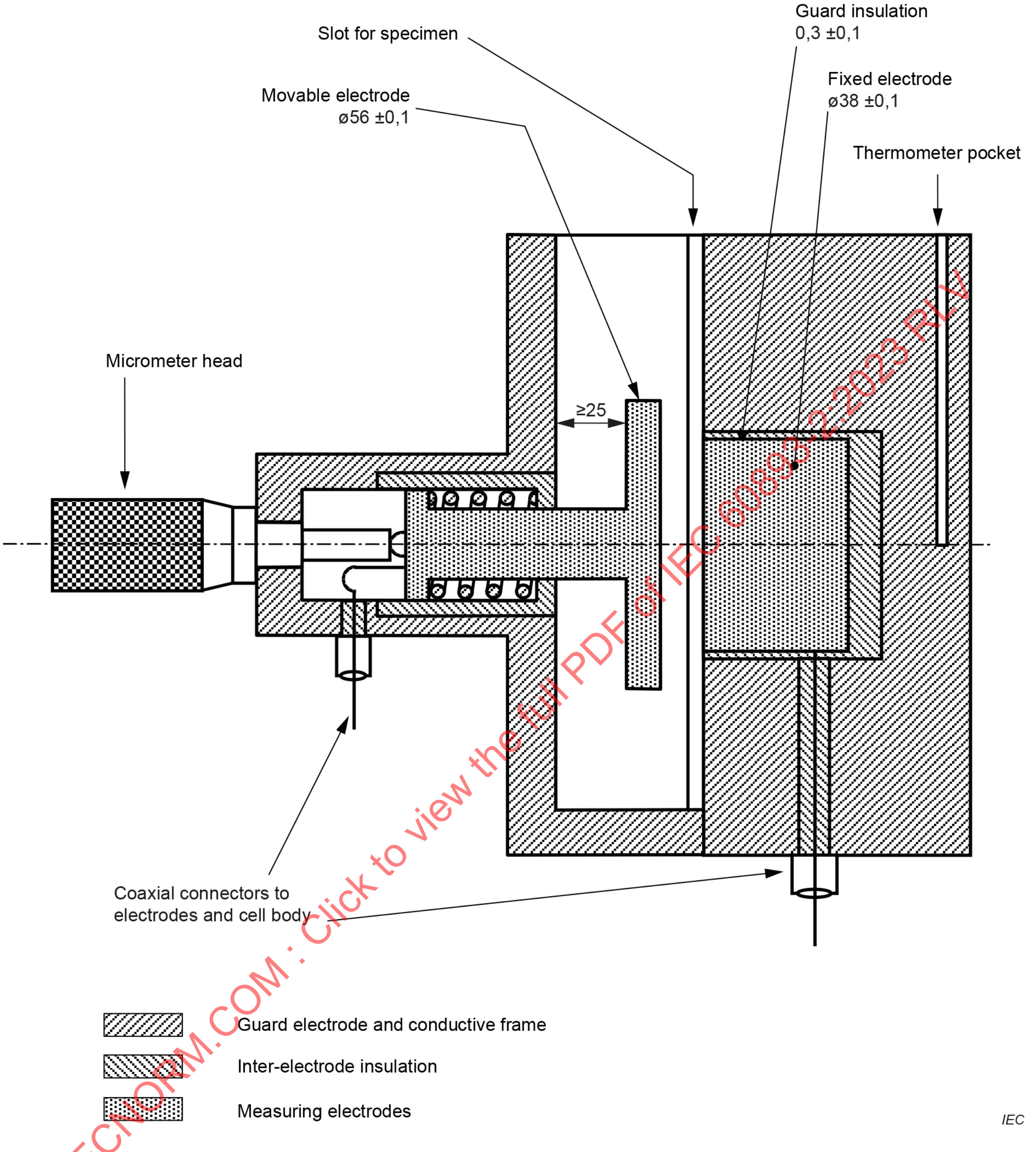


Figure 5 – Example of electrode system for method C

Annex A
(informative)

Modes of representation of capacitance

Some instruments represent a capacitance having finite losses as a parallel combination of loss-free capacitance C_p and a conductance G_p, (Figure A.1 a) while others use a series combination of a capacitance C_s and a resistance R_s (Figure A.1 b). In this document, the parallel representation is used, although both representations are valid. The value of the dissipation factor

$$\tan\delta = \omega C_p / G_p = \omega C_s R_s$$

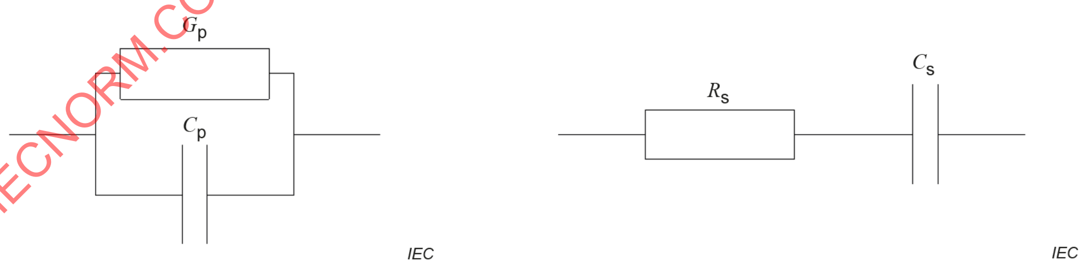
is the same in both representations, although the values of C_p, C_s, G_p and G_s depend upon the value of tan δ as follows:

$$C_p = C_s / (1 + \tan\delta^{\,2}) \qquad \text{(A.1)}$$

$$G_p = \tan\delta^{\,2} / (1 + \tan\delta^{\,2}) R_s \qquad \text{(A.2)}$$

Thus the capacitance values C_s measured by an instrument using a series representation will require conversion to C_p according to Equation (A.1) when calculating the permittivity by means of Equation (5) in 7.2.7.8, while the values of tan δ measured by the instrument can be used directly in Equation (6).

In many cases, however, the value of tan δ^2 is so small compared to 1 that (dependent upon the accuracy wanted) a correction of the C_p values will not be necessary.



Key

G_p	Conductance	R_s	Resistance
C_p	Capacitance	C_s	Capacitance

a) Parallel representation **b) Series representation**

Figure A.1 – Equivalent parallel and series representation of a capacitor

Annex B
(informative)

Liquids of known permittivity values

Liquids which have been found to be useful are as follows:

Table B.1 – Liquids of know permittivity values

Liquid	Permittivity value
Silicone (1 cSt to 2 cSt) (1 × 10^{-6} m^2/s to 2 × 10^{-6} m^2/s)	Ca 2,2
Heptane	Ca. 2,2
Perfluorocarbons	> 2,1
Chlorobenzene [a]	5 to 6
1, 2-dichloroethane [a]	9 to 11
Ethanol [a]	Ca. 30
Cyclohexane	Ca. 2,2

[a] The permittivity of these liquids is much more temperature dependent than that of the lower permittivity liquids.

Warning: Many of these liquids are toxic and it is recommended that require necessary precautions be taken for use.

NOTE Further information can be found in [2].

Bibliography

[1] IEC 60250:1969[13], *Recommended methods for the determination of the permittivity and dielectric dissipation factor of electrical insulating materials at power, audio and radio frequencies including metre wavelengths*

[2] National Bureau of Standards, *Tables of dielectric dispersion data for pure liquids*, in NBS Circular 589, Washington, November 1958

[13] This publication has been replaced by IEC 62631-2-1:2018.

IEC 60893-2

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INTERNATIONAL STANDARD

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Insulating materials – Industrial rigid laminated sheets based on thermosetting resins for electrical purposes –
Part 2: Methods of test

Matériaux isolants – Stratifiés industriels rigides en planches à base de résines thermodurcissables à usages électriques –
Partie 2: Méthodes d'essai

IEC 60893-2:2023-11(en-fr)

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

____

INSULATING MATERIALS – INDUSTRIAL RIGID LAMINATED SHEETS BASED ON THERMOSETTING RESINS FOR ELECTRICAL PURPOSES –

Part 2: Methods of test

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IEC 60893-2 has been prepared by IEC technical committee 15: Solid electrical insulating materials. It is an International Standard.

This third edition cancels and replaces the second edition published in 2003. This edition constitutes a technical revision.

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

a) removal of reference to withdrawn specification IEC 60167:1964;

b) inclusion of reference to IEC 62631-3-3:2015, which supersedes IEC 60167:1964. Details in 6.3 have been updated accordingly. The actual performance of the test has not changed;

c) normative references have been updated.

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

Draft	Report on voting
15/1017/FDIS	15/1023/RVD

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

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

A list of all parts in the IEC 60893 series, published under the general title *Insulating materials – Industrial rigid laminated sheets based on thermosetting resins for electrical purposes*, can be found on the IEC website.

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

- reconfirmed,
- withdrawn, or
- revised.

INTRODUCTION

This document is one of a series which deals with industrial rigid laminated sheets based on thermosetting resins for electrical purposes.

This series consists of four parts:

- Part 1: Definitions, designations and general requirements (IEC 60893-1);
- Part 2: Methods of test (IEC 60893-2);
- Part 3: Specifications for individual materials (IEC 60893-3);
- Part 4: Typical values (IEC TR 60893-4).

INSULATING MATERIALS – INDUSTRIAL RIGID LAMINATED SHEETS BASED ON THERMOSETTING RESINS FOR ELECTRICAL PURPOSES –

Part 2: Methods of test

1 Scope

This part of IEC 60893 describes methods of test for the materials defined in IEC 60893-1 (referred to also as Part 1).

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60112, *Method for the determination of the proof and the comparative tracking indices of solid insulating materials*

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

IEC 60216-1:2013, *Electrical insulating materials – Thermal endurance properties – Part 1: Ageing procedures and evaluation of test results*

IEC 60243-1:2013, *Electric strength of insulating materials – Test methods – Part 1: Tests at power frequencies*

IEC 60296:2012[1], *Fluids for electrotechnical applications – Unused mineral insulating oils for transformers and switchgear*

IEC 60587:2007[2], *Electrical insulating materials used under severe ambient conditions – Test methods for evaluating resistance to tracking and erosion*

IEC 60695-11-10:2013, *Fire hazard testing – Part 11-10: Test flames – 50 W horizontal and vertical flame test methods*

IEC 60893-1, *Insulating materials – Industrial rigid laminated sheets based on thermosetting resins for electrical purposes – Part 1: Definitions, designations and general requirements*

IEC 60893-3 (all parts), *Insulating materials – Industrial rigid laminated sheets based on thermosetting resins for electrical purposes – Part 3: Specifications for individual materials*

1 A fifth edition of this standard has been published in 2020.

2 A fourth edition of this standard has been published in 2022.

IEC TR 60893-4, *Insulating materials – Industrial rigid laminated sheets based on thermosetting resins for electrical purposes – Part 4: Typical values*

IEC 62631-3-3:2015, *Dielectric and resistive properties of solid insulating materials – Part 3-3: Determination of resistive properties (DC methods) – Insulation resistance*

ISO 62:2008, *Plastics – Determination of water absorption*

ISO 178:2010[3], *Plastics – Determination of flexural properties*

ISO 179-1:2000[4], *Plastics – Determination of Charpy impact properties – Part 1: Non-instrumented impact test*

ISO 179-2:1997[5], *Plastics – Determination of Charpy impact properties – Part 2: Instrumented impact test*

ISO 180:2000[6], *Plastics – Determination of Izod impact strength*

ISO 527-1:2012[7], *Plastics – Determination of tensile properties – Part 1: General principles*

ISO 527-4:1997[8], *Plastics – Determination of tensile properties – Part 4: Test conditions for isotropic and orthotropic fibre-reinforced plastic composites*

ISO 604:2002, *Plastics – Determination of compressive properties*

ISO 1183-1:2012[9], *Plastics – Methods for determining the density of non-cellular plastics – Part 1: Immersion method, liquid pyknometer method and titration method*

ISO 3611:2010[10], *Geometrical product specifications (GPS) – Dimensional measuring equipment: Micrometers for external measurements – Design and metrological characteristics*

3 Terms and definitions

No terms and definitions are listed in this document.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- IEC Electropedia: available at https://www.electropedia.org/
- ISO Online browsing platform: available at https://www.iso.org/obp

[3] A sixth edition of this standard has been published in 2019.

[4] A third edition of this standard has been published in 2023.

[5] A second edition of this standard has been published in 2020.

[6] A fifth edition of this standard has been published in 2023.

[7] A third edition of this standard has been published in 2019.

[8] A third edition of this standard has been published in 2023.

[9] A third edition of this standard has been published in 2019.

[10] A third edition of this standard has been published in 2023.

4 Conditioning of test specimens

Unless otherwise specified, test specimens shall be conditioned for at least 24 h in standard atmosphere B according to IEC 60212:2010 (temperature 23 ± 2 °C, relative humidity (50 ± 5) %).

Unless otherwise specified, each specimen shall be tested in the conditioning atmosphere and at the conditioning temperature, or the tests shall commence within 3 min of removal of each test specimen from the conditioning atmosphere.

Where testing at an elevated temperature is required in one of the specification sheets of IEC 60893-3, test specimens shall be conditioned for 1 h at that elevated temperature immediately before testing.

5 Dimensions

5.1 Thickness

5.1.1 General

Any method which enables the thickness of the laminated sheet to be measured at an appropriate number of points may be used, provided that the equipment used and the method of measurement are capable of a precision of 0,01 mm or better.

The following reference method has been shown to be suitable and shall be used in cases of dispute.

5.1.2 Test apparatus for reference method

In case of dispute, an external screw type micrometer in accordance with ISO 3611 having faces with diameters between 6 mm and 8 mm shall be used.

5.1.3 Procedure for reference method

Measure the thickness of the rigid laminated sheet as delivered to the nearest 0,01 mm at eight points, two along each edge but not less than 20 mm from the edge.

5.1.4 Results

Report the maximum and minimum measured values and the arithmetic mean of all measured values in mm.

5.2 Flatness

5.2.1 General

This test is applicable to all sheets having a thickness of 3 mm or greater.

5.2.2 Test specimens

The test specimen shall be the whole sheet or panel under test in the ‘as received’ condition.

5.2.3 Test method

When any sheet of nominal thickness 3,0 mm or more is placed without restraint, concave side up, on a flat surface, the departure at any point of the upper surface of the sheet from a light straight edge 1 000 mm or 500 mm in length, laid in any direction upon it, shall not exceed the value given in the relevant sheet of IEC 60893-3 appropriate to the material, its thickness and length of straight edge. The mass of the 1 000 mm straight edge shall not exceed 800 g, and the mass of the 500 mm straight edge shall not exceed 400 g.

5.2.4 Results

Report the maximum measured deviation from flatness in mm.

In cases where the sheet deviates from flatness in two directions, is saddle-shaped, measure both deviations and report the highest.

6 Mechanical tests

6.1 Flexural strength

6.1.1 General

The flexural strength is defined as the flexural stress at rupture. It shall be determined by the method specified in ISO 178. Method A shall be used.

6.1.2 Test specimens

Cut the test specimens from the sheet to be tested with their major axes parallel to the sides of the sheet. Test five test specimens in each direction, except for types with fibres aligned mainly in the same direction. In such cases, cut five specimens only, with their long axis parallel to the direction of the fibres.

If the nominal thickness of the sheet to be tested is more than 10 mm (20 mm in the case of types PF WV), reduce the thickness of the test specimens to 10 mm (20 mm in the case of PF WV).

When it is necessary to reduce the thickness of a test specimen, machine it, leaving one face of the sheet intact. In such cases, test specimens shall be tested with the original surface of the sheet in contact with the two supports.

6.1.3 Test method

The test shall be carried out with the load applied perpendicular to the plane of the laminations. The test speed shall be 5 mm/min with a tolerance of ±20 %.

6.1.4 Results

Report the arithmetic mean of the results for each direction in MPa. Take the lower of the two mean values as the minimum flexural strength of the sheet under test, except in cases where the reinforcing fibres run mainly in one direction. In such cases, take the mean value obtained in this direction.

6.2 Modulus of elasticity in flexure

6.2.1 General

The following test method shall be used in order to determine the modulus of elasticity in flexure.

6.2.2 Test specimens

The specimens shall be in the same form as described for the flexural strength test described in 6.1.2 above.

6.2.3 Test method

Modulus of elasticity shall be determined by the method specified in ISO 178.

6.2.4 Results

Results shall be expressed in MPa.

6.3 Compressive strength

6.3.1 General

The following test method shall be used in order to determine the compressive strength.

6.3.2 Test specimens

Specimens shall be cut from the sheet under test as described in ISO 604.

6.3.3 Test method

Compressive strength shall be determined by the method specified in ISO 604 with the load applied perpendicular to the plane of the laminations.

6.3.4 Results

Results shall be expressed in MPa.

6.4 Impact strength

6.4.1 General

This test is only applicable to sheets of nominal thickness equal to or greater than 5 mm.

6.4.2 Charpy Impact strength

6.4.2.1 Test specimens

Test specimens shall be cut from the sheet under test in accordance with Figure 1 a). Five specimens, with a thickness between 5 mm and 10 mm, shall be tested in each direction, except for types with fibres aligned mainly in the same direction. In such cases, cut five specimens only, with their longitudinal axis parallel to the direction of the fibres.

If the nominal thickness of the sheet to be tested is greater than 10 mm, reduce the thickness of the test specimen to 10 mm by machining equal amounts from both faces of the sheet.

6.4.2.2 Test method

The Charpy impact strength shall be determined in the edgewise direction as described by the method given in ISO 179-1 and ISO 179-2 except that the specimens shall be as described above, and the span shall be 70 mm. The material shall be tested with the major axes in each direction parallel to the sides of the sheet, except in the case of materials whose fibres lie mainly in the same direction. For these materials only specimens with their longitudinal axis parallel to the direction of the fibres shall be tested.

6.4.2.3 Results

Report the arithmetic mean of the results for each direction in kJ/m^2. Take the lower of the two mean values as the minimum Charpy impact strength of the sheet under test, except in cases where the reinforcing fibres run mainly in one direction. In such cases, take the mean value obtained in this direction.

6.4.3 Izod impact strength

6.4.3.1 Test specimens

The dimensions of the specimens shall be as described in Figure 1 b). Five specimens, with a thickness between 5 mm and 10 mm, shall be tested in each direction, except for types with fibres aligned mainly in the same direction. In such cases, cut five specimens only, with their longitudinal axis parallel to the direction of the fibres.

If the nominal thickness of the sheet to be tested is greater than 10 mm, reduce the thickness of the test specimen to 10 mm by machining equal amounts from both faces of the sheet.

6.4.3.2 Test method

The Izod impact strength shall be determined in the edgewise direction as described by the method given in ISO 180. The material shall be tested with the major axes in each direction parallel to the sides of the sheet, except in the case of materials whose fibres lie mainly in the same direction. For these materials only, specimens with their longitudinal axis parallel to the direction of the fibres shall be tested.

6.4.3.3 Results

Report the arithmetic mean of the results for each direction in kJ/m^2. Take the lower of the two mean values as the minimum Izod impact strength of the sheet under test, except in cases where the reinforcing fibres run mainly in one direction. In such cases, take the mean value obtained in this direction.

6.5 Shear strength parallel to laminations

6.5.1 General

The shear strength parallel to laminations test provides data that gives an indication of the degree of bonding or adhesion between laminations. The test is only applicable to sheets of nominal thickness greater than 5 mm.

6.5.2 Test specimens

Rectangular test specimens are cut with the following dimensions:

Length 20 mm ± 0,1 mm

Width and thickness $5\,^{0}_{-0,15}$ mm

Cut the test specimens from the sheet to be tested with their major axes parallel to the sides of the sheet. Prepare five sets of test specimens for each direction, each set of specimens comprising two pieces.

The two specimens in each pair shall have widths (dimension along the laminations orthogonal to the length) identical within 0,01 mm.

6.5.3 Test method

Two test specimens are simultaneously subjected to shearing stress in the device shown in Figure 2.

The test specimens shall be arranged so that the shearing stress acts in a plane parallel to the laminations. The relative rate of movement of the cross head of the testing machine shall be 2 mm/min with a tolerance of ±20 %.

6.5.4 Results

Calculate the shear strength by dividing the shear force through the total shear plane area of 2 × 100 mm^2.

Report the arithmetic mean value of the results for each direction in MPa and take the lower of the two mean values as the parallel shearing strength of the sheet under test.

6.6 Tensile strength

6.6.1 General

Tensile strength defined as tensile stress at maximum load shall be determined by the method specified in ISO 527-4, in conjunction with ISO 527-1.

6.6.2 Test specimens

Specimens shall be cut from the sheet under test with the major axis in each direction parallel to the sides of the sheet. Five specimens of nominal thickness between 1,5 mm and 10,0 mm shall be prepared from each direction according to type 1 of ISO 527-4, except in the case of materials whose fibres lie mainly in the same direction. For these materials, only specimens with their longitudinal axis parallel to the direction of the fibres shall be tested.

If the sheet to be tested is more than 10 mm thick, reduce the thickness of the test specimens to 10 mm by machining equal amounts from each face.

6.6.3 Test method

Carry out the test as described in ISO 527-4. The rate of separation of the jaws of the testing machine shall be 5 mm/min with a tolerance of ±20 %.

6.6.4 Results

Report the arithmetic mean of the results for each direction in MPa. Take the lower of the two mean values as the minimum tensile strength of the sheet under test, except in cases where the reinforcing fibres run mainly in one direction. In such cases, take the mean value obtained in this direction.

7 Electrical tests

7.1 Electric strength and breakdown voltage

7.1.1 General

Electric strength and breakdown voltage shall be determined by the methods specified in IEC 60243-1, which describes both the step-by-step and 60 s proof tests. Either test method may be used. Unless otherwise specified the test shall be carried out at 90 ± 2 °C in mineral oil as described in IEC 60296:2012, which is reasonably free from decomposition products. Immerse the specimens in oil maintained at that temperature for not less than 0,5 h and not more than 1 h immediately before test.

7.1.2 Test specimens

For electric strength, test three specimens normal to laminations. For breakdown voltage, test three specimens parallel to the laminations.

Test specimens shall be cut from the sheet under test. Specimen dimensions shall be as described in IEC 60243-1.

7.1.3 Test method

7.1.3.1 General

Test the material using either the 20 s step-by-step test as described in 10.2 of IEC 60243-1:2013, or using the 60 s proof test as described in 10.6 of IEC 60243-1:2013.

7.1.3.2 Electric strength perpendicular to laminations

For thicknesses not greater than 3 mm, the material shall be tested perpendicular to the laminations. The upper electrode shall be 25 mm in diameter and the lower electrode shall be 75 mm in diameter according to IEC 60243-1.

This test is usually not required for thicknesses above 3 mm, in the Part 3 series. When it is required, reduce the thickness of the specimens to 3 mm by machining one face according to 5.2.1.4 of IEC 60243-1:2013, and use the requirement of the 3 mm thickness.

7.1.3.3 Breakdown voltage parallel to laminations

For thicknesses above 3 mm and less than or equal to 10 mm, the material shall be tested edgewise in accordance with 5.3.3 of IEC 60243-1:2013 (taper pin electrodes) or with 5.3.2.1 of IEC 60243-1:2013, (parallel plate electrodes), and for thicknesses above 10 mm in accordance with 5.3.2.1 of IEC 60243-1:2013 (parallel plate electrodes). For types with their fibres mainly in the same direction the test shall be carried out in the fibre direction.

7.1.3.4 Results

For each of the above tests, the arithmetic mean of the test results shall be taken as the result. The minimum value shall also be reported. Results of the electric strength perpendicular to lamination test shall be reported in kV/mm, and the results of the breakdown voltage test parallel to laminations, shall be reported in kV.

7.2 Permittivity and dissipation factor

7.2.1 General requirements

Permittivity and dissipation factor may be determined by any one of the three methods given in 7.2.2. Unless otherwise indicated in the relevant clauses of IEC TR 60893-4, the specimens shall be conditioned for (96 ± 1) h in air at a temperature of 105 ± 5 °C with a relative humidity of less than 20 % (dry hot standard atmosphere according to IEC 60212:2010). At the end of this time, allow the specimens to cool to room temperature in a desiccator. Apply the electrodes, and/or otherwise make the measurements within 10 min of removal of each specimen from the desiccator.

Where intimate electrodes are required, silver paint shall be painted centrally on the test specimen. Conducting rubber, evaporated and sputtered electrodes shall not be used.

Unless otherwise specified, measurements shall be made at a temperature of 23 ± 2 °C at a power frequency between 48 Hz and 62 Hz or at a radio frequency of 1 MHz.

To ensure that the specimens, the electrodes and the immersion fluid are in thermal equilibrium with their environment during the measurement, they should all be kept at the measurement temperature for not less than 0,5 h immediately before the measurement. The test voltage shall be high enough to provide the required sensitivity, but low enough to avoid dielectric heating and discharges at the edges of the electrodes.

In all three methods, the test shall be carried out on two test specimens unless otherwise specified. At all times, the specimens shall be handled with stainless steel flat-faced forceps to minimize the likelihood of damage or contamination.

The average of the two determinations shall be taken as the result.

Reference to IEC 60250:1969 [1][11] should be made for additional guidance and clarification.

NOTE In total, the three methods described can be used for sheet materials in the thickness range 0,3 mm to 12,0 mm, dependent upon the design of the specimen holders and electrodes, but the precision of each method is influenced by specimen dimensions and properties.

7.2.2 Methods

Method A – A direct measuring method utilizing intimate electrodes

Method B – An air substitution technique without intimate electrodes

Method C – A two-fluid immersion technique without intimate electrodes

Method A is suitable for sheet materials of permittivity up to 10,0 and dissipation factors greater than 50×10^{-6}, having thicknesses in the range 0,3 mm to 12,0 mm, dependent upon the design of the specimen holders. Method A requires an accurate knowledge of the specimen thickness and may be used in all cases when this information is available. See 7.2.3.

Method B is suitable for sheet materials of permittivity up to 10,0 but can lack sufficient precision for materials of dissipation factor below 250×10^{-6}. Method B requires an accurate knowledge of the specimen thickness and may be used in place of method A when this information is available. Dependent upon the design of the specimen holders, specimens with thicknesses in the range 0,3 mm to 12,0 mm can be tested.

Method C is suitable for materials of permittivity up to 10,0 but may show a lack of precision for materials of dissipation factor below 250×10^{-6}. If the thickness is not sufficiently accurately known, method C may be used subject to the limitation that the method requires use of an inert liquid of approximately the same permittivity as the specimen.

The immersion method, C, is capable of better precision for permittivity for sheet materials of thickness 0,3 mm to 1,0 mm and has the advantage that accurate knowledge of the specimen thickness is not required, but it is not suitable for materials with an open cell structure.

7.2.3 Principles of the methods

In the methods described, the electrode assembly is an integral part of the specimen holder into which the specimen is placed. In method A, backing electrodes make contact with the intimate electrodes and the properties of the specimen are measured with the specimen in the form of a simple capacitor. The specific advantage of method A is that measurements may be made at elevated temperatures, limited only by the thermal properties of the specimen.

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[11] Numbers in square brackets refer to the Bibliography.

In Methods B and C, the specimen and appropriate insulating fluid(s) are introduced into the specimen holder, the capacitance and dissipation factor of the assembly being measured. Such systems introduce smaller errors in measurement than those using intimately applied electrodes, and facilitate the easier provision of guard electrodes that minimize electric field distortions and stray capacitances.

Suitable electrode systems for each of the methods are described in 7.2.5.2, 7.2.6.2 and 7.2.7.2. Suitable measuring instruments are described in 7.2.4.

The permittivity and dissipation factor of a dielectric can change considerably with frequency, temperature and relative humidity. Accordingly, the measured values should only be taken to indicate the dielectric properties of the specimen under conditions similar to those used for the test.

7.2.4 Measuring instruments

Instruments of adequate sensitivity shall be used. Minimum detectable changes in capacitance of 0,3 fF(= 0,3 × 10^{-15} F) and minimum detectable changes in dissipation factor of 0,000 01 (= 10 × 10^{-6}) have been found to be acceptable.

NOTE 1 A variety of modes of output is offered by commercial measuring equipment. Some of the more sophisticated offer a variety of outputs from the same instrument thus enabling the user to select the appropriate output. This standard assumes that the output is in the form of capacitance (C, in pF) and dissipation factor (tanδ). See Annex A for conversion of other forms of output to this format.

NOTE 2 The electrode systems described in methods A, B and C are of three terminal 'guarded' design. This practically eliminates the influence of stray electric fields at the electrode edges and removes the need for 'edge capacitance' corrections.

All measuring leads should be screened and kept as short as possible, consistent with the instrument manufacturer's instructions.

Some types of instruments require a 'short' and 'open' circuit calibration. The 'short circuit' should be established between the electrodes of the electrode system, in the position that the specimen would occupy. Care should be taken to ensure that the short circuit used is of low resistance and inductance and that it does not damage the surfaces of the electrodes. It is essential also to ensure the micrometer zero is not altered. A smooth-edged U-shaped piece of springy metal is suitable for use as a short circuit. The 'open' circuit is established by disconnection of the electrodes at the end of the cables farthest from the capacitance meter, so that allowance is again made for the effect of the measuring leads. Reference should be made to the manufacturer's instructions to determine whether it is necessary to link the outer connections of the coaxial cables during this calibration and whether the error introduced by omission of the electrode system is small and may be ignored. In any case it is preferable to use a three terminal measuring instrument, for example with 'high', 'low' and 'guard' connections.

Many commercial instruments are now based on measurement of current, voltage and phase angle. These instruments are commonly of four (or five) terminal design. Reference should be made to the manufacturer's instructions concerning the preferred mode of connecting a three terminal electrode system to such an instrument.

7.2.5 Method A: Direct measurement technique

7.2.5.1 Principle

After measurement of the specimen thickness, intimate electrodes are painted on to the specimen that is then inserted into the guarded specimen holder and placed between the backing electrodes. The separation of the backing electrodes is reduced until they make contact with the intimate electrodes. Measurements of the specimen capacitance and dissipation factor are made.

The permittivity of the test material is calculated from the measured capacitance and thickness. The dissipation factor is usually read directly from the measuring instrument.

7.2.5.2 Electrode system

The electrode system shall be of rigid mechanical design and of sufficient thermal capacity so that rapid changes in ambient temperature do not significantly affect its dimensions. It shall comprise a circular measuring electrode surrounded by a concentric coplanar guard electrode, and a movable electrode whose separation from the measuring electrode is controlled by a spring-loaded arrangement with a screw thread. Rotation of the screw drive mechanism allows the spring-loaded electrodes to close on to the intimate electrodes. The screw rotation should not be transmitted to the electrode.

Figure 3 illustrates a possible construction and means of connection to a three terminal measuring instrument.

For connection to instruments having four or more terminals, reference should be made to the manufacturer's instructions.

7.2.5.3 Test specimens

The test piece shall be essentially flat and uniform in thickness and shall extend beyond the unguarded electrode by at least 2 mm. Wherever possible, test specimens shall be used as recommended by the manufacturer of the electrode system. For the electrode system shown the test piece shall be either:

a) a flat circular sheet (61 ± 1) mm in diameter, or

b) a flat square sheet, 60 mm × 60 mm is sufficient but a rectangular sheet (61 ± 1) mm by (100 ± 1) mm is preferred to ease test specimen handling.

The thickness at any point shall not vary by more than 1 % from the mean value.

If possible, it is recommended that the specimen be of the same thickness and prepared by the same process as the electrical insulating material under evaluation. If it is necessary to reduce its thickness, its surfaces shall not be contaminated during the process.

The maximum tolerance deviation from a straight edge placed along a diameter or diagonal on the concave side, shall be less than 10 % of the thickness.

7.2.5.4 Determination of test piece thickness

Determine the test piece thickness with a micrometer conforming to 5.1.1. Measure four values of thickness at points equally spaced around the periphery of the test piece, and a fifth value centrally. Calculate the arithmetic mean thickness of each test piece as t.

7.2.5.5 Application of electrodes

Apply the silver paint electrodes using a masking technique and following the manufacturer's instructions. The outer diameter of the guarded electrode should be as specified by the manufacturer of the measuring instrument and should be larger than the corresponding backing electrode. The inner diameter of the guard electrode should be correspondingly smaller than the backing guard electrode.

The outer diameter of the unguarded electrode should be approximately the same as the diameter of the unguarded backing electrode.

7.2.5.6 Measurement of capacitance and dissipation factor

Place the specimen into the specimen holder and close the backing electrodes until they make contact with the intimate electrodes on the specimen, ensuring that the intimate electrodes align with the backing system.

Measure and record the specimen capacitance, dissipation factor, test frequency and humidity.

Repeat the measurements on a second specimen.

7.2.5.7 Calculations

Calculate the effective area of the test piece in cm²:

$$A = \left(\frac{\pi}{4}\right)(d_1 + g)^2 \tag{1}$$

and the (relative) permittivity

$$\varepsilon_r = \frac{3{,}6\pi C t}{A} \tag{2}$$

where

C is the measured capacitance in pF;

t is the test piece thickness in cm;

d_1 is the diameter of guarded electrode in cm;

g is the width of gap between the guard and guarded electrodes in cm;

A is the effective electrode area in cm².

Determine the dissipation factor from the instrument reading.

Calculate the permittivity and the dissipation factor as the average from the two determinations.

7.2.5.8 Results

Record the result, the test frequency, temperature and humidity.

7.2.6 Method B: Air substitution technique

7.2.6.1 Principle

The test piece is inserted into a guarded electrode system in which the electrode separation is variable. Small air gaps are left between the sample and electrodes to ensure that the test piece is not mechanically stressed. The capacitance and dissipation factor of the assembly are measured.

The test piece is removed, and the electrode separation adjusted to give a capacitance reading which is the same as the value measured with the specimen in place. The electrode movement and the new value of dissipation factor are measured.

The permittivity and dissipation factor of the test material are calculated, as shown in 7.2.6.7, from the test piece thickness, the change in electrode spacing and the change in observed values of dissipation factor.

7.2.6.2 Electrode system

The electrode system shall be of rigid mechanical design and of sufficient thermal capacity so that rapid changes in ambient temperature do not significantly affect its dimensions. The system shall comprise a circular measuring electrode surrounded by a concentric coplanar guard electrode, and a movable electrode whose separation from the measuring electrode is controlled by a micrometer head. The precision of the micrometer shall be 0,01 mm. Rotation of the drive mechanism should not be transmitted to the electrode.

The electrode surfaces shall be flat and shall remain substantially parallel at all times.

Figure 4 illustrates a possible construction and means of connection to a three terminal measuring instrument.

For connection to instruments with four or more terminals, reference should be made to the manufacturer's instructions.

A more precise means of determining the changes in electrode spacing, e.g. a displacement transducer, which will not disturb the electric field between the electrodes, can be introduced.

7.2.6.3 Test specimens

The test piece shall be approximately flat and uniform in thickness and shall extend beyond the unguarded electrode by at least 2 mm. Wherever possible, test specimens shall be used as recommended by the manufacturer of the electrode system. For the electrode system shown, the test piece shall be either:

a) a flat circular sheet (61 ± 1) mm in diameter, or

b) a flat square sheet, 60 mm × 60 mm is sufficient but a rectangular sheet (61 ± 1) mm by (100 ± 1) mm is preferred to ease test specimen handling.

The thickness shall be in the range appropriate for the specific test specimen holder. In most cases this will be between 0,3 mm and 12,0 mm. The thickness at any point shall not vary by more than 1 % from the mean value t, measured according to 7.2.6.4.

If possible, it is recommended that the specimen be of the same thickness and prepared by the same process as the electrical insulating material under evaluation. If it is necessary to reduce its thickness, its surfaces shall not be contaminated during the process.

The maximum tolerance deviation from a straight edge placed along a diameter or diagonal shall be less than 10 % of the thickness.

7.2.6.4 Determination of test piece thickness

Determine the test piece thickness with a micrometer conforming to 5.1.1. Measure four values of thickness at points equally spaced around the periphery of the test piece, and a fifth value centrally. Calculate the arithmetic mean thickness of each test piece as t.

7.2.6.5 Measurement of capacitance and dissipation factor

Insert the test piece between the electrodes and decrease the electrode gap until the upper electrode just fails to touch the test piece.

Turn the micrometer screw until the upper electrode just touches the test piece, then turn the micrometer screw in the reverse direction until no resistance is felt against a small lateral movement of the sample.

Measure the capacitance and dissipation factor.

Record the value of the dissipation factor as tan δ_1, and the electrode spacing as m_1. Remove the test piece and decrease the electrode gap until the capacitance is returned to the original value. Record the new value of the dissipation factor as tan δ_2 and the electrode spacing as m_2.

Repeat this procedure for a further test piece.

Record the frequency, temperature and relative humidity at which the measurements were made.

Calculate the values of permittivity and dissipation factor for each set of measurements as shown in 7.2.6.7.

Calculate the means of these values as the permittivity and dissipation factor of the material under test.

7.2.6.6 Symbols

tan δ_1 is the dissipation factor of electrode assembly with test piece present;

tan δ_2 is the dissipation factor of electrode assembly without test piece;

Δtan δ = (tan δ_1 – tan δ_2);

m_1 is the micrometer reading with test piece present, in mm;

m_2 is the micrometer reading without test piece, in mm;

Δm = ($m_1 - m_2$) in mm;

t is the specimen thickness in mm;

tan δ is the dissipation factor of material;

ε_r is the (relative) permittivity of material.

7.2.6.7 Calculation of permittivity and dissipation factor

Permittivity:

Calculate the (relative) permittivity

$$\varepsilon_r = \frac{t}{t - \Delta m} \tag{3}$$

Dissipation factor:

Calculate the dissipation factor

$$\tan \delta = \Delta \tan \delta \left(\frac{m_2}{t - \Delta m} \right) \tag{4}$$

7.2.6.8 Expression of results

The result shall be the arithmetic mean of the determinations on individual test specimens. Record all of the individual values.

7.2.7 Method C: Two fluid immersion technique

7.2.7.1 Principle

As with method B, the electrode spacing is only slightly greater than the test piece thickness. Although, in principle, either or both of the fluids used in this method may be liquids or gases, this standard permits only the use of a gas (usually air) as the first fluid, and a liquid as the second fluid.

The test piece is inserted into a guarded electrode system, the electrode spacing adjusted, the test piece removed and the capacitance and dissipation factor measured. The test piece is replaced and the capacitance and dissipation factor of the electrode system are re-measured. After removal of the test piece, the space between the electrodes is filled with the immersion liquid and the capacitance and dissipation factor measured. The test piece is inserted and the capacitance and dissipation factor re-measured. The permittivity and dissipation factor of the test material are calculated as shown in 7.2.7.8.

7.2.7.2 Electrode system

The electrode system shall be of rigid mechanical design and of sufficient thermal capacity so that rapid changes in ambient temperature do not significantly affect its dimensions. The system shall comprise a circular measuring electrode surrounded by a concentric coplanar guard electrode, and a moveable electrode, the separation of which from the measuring electrode is controlled by a micrometer head. The drive mechanism shall be linked with the electrodes so that the electrode does not rotate with the drive mechanism. Both electrodes shall be mounted vertically so that air bubbles dragged into the liquid with the specimen may escape.

The electrode surfaces shall be flat and shall remain substantially parallel at all times.

Figure 5 illustrates a possible construction and means of connection to a three terminal measuring instrument.

For connection to instruments with four or more terminals, reference should be made to the manufacturer's instructions.

NOTE The temperature of this cell can be controlled to ±0,1 °C by a liquid circulation system.

The electrodes are preferably made from stainless steel. If they are made from brass, then all metal parts shall be plated with hard bright gold having a minimum thickness of 10 µm.

7.2.7.3 Immersion fluids

Suitable liquids of known permittivity values are listed in Annex B (see Table B.1). Liquids which affect the properties of the test material, whether by swelling or by any other interaction shall not be used. The immersion fluid shall not be reused if the value of the dissipation factor of the cell fluid changes from its original value by more than 2 % or 10×10^{-6}, whichever is the greater.

Silicone fluid of viscosity 1×10^{-6} m^2/s to 2×10^{-6} m^2/s (1 cSt to 2 cSt) is satisfactory for use with many plastic materials, e.g. the polyolefins PE, PTFE, PET and polycarbonates. Cyclohexane is an acceptable fluid for use with PTFE. Perfluorinated liquids are excellent as they do not interact with most organic polymers. The liquid shall not be reused if the value of the dissipation factor of the cell fluid has changed by more than 2 % or 10×10^{-6}, whichever is the greater.

7.2.7.4 Test specimens

For the electrode system shown, the test piece shall be a rectangular sheet (61 ± 1) mm × (100 ± 1) mm. The thickness shall be between 0,3 mm and 1,0 mm.

The precise specimen thickness is not required. However, it can be measured and used for comparison with that derived from the electrical measurements as a cross-check on the procedure. Wherever possible, specimens should be used as prepared by the manufacturer. However, if it is necessary to reduce their thickness, the surfaces shall not be contaminated during the process.

7.2.7.5 Preparation of test cell

Prepare a cell by rinsing several times with warm de-ionized water and then rinse with acetone. Dry the cell at 50 °C and allow to cool to the measuring temperature (see 7.2.1). After allowing at least 1 h for stabilization, the dissipation factor shall be less than (10×10^{-6}). Ensure that the electrode assembly, the liquids and the test piece in the desiccator, are in thermal equilibrium at the measuring temperature to within ±0,1 °C before commencing a test. Adjust the electrode spacing so that the specimen occupies at least 80 % of the gap but without filling the gap completely so that it can be easily moved in and out.

7.2.7.6 Measurement of capacitance and dissipation factor

Connect the leads to the cell and follow the manufacturer's instructions as to the initial bridge calibration. Record the values of capacitance and dissipation factor as C_1 and tan δ_1 with air between the electrodes.

Insert the specimen into the air-filled cell. Record the values of capacitance and dissipation factor as C_2 and tan δ_2. Record the cell temperature to ±0,1 °C.

The temperature of the test specimen and fluid shall be very close to that of the guard block.

Remove the specimen from the cell and fill the cell with the fluid chosen. Measure the capacitance and dissipation factor and record the values as C_3 and tan δ_3.

Insert the specimen into the cell. Measure the capacitance and dissipation factor and record the values as C_4 and tan δ_4.

Remove the specimen from the cell after this measurement and repeat the procedure for a further test piece.

Calculate the values of permittivity and dissipation factor for each set of measurements as shown in 7.2.7.8.

Calculate the mean values of permittivity and material dissipation factor. Record the frequency, temperature and relative humidity at which measurements are made.

For routine measurements, the following sequence, as shown in Table 1, can be found more convenient, but in cases of dispute, the sequence of measurements given in the main text shall be used:

Table 1 – Sequence employed for routine measurements

Test specimen	Fluid	Use reading as
None	Air	$(C_1)_1$ $(C_1)_2$
1	Air	$(C_2)_1$
2	Air	$(C_2)_2$
None	Liquid	$(C_3)_1$ $(C_3)_2$
1	Liquid	$(C_4)_1$
2	Liquid	$(C_4)_2$
None	Liquid	$(C_3)_3$

7.2.7.7 Symbols

C_1 is the cell capacitance with air alone in pF;

C_2 is the cell capacitance with specimen in air in pF;

C_3 is the cell capacitance with fluid alone in pF;

C_4 is the cell capacitance with specimen in fluid in pF;

ΔC_A = $(C_2 - C_1)$ in pF;

ΔC_F = $(C_4 - C_3)$ in pF;

$\tan \delta$ is the dissipation factor of specimen;

D_1 is the dissipation factor of cell in air;

D_2 is the dissipation factor with specimen in air;

ΔD_A = $(D_2 - D_1)$;

A is the effective electrode area in m^2;

ε_0 is the electric constant 8,8542 pF × m^{-1}.

7.2.7.8 Calculation of permittivity and dissipation factor

Permittivity:

Calculate the (relative) permittivity

$$\varepsilon_r = 1 + \frac{C_4 \Delta C_A (C_3 - C_1)}{C_1 (C_4 \Delta C_A - C_2 \Delta C_F)} \qquad (5)$$

Dissipation factor:

Calculate the dissipation factor from

$$\tan \delta = \frac{C_5 \Delta D_A}{\Delta C_A} \quad (6)$$

where

$$C_5 = \frac{C_2 C_4 (C_3 - C_1)}{(C_4 \Delta C_A - C_2 \Delta C_F)} \quad (7)$$

NOTE The calculated specimen thickness, t, is given by:

$$t = \frac{\varepsilon_r \varepsilon_0 A}{C_5} \quad (8)$$

This can be compared with the measured thickness as an accuracy check.

7.2.7.9 Expression of results

The result shall be the mean of the determinations on individual specimens. Record also the individual values.

7.2.8 Test report

The following information shall be included in the test report:

a) reference to this standard and test method used, i.e. IEC 60893-2, Method A, B, or C;
b) type or designation of the insulating material and the form in which it was delivered;
c) method of fabrication of the specimen;
d) specimen thickness and information concerning the surface treatment (if any) at the electrode contact areas of the specimens;
e) method and duration of conditioning of the specimens if not as specified;
f) measuring instrument;
g) electrode and specimen dimensions if not as specified;
h) temperature and relative humidity during the test;
i) test voltage;
j) test frequency;
k) relative permittivity ε_r: arithmetic mean value, individual values;
l) dielectric dissipation factor (tan δ): arithmetic mean value, individual values;
m) date of test;
n) any unusual features noticed during the test.

7.3 Insulation resistance after immersion in water

7.3.1 General

Insulation resistance shall be determined using the method with taper pin electrodes, as specified in IEC 62631-3-3 and modified as described below. This test is applicable only to sheets of nominal thickness up to 25 mm inclusive.

7.3.2 Test specimens

Test specimens shall be cut from the sheet under test. Dimensions of the specimens shall be as described in IEC 62631-3-3:2015, Figure 1 a).

The holes in the test specimens shall be drilled with a suitable drill and then reamed with a taper pin reamer so that the diameter of each hole at the larger end is not less than 4,5 mm and not greater than 5,5 mm.

The material shall be tested with major axes in each direction, parallel to the sides of the sheet. Two specimens shall be tested in each direction. The thickness of the specimen shall be the thickness of the sheet under test.

7.3.3 Test method

Dry the test specimens in an oven at a temperature of 50 ± 2 °C for (24 ± 1) h and then immerse them in distilled or de-ionized water for (24 ± 1) h at a temperature of 23 ± 2 °C. At the end of this time, remove the test specimens from the water and remove the surface moisture by wiping with a clean dry cloth, absorbent paper or filter paper and insert the electrodes. Measure the insulation resistance at 25 ± 10 °C in an atmosphere of not more than 75 % relative humidity. Complete each measurement within 1,5 min to 2 min after removal from the water.

When it is possible to demonstrate that it does not affect the results, other drying conditions may be used (for example, drying for 1 h ± 5 min at 105 ± 5 °C) but in case of dispute, the specified method shall be used.

The applied voltage shall be 500 ± 10 V.

7.3.4 Results

Calculate the arithmetic mean of the measured values in each direction in MΩ and take the lower of the two arithmetic means as the insulation resistance after water immersion of the sheet under test.

7.4 Comparative and proof tracking indices

7.4.1 General

Test in accordance with IEC 60112.

7.4.2 Test specimens

Test specimens shall be cut from the sheet under test and shall be not less than 15 mm × 15 mm × the thickness of the sheet under test. The specimen thickness shall be equal or greater than 3 mm, which can be accomplished by stacking materials if necessary.

7.4.3 Test method

Comparative and proof tracking indices shall be determined by the method specified in IEC 60112. Test solution A shall be used.

7.4.4 Results

In the case of the Proof Tracking Index test, report pass or fail at the specified voltage as described in IEC 60112, and the thickness of the specimens tested. In the case of Comparative Tracking Index, report the value determined and the thickness of the specimens tested.

7.5 Tracking and erosion resistance

7.5.1 General

Test in accordance with IEC 60587.

7.5.2 Test specimens

Test specimens shall be cut from the sheet under test and shall be 50 mm × 120 mm × thickness of the sheet under test.

7.5.3 Test method

Tracking and erosion resistance shall be determined in accordance with IEC 60587 using the method specified in the relevant sheet of IEC 60893-3.

7.5.4 Results

Report pass or fail at the specified voltage as described in IEC 60587. Report also the thickness of the specimen tested.

8 Thermal tests

8.1 Thermal endurance

8.1.1 General

Thermal endurance shall be determined by the method specified in IEC 60216-1, and the relevant test specifications (i.e. IEC 60216-1 and ISO 178).

8.1.2 Test specimens

Specimens shall be cut from the sheet under test and their dimensions shall be as described in 6.1.2.

8.1.3 Test method

The ageing procedure used shall be as described in 5.5 and 5.6 of IEC 60216-1:2013. Unless otherwise specified, thermal endurance shall be determined using flexural strength as the distinguishing property (see 6.1) with 50 % reduction of the initial value as the end-point. Tests shall be carried out at 23 ± 5 °C.

8.1.4 Results

The thermal endurance shall be expressed, as described in 6.2 of IEC 60216-1:2013, with the temperature index at 20 000 h.

8.2 Flammability

8.2.1 General

Flammability shall be determined according to one of the methods given in IEC 60695-11-10, as specified in the relevant sheet of IEC 60893-3.

8.2.2 Test specimens

Specimens shall be cut from the sheet under test and their dimensions shall be as described in IEC 60695-11-10. Ensure that the specimens are free from dust or contamination.

8.2.3 Test method

Carry out the tests in accordance with the relevant clause of IEC 60695-11-10.

8.2.4 Results

Report the assigned classification in accordance with IEC 60695-11-10.

9 Other tests

9.1 Density

9.1.1 General

The following test method shall be used in order to determine the density.

9.1.2 Test specimens

Specimens shall be cut from the sheet under test as described in ISO 1183-1.

9.1.3 Test method

Density shall be determined using method A specified in ISO 1183-1.

9.1.4 Results

Results shall be expressed in g/cm^3.

9.2 Water absorption

9.2.1 General

Water absorption shall be determined in accordance with method 1 (6.2) of ISO 62:2008 and as modified below.

9.2.2 Test specimens

Three specimens shall be tested. The specimen dimensions shall be (50 ± 1) mm × (50 ± 1) mm × the thickness of the sheet under test except in cases where the nominal thickness of the sheet under test is greater than 25 mm. In such cases, the thickness of the test specimens shall be reduced to 22,5 mm ± 0,3 mm by machining one face only to a relatively smooth finish.

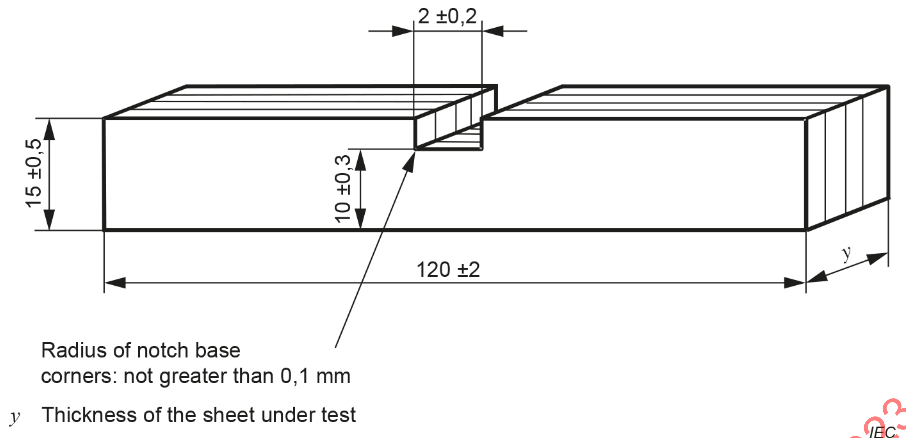
9.2.3 Test method

The test shall be performed as described in 6.2 of ISO 62:2008, maintaining the distilled or de-ionised water at 23 ± 0,5 °C.

9.2.4 Results

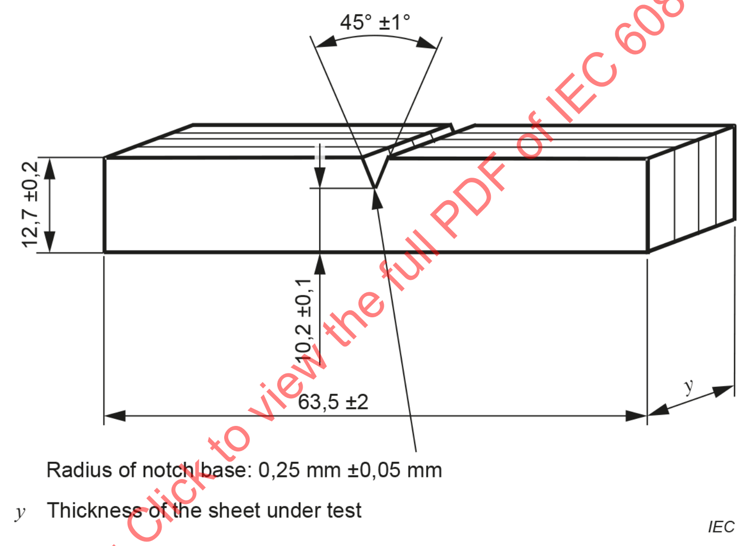
Results shall be expressed in mg in accordance with Clause 7 of ISO 62:2008. The arithmetic mean of the three results shall be reported as the water absorption.

Dimensions in millimetres



a) Test specimen for Charpy impact strength test

Dimensions in millimetres



b) Test specimen for Izod impact strength test

Figure 1 – Test specimens for impact strength test

Dimensions in millimetres

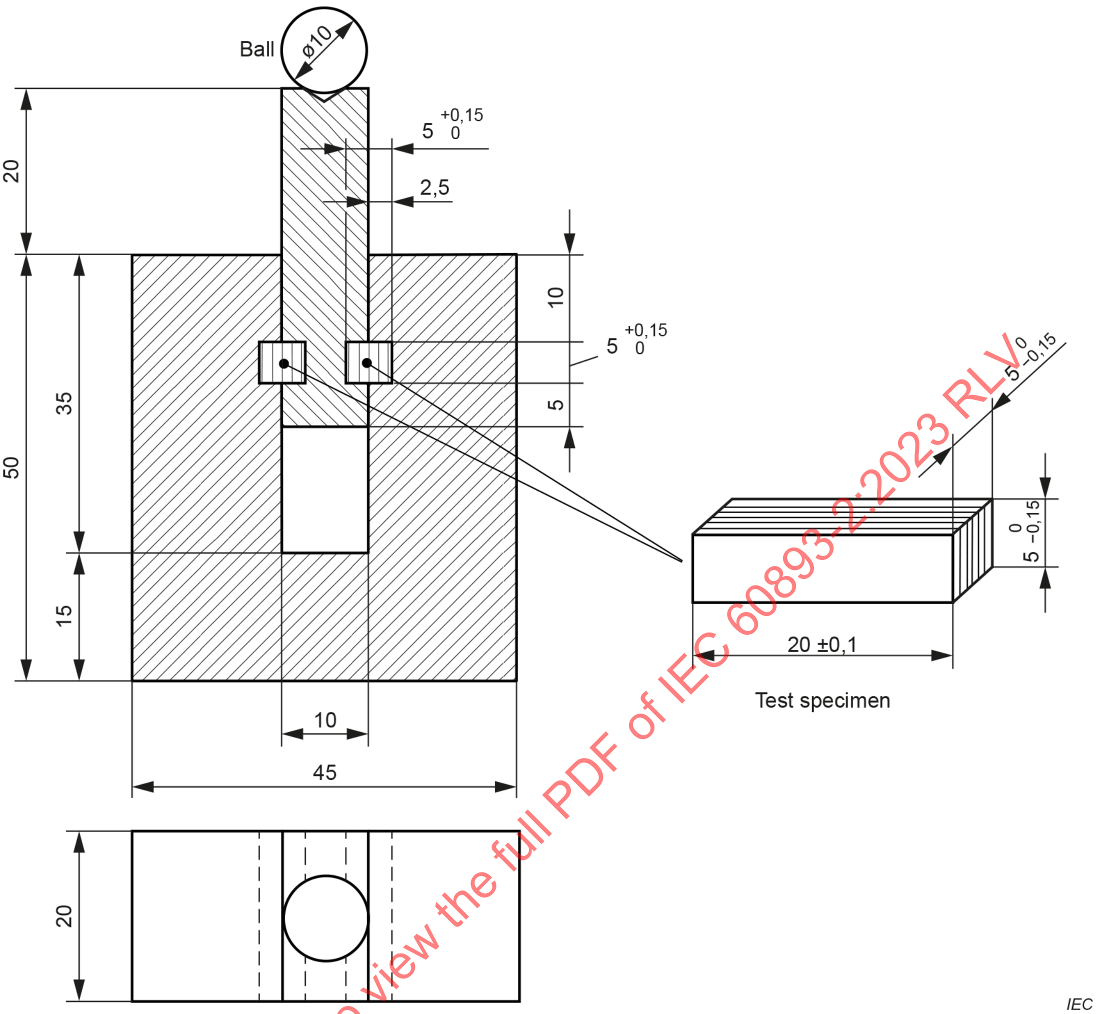


Figure 2 – Device for testing parallel shearing strength

Dimensions in millimetres

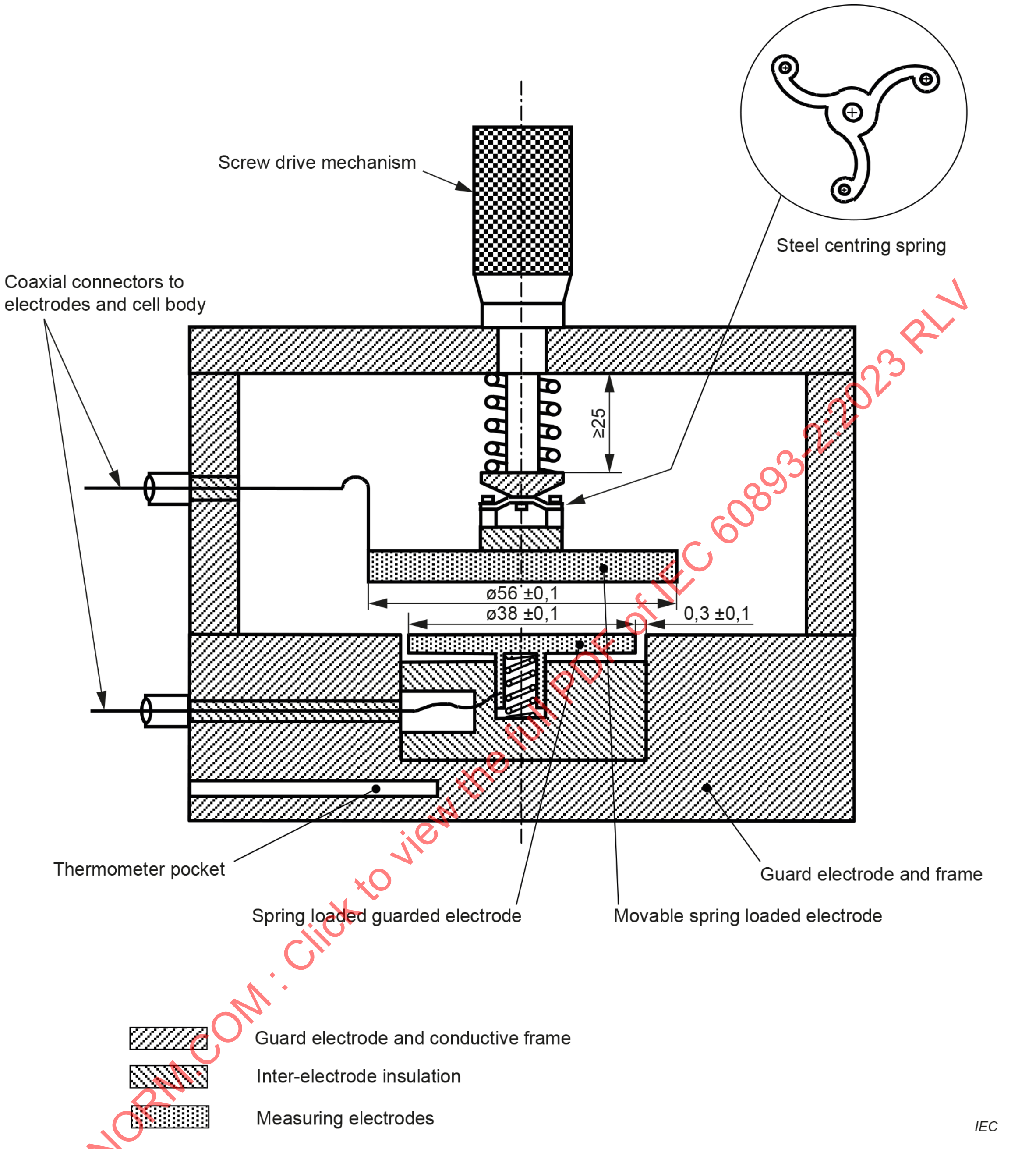


Figure 3 – Example of electrode system for method A

Dimensions in millimetres

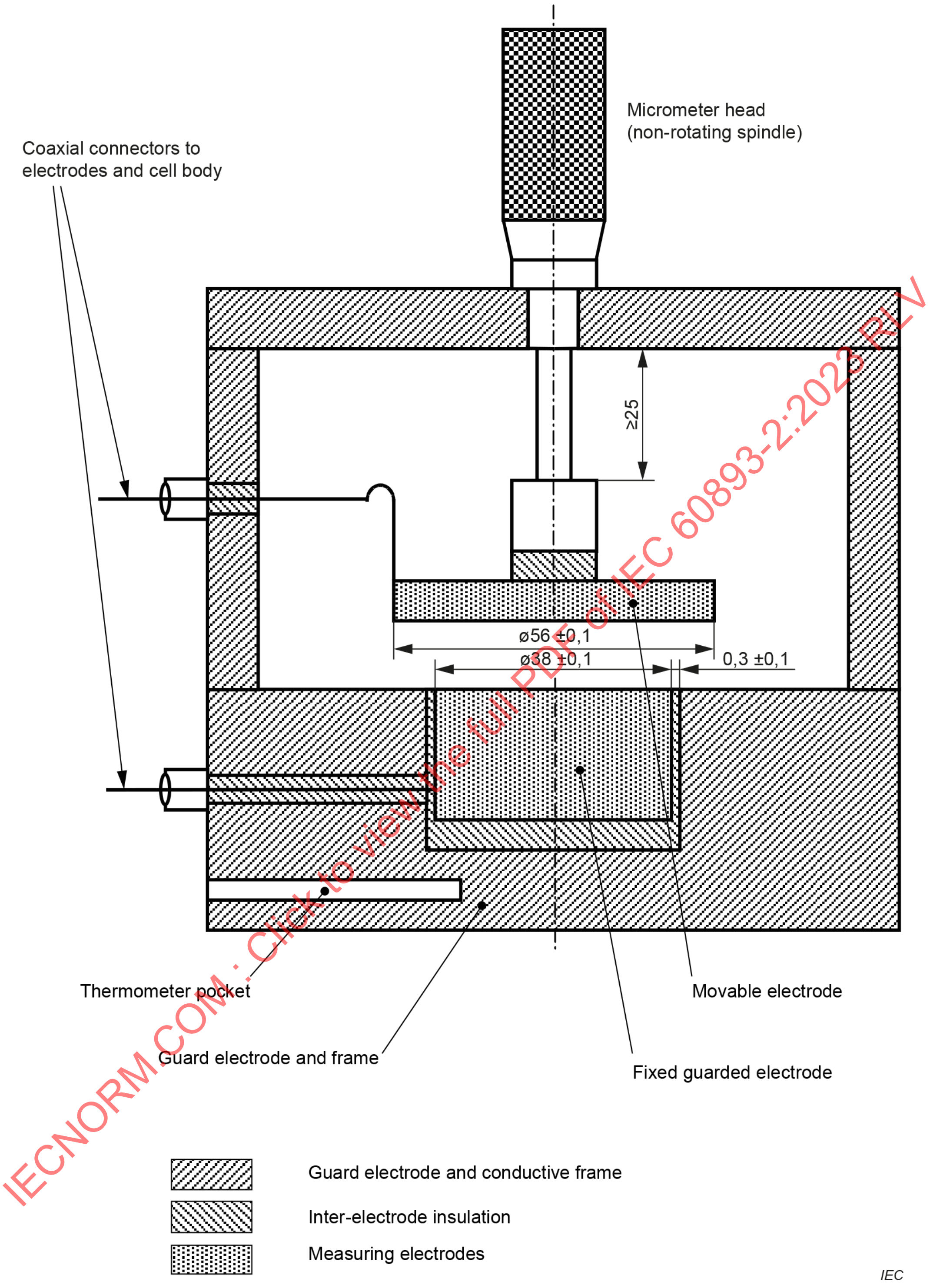


Figure 4 – Example of electrode system for method B

Dimensions in millimetres

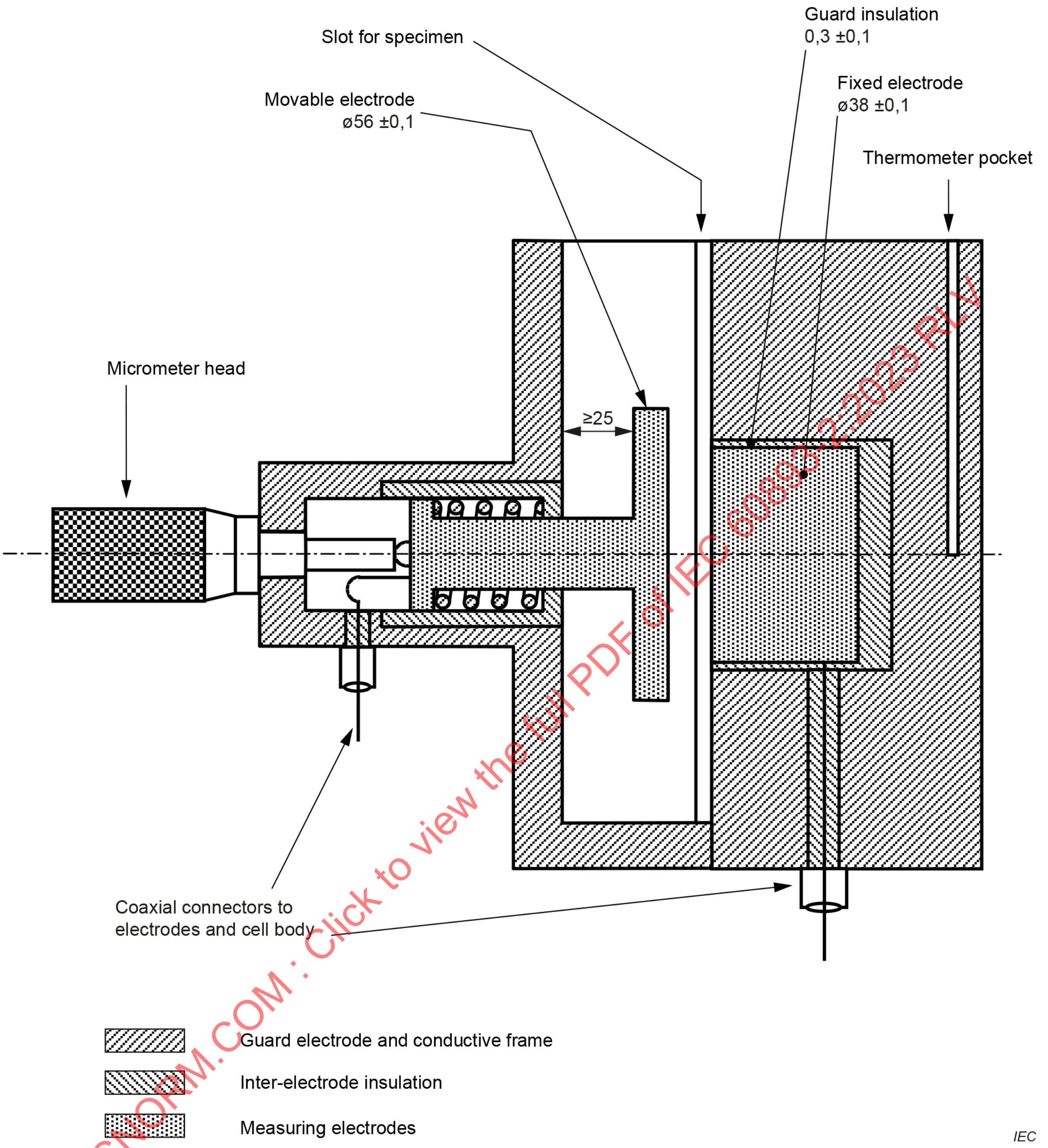


Figure 5 – Example of electrode system for method C

Annex A
(informative)

Modes of representation of capacitance

Some instruments represent a capacitance having finite losses as a parallel combination of loss-free capacitance C_p and a conductance G_p, (Figure A.1 a) while others use a series combination of a capacitance C_s and a resistance R_s (Figure A.1 b). In this document, the parallel representation is used, although both representations are valid. The value of the dissipation factor

$$\tan\delta = \omega C_p / G_p = \omega C_s R_s$$

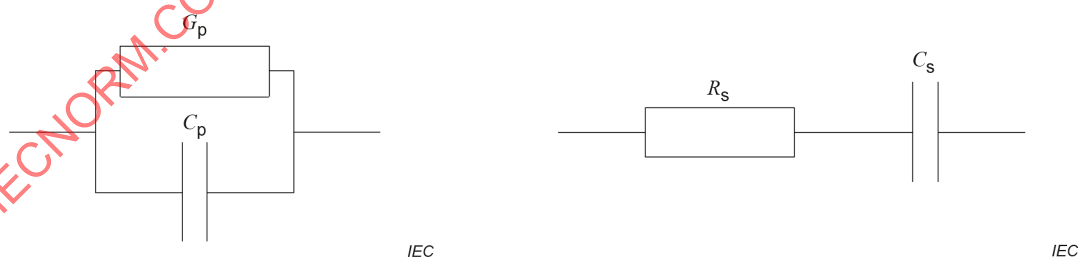
is the same in both representations, although the values of C_p, C_s, G_p and G_s depend upon the value of tan δ as follows:

$$C_p = C_s / (1 + \tan\delta^{\,2}) \quad \text{(A.1)}$$

$$G_p = \tan\delta^{\,2} / (1 + \tan\delta^{\,2}) R_s \quad \text{(A.2)}$$

Thus the capacitance values C_s measured by an instrument using a series representation will require conversion to C_p according to Equation (A.1) when calculating the permittivity by means of Equation (5) in 7.2.7.8, while the values of tan δ measured by the instrument can be used directly in Equation (6).

In many cases, however, the value of tan δ^2 is so small compared to 1 that (dependent upon the accuracy wanted) a correction of the C_p values will not be necessary.



Key

G_p	Conductance	R_s	Resistance
C_p	Capacitance	C_s	Capacitance

a) Parallel representation **b) Series representation**

Figure A.1 – Equivalent parallel and series representation of a capacitor

Annex B
(informative)

Liquids of known permittivity values

Liquids which have been found to be useful are as follows:

Table B.1 – Liquids of know permittivity values

Liquid	Permittivity value
Silicone (1 × 10^{-6} m^2/s to 2 × 10^{-6} m^2/s)	Ca. 2,2
Heptane	Ca. 2,2
Perfluorocarbons	> 2,1
Chlorobenzene [a]	5 to 6
1, 2-dichloroethane [a]	9 to 11
Ethanol [a]	Ca. 30
Cyclohexane	Ca. 2,2

[a] The permittivity of these liquids is much more temperature dependent than that of the lower permittivity liquids.

Warning: Many of these liquids are toxic and require necessary precautions for use.

NOTE Further information can be found in [2].

Bibliography

[1] IEC 60250:1969[12], *Recommended methods for the determination of the permittivity and dielectric dissipation factor of electrical insulating materials at power, audio and radio frequencies including metre wavelengths*

[2] National Bureau of Standards, *Tables of dielectric dispersion data for pure liquids*, in NBS Circular 589, Washington, November 1958

12 This publication has been replaced by IEC 62631-2-1:2018.

SOMMAIRE

COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

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MATÉRIAUX ISOLANTS – STRATIFIÉS INDUSTRIELS RIGIDES EN PLANCHES À BASE DE RÉSINES THERMODURCISSABLES À USAGES ÉLECTRIQUES –

Partie 2: Méthodes d'essai

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Cette troisième édition annule et remplace la deuxième édition parue en 2003. Cette édition constitue une révision technique.

Cette édition inclut les modifications techniques majeures suivantes par rapport à l'édition précédente:

a) la référence à la spécification IEC 60167:1964, qui a été annulée, a été supprimée;
b) des références à l'IEC 62631-3-3:2015, qui remplace l'IEC 60167:1964, ont été ajoutées. Le contenu du 6.3 a été mis à jour en conséquence. La procédure d'essai n'a pas changé;
c) les références normatives ont été mises à jour.

Le texte de cette Norme internationale est issu des documents suivants:

Projet	Rapport de vote
15/1017/FDIS	15/1023/RVD

Le rapport de vote indiqué dans le tableau ci-dessus donne toute information sur le vote ayant abouti à son approbation.

La langue employée pour l'élaboration de cette Norme internationale est l'anglais.

Le présent document a été rédigé selon les Directives ISO/IEC, Partie 2, il a été développé selon les Directives ISO/IEC, Partie 1 et les Directives ISO/IEC, Supplément IEC, disponibles sous www.iec.ch/members_experts/refdocs. Les principaux types de documents développés par l'IEC sont décrits plus en détail sous www.iec.ch/publications.

Une liste de toutes les parties de la série IEC 60893, publiées sous le titre général *Matériaux isolants – Stratifiés industriels rigides en planches à base de résines thermodurcissables à usages électriques*, se trouve sur le site web de l'IEC.

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- reconduit,
- supprimé, ou
- révisé.

INTRODUCTION

Le présent document fait partie d'une série de normes qui traitent des stratifiés industriels rigides en planches à base de résines thermodurcissables à usages électriques.

Cette série comporte quatre parties:

- Partie 1: Définitions, désignations et exigences générales (IEC 60893-1);
- Partie 2: Méthodes d'essai (IEC 60893-2);
- Partie 3: Spécifications pour matériaux particuliers (IEC 60893-3);
- Partie 4: Valeurs typiques (IEC TR 60893-4).

MATÉRIAUX ISOLANTS – STRATIFIÉS INDUSTRIELS RIGIDES EN PLANCHES À BASE DE RÉSINES THERMODURCISSABLES À USAGES ÉLECTRIQUES –

Partie 2: Méthodes d'essai

1 Domaine d'application

La présente partie de l'IEC 60893 décrit les méthodes d'essai applicables aux matériaux définis dans l'IEC 60893-1 (également désignée sous le nom de Partie 1).

2 Références normatives

Les documents suivants sont cités dans le texte de sorte qu'ils constituent, pour tout ou partie de leur contenu, des exigences du présent document. Pour les références datées, seule l'édition citée s'applique. Pour les références non datées, la dernière édition du document de référence s'applique (y compris les éventuels amendements).

IEC 60112, *Méthode de détermination des indices de résistance et de tenue au cheminement des matériaux isolants solides*

IEC 60212:2010, *Conditions normales à observer avant et pendant les essais de matériaux isolants électriques solides*

IEC 60216-1:2013, *Matériaux isolants électriques – Propriétés d'endurance thermique – Partie 1: Méthodes de vieillissement et évaluation des résultats d'essai*

IEC 60243-1:2013, *Rigidité diélectrique des matériaux isolants – Méthodes d'essai – Partie 1: Essais aux fréquences industrielles*

IEC 60296:2012[1], *Fluides pour applications électrotechniques – Huiles minérales isolantes neuves pour transformateurs et appareillages de connexion*

IEC 60587:2007[2], *Matériaux isolants électriques utilisés dans des conditions ambiantes sévères – Méthodes d'essai pour évaluer la résistance au cheminement et à l'érosion*

IEC 60695-11-10:2013, *Essais relatifs aux risques du feu – Partie 11-10: Flammes d'essai – Méthodes d'essai horizontale et verticale à la flamme de 50 W*

IEC 60893-1, *Matériaux isolants – Stratifiés industriels rigides en planches à base de résines thermodurcissables à usages électriques – Partie 1 Définitions, désignations et exigences générales*

IEC 60893-3 (toutes les parties), *Matériaux isolants – Stratifiés industriels rigides en planches à base de résines thermodurcissables à usages électriques – Partie 3: Spécifications pour matériaux particuliers*

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[1] Une cinquième édition de cette norme a été publiée en 2020.

[2] Une quatrième édition de cette norme a été publiée en 2022.

IEC TR 60893-4, *Matériaux isolants – Stratifiés industriels rigides en planches à base de résines thermodurcissables à usages électriques – Partie 4 Valeurs typiques*

IEC 62631-3-3:2015, *Propriétés diélectriques et résistives des matériaux isolants solides – Partie 3-3: Détermination des propriétés résistives (méthodes en courant continu) – Résistance d'isolement*

ISO 62:2008, *Plastiques – Détermination de l'absorption d'eau*

ISO 178:2010[3], *Plastiques – Détermination des propriétés en flexion*

ISO 179-1:2000[4], *Plastiques – Détermination des caractéristiques au choc Charpy – Partie 1: Essai de choc non instrumenté*

ISO 179-2:1997[5], *Plastiques – Détermination des caractéristiques au choc Charpy – Partie 2: Essai de choc instrumenté*

ISO 180:2000[6], *Plastiques – Détermination de la résistance au choc Izod*

ISO 527-1:2012[7], *Plastiques – Détermination des propriétés en traction – Partie 1: Principes généraux*

ISO 527-4:1997[8], *Plastiques – Détermination des propriétés en traction – Partie 4: Conditions d'essai pour les composites plastiques renforcés de fibres isotropes et orthotropes*

ISO 604:2002, *Plastiques – Détermination des propriétés en compression*

ISO 1183-1:2012[9], *Plastiques – Méthodes de détermination de la masse volumique des plastiques non alvéolaires – Partie 1: Méthode par immersion, méthode du pycnomètre en milieu liquide et méthode par titrage*

ISO 3611:2010[10], *Spécification géométrique des produits (GPS) – Équipement de mesurage dimensionnel: Micromètres d'extérieur – Caractéristiques de conception et caractéristiques métrologiques*

3 Une sixième édition de cette norme a été publiée en 2019.

4 Une troisième édition de cette norme a été publiée en 2023.

5 Une cinquième édition de cette norme a été publiée en 2020.

6 Une cinquième édition de cette norme a été publiée en 2023.

7 Une troisième édition de cette norme a été publiée en 2019.

8 Une troisième édition de cette norme a été publiée en 2023.

9 Une troisième édition de cette norme a été publiée en 2019.

10 Une troisième édition de cette norme a été publiée en 2023.

3 Termes et définitions

Aucun terme n'est défini dans le présent document.

L'ISO et l'IEC tiennent à jour des bases de données terminologiques destinées à être utilisées en normalisation, consultables aux adresses suivantes:

- IEC Electropedia: disponible à l'adresse https://www.electropedia.org/
- ISO Online browsing platform: disponible à l'adresse https://www.iso.org/obp

4 Conditionnement des éprouvettes

Sauf spécification contraire, les éprouvettes doivent être conditionnées pendant au moins 24 h en atmosphère normale B selon l'IEC 60212:2010 (température de 23 ± 2 °C, humidité relative de (50 ± 5) %).

Sauf spécification contraire, chaque éprouvette doit être soumise à l'essai dans l'atmosphère de conditionnement et à la température de conditionnement, ou les essais doivent démarrer dans les 3 min qui suivent le retrait de chaque éprouvette de l'atmosphère de conditionnement.

Lorsqu'un essai à température élevée est exigé dans l'une des feuilles de spécification de l'IEC 60893-3, les éprouvettes doivent être conditionnées pendant 1 h à cette température élevée, immédiatement avant l'essai.

5 Dimensions

5.1 Épaisseur

5.1.1 Généralités

Il est permis d'utiliser toute méthode qui permet de mesurer l'épaisseur de la planche stratifiée en un nombre de points approprié, sous réserve que le matériel employé et la méthode de mesure permettent une précision de 0,01 mm ou mieux.

Il a été démontré que la méthode de référence suivante était appropriée; celle-ci doit être utilisée en cas de contestation.

5.1.2 Appareillage d'essai pour la méthode de référence

En cas de contestation, un micromètre d'extérieur conforme à l'ISO 3611, avec des faces de mesure d'un diamètre compris entre 6 mm à 8 mm, doit être utilisé.

5.1.3 Procédure pour la méthode de référence

Mesurer l'épaisseur de la planche stratifiée rigide en l'état de livraison à 0,01 mm près, en huit points, à raison de deux points sur chacun des côtés et à au moins 20 mm du bord.

5.1.4 Résultats

Consigner les valeurs minimale et maximale ainsi que la moyenne arithmétique de toutes les valeurs mesurées, en mm.

5.2 Planéité

5.2.1 Généralités

Cet essai s'applique à toutes les planches d'épaisseur supérieure ou égale à 3 mm.

5.2.2 Éprouvettes

L'éprouvette doit être la planche entière ou le panneau en essai, en l'état de livraison.

5.2.3 Méthode d'essai

Lorsqu'une planche d'épaisseur nominale supérieure ou égale à 3,0 mm est posée sans contrainte, face concave au-dessus, sur une surface plane, la distance d'un point de la surface supérieure à une règle rigide légère, d'une longueur de 1 000 mm ou de 500 mm, déposée sur celle-ci dans n'importe quel sens, ne doit pas dépasser la valeur indiquée dans la feuille correspondante de l'IEC 60893-3 applicable au matériau concerné, à son épaisseur et à la longueur de la règle. La masse de la règle de 1 000 mm ne doit pas dépasser 800 g, et la masse de la règle de 500 mm ne doit pas dépasser 400 g.

5.2.4 Résultats

Consigner l'écart de planéité maximal mesuré, en mm.

Lorsque la planche diffère de la planéité dans les deux directions et qu'elle est voilée, mesurer les deux écarts et consigner la mesure la plus élevée.

6 Essais mécaniques

6.1 Résistance à la flexion

6.1.1 Généralités

La résistance à la flexion est définie comme étant la contrainte de flexion à la rupture. Elle doit être déterminée selon la méthode spécifiée dans l'ISO 178. La Méthode A doit être utilisée.

6.1.2 Éprouvettes

Découper les éprouvettes dans la planche à soumettre à l'essai, leurs axes principaux étant parallèles aux côtés de la planche. Soumettre à l'essai cinq éprouvettes dans chaque direction, sauf pour les types dont les fibres sont alignées principalement dans la même direction. Dans ces cas, découper seulement cinq éprouvettes, leur axe longitudinal étant parallèle à la direction des fibres.

Si l'épaisseur nominale de la planche à soumettre à l'essai est supérieure à 10 mm (20 mm dans le cas du type PF WV), réduire l'épaisseur des éprouvettes à 10 mm (20 mm dans le cas du type PF WV).

Lorsqu'il est nécessaire de réduire l'épaisseur d'une éprouvette, procéder par usinage en laissant une face de la planche intacte. Dans ces cas, l'éprouvette doit être soumise à l'essai en mettant la surface initiale de la planche en contact avec les deux supports.

6.1.3 Méthode d'essai

L'essai doit être effectué en appliquant la charge perpendiculairement au plan de stratification. La vitesse d'essai doit être de 5 mm/min avec une tolérance de ±20 %.

6.1.4 Résultats

Consigner la moyenne arithmétique des résultats mesurés pour chaque direction, en MPa. Prendre la plus petite des deux moyennes comme la résistance à la flexion minimale de la planche en essai, sauf lorsque les fibres de renfort sont disposées principalement dans une direction. Dans ces cas, prendre la valeur moyenne obtenue dans cette direction.

6.2 Module d'élasticité en flexion

6.2.1 Généralités

La méthode d'essai suivante doit être utilisée pour déterminer le module d'élasticité en flexion.

6.2.2 Éprouvettes

Les éprouvettes doivent avoir la même forme que celle décrite pour l'essai de résistance à la flexion décrit au 6.1.2 ci-dessus.

6.2.3 Méthode d'essai

Le module d'élasticité doit être déterminé selon la méthode spécifiée dans l'ISO 178.

6.2.4 Résultats

Les résultats doivent être exprimés en MPa.

6.3 Résistance à la compression

6.3.1 Généralités

La méthode d'essai suivante doit être utilisée pour déterminer la résistance à la compression.

6.3.2 Éprouvettes

Les éprouvettes doivent être découpées dans la planche en essai, comme cela est décrit dans l'ISO 604.

6.3.3 Méthode d'essai

La résistance à la compression doit être déterminée selon la méthode spécifiée dans l'ISO 604, en appliquant la charge perpendiculairement au plan de stratification.

6.3.4 Résultats

Les résultats doivent être exprimés en MPa.

6.4 Résistance au choc

6.4.1 Généralités

Cet essai ne s'applique qu'aux planches d'épaisseur nominale supérieure ou égale à 5 mm.

6.4.2 Résistance au choc Charpy

6.4.2.1 Éprouvettes

Les éprouvettes doivent être découpées dans la planche en essai conformément à la Figure 1 a). Cinq éprouvettes d'épaisseur comprise entre 5 mm et 10 mm doivent être soumises à l'essai dans chaque direction, sauf pour les types dont les fibres sont alignées principalement dans la même direction. Dans ces cas, découper seulement cinq éprouvettes, leur axe longitudinal étant parallèle à la direction des fibres.

Si l'épaisseur nominale de la planche à soumettre à l'essai est supérieure à 10 mm, réduire l'épaisseur des éprouvettes à 10 mm, par usinage de la même quantité sur les deux faces de la planche.

6.4.2.2 Méthode d'essai

La résistance au choc Charpy doit être déterminée parallèlement au plan de stratification selon la méthode spécifiée dans l'ISO 179-1 et l'ISO 179-2, excepté que les éprouvettes doivent être telles que décrites ci-dessus et que l'écartement des supports doit être égal à 70 mm. Le matériau doit être soumis à l'essai, l'axe principal étant parallèle aux côtés de la planche dans chaque direction, sauf dans le cas des matériaux dont les fibres sont disposées principalement dans la même direction. Pour ces matériaux, seules des éprouvettes dont leur axe longitudinal est parallèle à la direction des fibres doivent être soumises à l'essai.

6.4.2.3 Résultats

Consigner la moyenne arithmétique des résultats mesurés pour chaque direction, en kJ/m^2. Prendre la plus petite des deux moyennes comme la résistance au choc Charpy minimale de la planche en essai, sauf lorsque les fibres de renfort sont disposées principalement dans une direction. Dans ces cas, prendre la valeur moyenne obtenue dans cette direction.

6.4.3 Résistance au choc Izod

6.4.3.1 Éprouvettes

Les éprouvettes doivent avoir les dimensions décrites à la Figure 1 b). Cinq éprouvettes d'épaisseur comprise entre 5 mm et 10 mm doivent être soumises à l'essai dans chaque direction, sauf pour les types dont les fibres sont alignées principalement dans la même direction. Dans ces cas, découper seulement cinq éprouvettes, leur axe longitudinal étant parallèle à la direction des fibres.

Si l'épaisseur nominale de la planche à soumettre à l'essai est supérieure à 10 mm, réduire l'épaisseur des éprouvettes à 10 mm, par usinage de la même quantité sur les deux faces de la planche.

6.4.3.2 Méthode d'essai

La résistance au choc Izod doit être déterminée parallèlement au plan de stratification selon la méthode spécifiée dans l'ISO 180. Le matériau doit être soumis à l'essai, l'axe principal étant parallèle aux côtés de la planche dans chaque direction, sauf dans le cas des matériaux dont les fibres sont disposées principalement dans la même direction. Pour ces matériaux, seules des éprouvettes dont leur axe longitudinal est parallèle à la direction des fibres doivent être soumises à l'essai.

6.4.3.3 Résultats

Consigner la moyenne arithmétique des résultats mesurés pour chaque direction, en kJ/m^2. Prendre la plus petite des deux moyennes comme la résistance au choc Izod minimale de la planche en essai, sauf lorsque les fibres de renfort sont disposées principalement dans une direction. Dans ces cas, prendre la valeur moyenne obtenue dans cette direction.

6.5 Résistance au cisaillement parallèlement au plan de stratification

6.5.1 Généralités

Les données issues de l'essai de résistance au cisaillement parallèlement au plan de stratification donnent une indication concernant le degré d'agglomération ou la cohésion entre les couches. L'essai ne s'applique qu'aux planches d'épaisseur nominale supérieure à 5 mm.

6.5.2 Éprouvettes

Des éprouvettes rectangulaires sont découpées aux dimensions suivantes:

longueur 20 mm ± 0,1 mm;

largeur et épaisseur $5\,^{0}_{-0,15}$ mm.

Découper les éprouvettes dans la planche à soumettre à l'essai, leurs axes principaux étant parallèles aux côtés de la planche. Préparer cinq ensembles de deux éprouvettes dans chaque direction.

Les deux éprouvettes de chaque paire doivent avoir des largeurs (dimension dans le sens des couches orthogonales à la longueur) identiques à 0,01 mm près.

6.5.3 Méthode d'essai

Deux éprouvettes sont simultanément soumises à une contrainte de cisaillement dans le dispositif représenté à la Figure 2.

Les éprouvettes doivent être disposées de sorte que la contrainte de cisaillement s'exerce parallèlement au plan de stratification. La vitesse relative de déplacement de la traverse de la machine d'essai doit être de 2 mm/min avec une tolérance de ±20 %.

6.5.4 Résultats

Calculer la résistance au cisaillement en divisant la force de cisaillement par la surface totale de 2 × 100 mm^2 des plans de cisaillement.

Consigner la moyenne arithmétique des résultats mesurés pour chaque direction, en MPa, et prendre la plus petite des deux moyennes comme résistance au cisaillement parallèle de la plaque en essai.

6.6 Résistance à la traction

6.6.1 Généralités

La résistance à la traction, définie comme étant la contrainte de traction à l'effort maximal, doit être déterminée selon la méthode spécifiée dans l'ISO 527-4, conjointement avec l'ISO 527-1.

6.6.2 Éprouvettes

Les éprouvettes doivent être découpées dans la planche en essai, leurs axes principaux étant parallèles aux côtés de la planche dans chaque direction. Cinq éprouvettes d'épaisseur nominale comprise entre 1,5 mm et 10,0 mm doivent être préparées dans chaque direction conformément au type 1 de l'ISO 527-4, sauf dans le cas des matériaux dont les fibres sont disposées principalement dans la même direction. Pour ces matériaux, seules des éprouvettes dont l'axe longitudinal est parallèle à la direction des fibres doivent être soumises à l'essai.

Si l'épaisseur de la planche à soumettre à l'essai est supérieure à 10 mm, réduire l'épaisseur des éprouvettes à 10 mm par usinage de la même quantité sur les deux faces de la planche.

6.6.3 Méthode d'essai

Effectuer l'essai, comme cela est décrit dans l'ISO 527-4. La vitesse de séparation des mâchoires de la machine d'essai doit être de 5 mm/min avec une tolérance de ±20 %.

6.6.4 Résultats

Consigner la moyenne arithmétique des résultats mesurés pour chaque direction, en MPa. Prendre la plus petite des deux moyennes comme la résistance à la traction minimale de la planche en essai, sauf lorsque les fibres de renfort sont disposées principalement dans une direction. Dans ces cas, prendre la valeur moyenne obtenue dans cette direction.

7 Essais électriques

7.1 Rigidité diélectrique et tension de claquage

7.1.1 Généralités

La rigidité diélectrique et la tension de claquage doivent être déterminées selon les méthodes spécifiées dans l'IEC 60243-1 qui décrit l'essai par paliers et l'essai d'épreuve de 60 s. L'une ou l'autre méthode d'essai peut être utilisée. Sauf spécification contraire, l'essai doit être effectué à 90 °C ± 2 °C dans l'huile minérale décrite dans l'IEC 60296:2012, raisonnablement exempte de produits de décomposition. Immédiatement avant l'essai, immerger les éprouvettes dans l'huile maintenue à cette température sur une période comprise entre 0,5 h et 1 h.

7.1.2 Éprouvettes

Pour la rigidité diélectrique, soumettre à l'essai trois éprouvettes perpendiculairement au plan de stratification. Pour la tension de claquage, soumettre à l'essai trois éprouvettes parallèlement au plan de stratification.

Les éprouvettes doivent être découpées dans la planche en essai. Les éprouvettes doivent avoir les dimensions décrites dans l'IEC 60243-1.

7.1.3 Méthode d'essai

7.1.3.1 Généralités

Soumettre le matériau à l'essai par paliers de 20 s décrit au 10.2 de l'IEC 60243-1:2013 ou à l'essai d'épreuve de 60 s décrit au 10.6 de l'IEC 60243-1:2013.

7.1.3.2 Rigidité diélectrique perpendiculairement au plan de stratification

Pour les épaisseurs inférieures ou égales à 3 mm, le matériau doit être soumis à l'essai perpendiculairement au plan de stratification. L'électrode supérieure doit avoir un diamètre de 25 mm et l'électrode inférieure doit avoir un diamètre de 75 mm, conformément à l'IEC 60243-1.

Cet essai n'est généralement pas exigé pour les épaisseurs supérieures à 3 mm, dans la série des Parties 3. Lorsque cela est exigé, réduire l'épaisseur des éprouvettes à 3 mm par usinage sur une seule face, conformément au 5.2.1.4 de l'IEC 60243-1:2013, et appliquer l'exigence d'épaisseur de 3 mm.

7.1.3.3 Tension de claquage parallèlement au plan de stratification

Pour les épaisseurs supérieures à 3 mm et inférieures ou égales à 10 mm, le matériau doit être soumis à l'essai parallèlement au plan de stratification selon le 5.3.3 de l'IEC 60243-1:2013 (électrodes à broches coniques) ou selon le 5.3.2.1 de l'IEC 60243-1:2013 (électrodes plaques parallèles). Pour les épaisseurs supérieures à 10 mm, le matériau doit être soumis à l'essai selon le 5.3.2.1 de l'IEC 60243-1:2013 (électrodes plaques parallèles). Pour les types de matériaux dont les fibres sont disposées principalement dans la même direction, l'essai doit être effectué dans la direction des fibres.

7.1.3.4 Résultats

Pour chacun des essais ci-dessus, la moyenne arithmétique des résultats d'essai doit être prise comme résultat. La valeur minimale doit également être consignée. Les résultats de l'essai de rigidité diélectrique perpendiculairement au plan de stratification doivent être consignés en kV/mm et les résultats de l'essai de tension de claquage parallèlement au plan de stratification doivent être consignés en kV.

7.2 Permittivité et facteur de dissipation

7.2.1 Exigences générales

La permittivité et le facteur de dissipation peuvent être déterminés selon n'importe laquelle des trois méthodes indiquées au 7.2.2. Sauf indication contraire dans les articles correspondants de l'IEC TR 60893-4, les éprouvettes doivent être conditionnées pendant (96 ± 1) h, dans l'air, à une température de 105 °C ± 5 °C avec une humidité relative inférieure à 20 % (atmosphère normale chaude et sèche selon l'IEC 60212:2010). À l'issue de cette période, laisser les éprouvettes refroidir à température ambiante dans un dessiccateur. Appliquer les électrodes et/ou effectuer les mesurages dans les 10 min qui suivent le retrait de chaque éprouvette du dessiccateur.

Lorsque des électrodes solidaires de l'éprouvette sont exigées, de la peinture à l'argent doit être appliquée au centre de l'éprouvette. Des électrodes en caoutchouc conducteur, des électrodes obtenues par vaporisation ou par pulvérisation ne doivent pas être utilisées.

Sauf spécification contraire, les mesurages doivent être effectués à une température de 23 °C ± 2 °C à une fréquence industrielle comprise entre 48 Hz et 62 Hz ou à la fréquence radioélectrique de 1 MHz.

Pour s'assurer que les éprouvettes, les électrodes et le fluide d'immersion sont en équilibre thermique avec leur environnement pendant le mesurage, il convient de les maintenir à la température de mesure pendant au moins 0,5 h immédiatement avant d'effectuer le mesurage. La tension doit être suffisamment élevée pour procurer la sensibilité exigée, mais suffisamment basse pour éviter un chauffage diélectrique et des décharges aux bords des électrodes.

Sauf spécification contraire, l'essai doit être effectué sur deux éprouvettes pour l'ensemble des trois méthodes. À tout moment, les éprouvettes doivent être manipulées avec des pinces plates en acier inoxydable afin de réduire le plus possible les possibilités d'endommagement ou de contamination.

La moyenne des deux valeurs mesurées doit être prise comme résultat.

Pour obtenir des recommandations et explications supplémentaires, il convient de consulter l'IEC 60250:1969 [1][11].

NOTE Dans l'ensemble, les trois méthodes décrites peuvent être utilisées pour des matériaux en planches d'épaisseur comprise entre 0,3 mm et 12,0 mm, en fonction de la conception des supports d'éprouvettes et des électrodes, mais la précision de chaque méthode est influencée par les dimensions et les propriétés de l'éprouvette.

[11] Les chiffres entre crochets renvoient à la Bibliographie.

7.2.2 Méthodes

Méthode A – Méthode de mesure directe utilisant des électrodes solidaires de l'éprouvette

Méthode B – Technique de substitution dans l'air n'utilisant pas d'électrodes solidaires de l'éprouvette

Méthode C – Technique par immersion dans deux fluides n'utilisant pas d'électrodes solidaires de l'éprouvette

La Méthode A convient aux matériaux en planches de permittivité inférieure ou égale à 10,0 et dont les facteurs de dissipation sont supérieurs à 50×10^{-6}, d'épaisseur comprise entre 0,3 mm et 12,0 mm, en fonction de la conception des supports d'éprouvettes. La Méthode A exige une connaissance exacte de l'épaisseur de l'éprouvette et peut être utilisée dans tous les cas lorsque cette information est disponible. Voir 7.2.3.

La Méthode B convient aux matériaux en planches de permittivité inférieure ou égale à 10,0, mais peut ne pas être suffisamment précise pour les matériaux dont le facteur de dissipation est inférieur à 250×10^{-6}. La Méthode B exige une connaissance exacte de l'épaisseur de l'éprouvette et peut être utilisée en lieu et place de la Méthode A lorsque cette information est disponible. En fonction de la conception des supports d'éprouvettes, les éprouvettes d'épaisseur comprise entre 0,3 mm et 12,0 mm peuvent être soumises à l'essai.

La Méthode C convient aux matériaux de permittivité inférieure ou égale à 10,0, mais peut ne pas être suffisamment précise pour les matériaux dont le facteur de dissipation est inférieur à 250×10^{-6}. Si l'épaisseur n'est pas connue avec une exactitude suffisante, la Méthode C peut être utilisée, excepté que la méthode exige l'utilisation d'un liquide inerte qui présente approximativement la même permittivité que celle de l'éprouvette.

La Méthode C par immersion peut fournir une meilleure précision pour la permittivité des matériaux en planches d'épaisseur comprise entre 0,3 mm et 1,0 mm. Cette méthode présente en outre l'avantage de ne pas exiger une connaissance exacte de l'épaisseur de l'éprouvette, mais ne convient pas aux matériaux qui ont une structure à cellules ouvertes.

7.2.3 Principes des méthodes

Dans les méthodes décrites, l'ensemble d'électrodes fait partie intégrante du support d'éprouvette dans lequel l'éprouvette est placée. Dans la Méthode A, les électrodes supports sont en contact avec les électrodes solidaires et les propriétés de l'éprouvette sont mesurées avec l'éprouvette formant un condensateur simple. L'avantage spécifique de la Méthode A est que ces mesurages peuvent être effectués à température élevée, avec comme seule limite les propriétés thermiques de l'éprouvette.

Dans les Méthodes B et C, l'éprouvette et le ou les fluides isolants appropriés sont introduits dans le support d'éprouvette, puis la capacité et le facteur de dissipation de l'ensemble sont mesurés. Ces systèmes introduisent de plus faibles erreurs de mesure que les électrodes solidaires. Ils facilitent également l'installation des électrodes de garde pour réduire le plus possible les distorsions de champ électrique et les capacités parasites.

Des systèmes d'électrodes appropriés pour chacune des méthodes sont décrits au 7.2.5.2, au 7.2.6.2 et au 7.2.7.2. Des instruments de mesure appropriés sont décrits au 7.2.4.

La permittivité et le facteur de dissipation d'un diélectrique peuvent varier considérablement en fonction de la fréquence, la température et l'humidité relative. Par conséquent, il convient de prendre les valeurs mesurées uniquement pour indiquer les propriétés diélectriques de l'éprouvette dans des conditions similaires à celles utilisées lors de l'essai.