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BASIC SAFETY PUBLICATION

PUBLICATION FONDAMENTALE DE SÉCURITÉ

Method for the determination of the proof and the comparative tracking indices of solid insulating materials

Méthode de détermination des indices de résistance et de tenue au cheminement des matériaux isolants solides

IEC 60112:2020-10(en-fr)

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

COMMISSION ELECTROTECHNIQUE INTERNATIONALE

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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METHOD FOR THE DETERMINATION OF THE PROOF AND THE COMPARATIVE TRACKING INDICES OF SOLID INSULATING MATERIALS

FOREWORD

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International Standard IEC 60112 has been prepared by IEC technical committee 112: Evaluation and qualification of electrical insulating materials and systems.

This fifth edition cancels and replaces the fourth edition published in 2003 and Amendment 1:2009. This edition constitutes a technical revision.

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

- Introduction of a new contaminant, solution C with a surfactant aligned with the test method of IEC 60587. The definition of the solution B was transferred to Annex B for backward reference.
- Introduction of a screening test, considering the fact that some materials can withstand high test voltages, but fail at lower test voltages.

It has the status of a basic safety publication in accordance with IEC Guide 104.

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

FDIS	Report on voting
112/479/FDIS	112/484/RVD

Full information on the voting for the approval of this International Standard can be found in the report on voting indicated in the above table.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

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

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- withdrawn,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

METHOD FOR THE DETERMINATION OF THE PROOF AND THE COMPARATIVE TRACKING INDICES OF SOLID INSULATING MATERIALS

1 Scope

This document specifies the method of test for the determination of the proof and comparative tracking indices of solid insulating materials on pieces taken from parts of equipment and on plaques of material using alternating voltage.

This document provides a procedure for the determination of erosion when required.

NOTE 1 The proof tracking index is used as an acceptance criterion as well as a means for the quality control of materials and fabricated parts. The comparative tracking index is mainly used for the basic characterization and comparison of the properties of materials.

This test method evaluates the composition of the material as well as the surface of the material being evaluated. Both the composition and surface condition directly influence the results of the evaluation and are considered when using the results in material selection process.

Test results are not directly suitable for the evaluation of safe creepage distances when designing electrical apparatus.

NOTE 2 This is in compliance with IEC 60664-1, *Insulation coordination for equipment within low-voltage systems – Part 1: Principles, requirements and tests.*

NOTE 3 This test discriminates between materials with relatively poor resistance to tracking, and those with moderate or good resistance, for use in equipment which can be used under moist conditions. More severe tests of longer duration are available for the assessment of performance of materials for outdoor use, utilizing higher voltages and larger test specimens (see the inclined plane test of IEC 60587). Other test methods such as the inclined method can rank materials in a different order from the drop test given in this document.

This basic safety publication focusing on a safety test method is primarily intended for use by technical committees in the preparation of safety publications in accordance with the principles laid down in IEC Guide 104 and ISO/IEC Guide 51.

One of the responsibilities of a technical committee is, wherever applicable, to make use of basic safety publications in the preparation of its publications.

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.

ISO 4287, *Geometrical Product Specifications (GPS) – Surface texture: Profile method – Terms, definitions and surface texture parameters*

3 Terms and definitions

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

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

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

3.1
tracking
progressive formation of conducting paths, which are produced on the surface and/or within a solid insulating material, due to the combined effects of electric stress and electrolytic contamination

3.2
tracking failure
failure of insulation due to tracking between conductive parts

Note 1 to entry: In the present test, tracking is indicated by operation of an over-current device due to the passage of a current across the test surface and/or within the specimen.

3.3
electrical erosion
wearing away of insulating material by the action of electrical discharges

3.4
air arc
arc between the electrodes above the surface of the specimen

3.5
comparative tracking index
CTI
numerical value of the maximum voltage (in V) at which five test specimens withstand the test period for 50 drops without tracking failure and without a persistent flame occurring and including also a statement relating to the behaviour of the material when tested using 100 drops (see 11.3)

Note 1 to entry: No tracking failure and no persistant flame are allowed at any lower test voltage.

Note 2 to entry: The criteria for CTI may also require a statement concerning the degree of erosion.

Note 3 to entry: Although a non-persistent flame is allowed in the test without constituting failure, materials which generate no flame at all are preferred unless other factors are considered to be more important. See also Annex A.

Note 4 to entry: Some materials can withstand high test voltages, but fail at lower test voltages. See also 11.2.

3.6
persistent flame
flame which burns for more than 2 s

3.7
proof tracking index
PTI
numerical value of the proof voltage (in V) at which five test specimens withstand the test period for 50 drops without tracking failure and without a persistent flame occurring

Note 1 to entry: Although a non-persistent flame is allowed in the test without constituting failure, materials which generate no flame at all are preferred unless other factors are considered to be more important. See also Annex A.

3.8
de-ionized water
water for analytical laboratory use in accordance with ISO 3696, grade 3, or equivalent quality

4 Principle

The upper surface of the test specimen is supported in a horizontal plane and subjected to an electrical stress via two electrodes. The surface between the electrodes is subjected to a succession of drops of electrolyte either until the over-current device operates, or until a persistent flame occurs, or until the test period has elapsed.

The individual tests are of short duration (less than 1 h) with up to 50 or 100 drops of about 20 mg of electrolyte falling at 30 s intervals between platinum electrodes, 4 mm apart on the test specimen surface.

An AC voltage between 100 V and 600 V is applied to the electrodes during the test.

During the test, specimens may also erode or soften, thereby allowing the electrodes to penetrate them. The formation of a hole through the test specimen during a test is to be reported together with the hole depth (test specimen thickness). Retests may be made using thicker test specimens, up to a maximum of 10 mm.

NOTE The number of drops needed to cause failure by tracking usually increases with decreasing applied voltage and, below a critical value, tracking ceases to occur. For some materials, tracking also ceases to occur above an upper critical value.

5 Test specimen

Any approximately flat surface may be used, provided that the area is sufficient to ensure that during the test no liquid flows away from the test electrodes.

NOTE 1 In general flat surfaces of not less than 20 mm × 20 mm are used to reduce the probability of electrolyte flows away from the test electrodes although smaller sizes can be used, subject to no electrolyte loss, e.g. ISO 3167, 15 mm × 15 mm multi-purpose test specimens.

NOTE 2 In general separate test specimens for each test are used. If several tests are to be made on the same test piece, testing points can be sufficiently far from each other so that splashes, fumes, or erosion, from the testing point will not contaminate or influence the other areas to be tested.

The thickness of the test specimen shall be 3 mm or more. Individual pieces of material may be stacked to obtain the required thickness of at least 3 mm.

NOTE 3 The values of the CTI obtained on specimens with a thickness below 3 mm cannot be comparable with those obtained on thicker specimens because of greater heat transmission to the glass support through thinner test specimens. For this reason, stacked specimens are possible.

Test specimens shall have uniformly smooth and untextured surfaces which are free from surface imperfections such as scratches, blemishes, impurities, etc, unless otherwise stated in the product standard. If this is impossible, the results shall be reported together with a statement describing the surface of the specimen because certain characteristics on the surface of the specimen could add to the dispersion of the results.

For tests on parts of products, where it is impossible to cut a suitable test specimen from a part of a product, specimens cut from moulded plaques of the same insulating material may be used. In these cases, care should be taken to ensure that both the part and the plaque are produced by the same fabrication process, resulting in the same surface texture, wherever possible. Where the details of the final fabrication process are unknown, methods given in ISO 293, ISO 294-1 and ISO 294-3 and ISO 295 may be appropriate.

NOTE 4 The use of different fabrication conditions/processes can lead to different levels of performance in the PTI and CTI test.

NOTE 5 Parts moulded using different flow directions can also exhibit different levels of performance in the PTI and CTI test.

In special cases, the test specimen may be ground to obtain a flat surface. In this case, the surface texture according ISO 4287 (e.g. R_z values) shall be reported (see 10.2 and 11.5).

NOTE 6 Any grinding can damage the specimen. In this case, material surface made by grinding has higher or lower tracking value than the original surface.

Where the direction of the electrodes relative to any feature of the material is significant, measurements shall be made in the direction of the feature and orthogonal to it. The direction giving the lower CTI shall be reported, unless otherwise specified.

NOTE 7 Use of an aggressive electrolyte, such as solution C, is common, when the material has a hydrophobic surface.

6 Test specimen conditioning

6.1 Environmental conditioning

Unless otherwise specified, the test specimens shall be conditioned for a minimum of 24 h at (23 ± 5) °C, with (50 ± 10) % RH. Once the test specimen has been removed from the conditioning chamber (see 7.7) the test shall be started within 30 minutes.

6.2 Test specimen surface state

Unless otherwise specified,

a) tests shall be made on clean surfaces;

b) any cleaning procedure used shall be reported. Wherever possible, the details shall be agreed between supplier and customer.

Dust, dirt, fingerprints, grease, oil, mould release or other contaminants can influence the results. When cleaning the test specimen, swelling, softening, abrasion or other damage to the material shall be avoided.

7 Test apparatus

7.1 Electrodes

Two electrodes of platinum with a minimum purity of 99 % shall be used (see Annex C). The two electrodes shall have a rectangular cross-section of (5 ± 0,1) mm × (2 ± 0,1) mm, with one end chisel-edged with an angle of (30 ± 2)° (see Figure 1). The sharp edge shall be removed to produce an approximately flat surface, 0,01 mm to 0,1 mm wide.

NOTE 1 A microscope with a calibrated eyepiece has been found suitable for checking the size of the end surface.

NOTE 2 In general, mechanical means are used to re-furbish the electrode shape after a test to ensure that the electrodes maintain the required tolerances, especially with respect to the edges and corners.

At the start of the test, the electrodes shall be symmetrically arranged in a vertical plane, the total angle between them being (60 ± 5)° and with opposing electrode faces approximately vertical on a flat horizontal surface of the test specimen (see Figure 2). Their separation along the surface of the test specimen at the start of the test shall be (4,0 ± 0,1) mm.

A thin metal rectangular slip gauge shall be used to check the electrode separation. The electrodes shall move freely and the force exerted by each electrode on the surface of the

test specimen at the start of the test shall be (1,00 ± 0,05) N. The design shall be such that the force can be expected to remain at the initial level during the test.

One typical type of arrangement for applying the electrodes to the test specimen is shown in Figure 3. The force shall be verified at appropriate intervals.

Where tests are made solely on those materials where the degree of electrode penetration is small, the electrode force may be generated by the use of springs. However, gravity should be used to generate the force on general purpose equipment (see Figure 3).

NOTE 3 With most, but not all designs of apparatus, if the electrodes move during a test due to softening or erosion of the specimen, their tips will prescribe an arc and the electrode gap will change. The magnitude and direction of the gap change will depend on the relative positions of the electrode pivots and the electrode/specimen contact points. The significance of these changes will probably be material dependent and has not been determined. Differences in design could give rise to differences in inter-apparatus results.

7.2 Test circuit

The electrodes shall be supplied with a substantially sinusoidal voltage, variable between 100 V and 600 V at a frequency of 48 Hz to 62 Hz. The voltage measuring device shall indicate a true RMS value and shall have an accuracy of 1,5 % or better for the reading. The power of the source shall be not less than 0,6 kVA. An example of a suitable test circuit is shown in Figure 4.

A variable resistor shall be capable of adjusting the current between the short-circuited electrodes to (1,0 ± 0,1) A and the voltage indicated by the voltmeter shall not decrease by more than 10 % when this current flows. The instrument used to measure the value of the short-circuit current shall have an accuracy of ±3 % or better for the reading.

NOTE To achieve the tolerance requirement it may be necessary that the suppply voltage to the apparatus is sufficiently stable.

The over-current device shall operate when a current with an RMS value of (0,50 ± 0,05) A has persisted for (2,00 ± 0,20) s.

7.3 Test solutions

Solution A:

Dissolve approximately 0,1 % by mass of analytical reagent grade anhydrous ammonium chloride (NH_4Cl), of a purity of not less than 99,8 %, in de-ionized water to give a resistivity of (3,95 ± 0,05) Ωm at (23 ± 1) °C.

NOTE 1 The quantity of ammonium chloride is selected to give a solution in the required range of resistivity.

NOTE 2 The conductivity of the solution A at 25°C is (3,75 ± 0,05) Ωm, and (4,25 ± 0,05) Ωm at 20 °C.

Solution B:

Description of this solution is given in Annex B (informative).

Solution C:

Dissolve approximately 0,2 % by mass of analytical reagent grade anhydrous ammonium chloride (NH_4Cl), of a purity of not less than 99,8 %, and (0,5 ± 0,02) % by mass of a non-ionic surfactant (*t-octylphenoxypolyethoxyethanol, CAS Registry Number 9002-93-1)* in de-ionized water to give a resistivity of (1,98 ± 0,05) Ωm at (23 ± 1) °C and a surface tension of < 40 mN/m according to ISO 304.

NOTE 3 The quantity of ammonium chloride is selected to give a solution in the required range of resistivity, and the quantity of the surfactant to give a surface tension of the solution in the required range.

Solution A is normally used, but where a more aggressive contaminant is required, solution C is recommended. To indicate that solution C was used, the CTI or PTI value shall be followed by the letter "C". The use of solution B may be stipulated for comparability with prior results.

7.4 Dropping device

Drops of the test solution shall fall on to the specimen surface at intervals of (30 ± 5) s. The drops shall fall approximately centrally between the two contact areas of the electrodes from a height of (35 ± 5) mm.

The target time between single drops shall be 30 s. The mass of a sequence of 50 drops shall lie between 0,997 g and 1,147 g. The mass of a sequence of 20 drops shall lie between 0,380 g and 0,480 g.

NOTE 1 The mass of the drops can be determined by weighing with the appropriate laboratory balance.

NOTE 2 The target mass for 50 drops is 1,07 g and for 20 drops it is 0,43 g.

The mass of the drops shall be checked at appropriate time intervals.

NOTE 3 For solution A, a length of thin walled stainless steel tubing (e.g. hypodermic needle tubing), having an outer diameter of between 0,9 mm and 1,2 mm, dependent upon the dropping system, has been found to be suitable for the tip of the dropping device. For solution B and solution C, tubes having outer diameters over the range 0,9 mm to 3,45 mm have been found to be necessary with the different dropping systems in use.

NOTE 4 A drop detector or counter can be used to ascertain whether there are any double drops or whether drops are missing.

7.5 Test specimen support platform

A glass plate or plates, having a total thickness of not less than 4 mm and of a suitable size shall be used to support the test specimen during the test.

NOTE 1 In order to avoid the problem of cleaning the specimen support table, it is common that a disposable glass microscope slide is placed on the specimen support table immediately under the test specimen.

NOTE 2 The use of thin metal foil conductors around the edge of the glass plate to detect electrolyte loss has been found useful.

7.6 Electrode assembly installation

The specimen and the contacting electrodes shall be mounted in an essentially draught-free space in a chamber.

NOTE To keep the chamber reasonably free of fumes, it can be necessary, for certain classes of materials, to have a small air flow across the surface of the test specimen and between the electrodes. An air velocity of the order of 0,2 m/s before the start of the test and as far as possible during the test has been found suitable. The air velocity in other areas of the chamber can be substantially higher to assist in fume removal. The air velocity can be measured with an appropriately scaled hot wire anemometer.

A suitable fume extraction system shall be provided to allow safe venting of the chamber after the test.

7.7 Conditioning chamber

The conditioning chamber shall be maintained at (23 ± 2) °C and a relative humidity of (50 ± 10) %.

NOTE Standard conditions for use prior to and during the testing of solid electrical insulating materials are specified in IEC 60212.

8 Basic test procedure

8.1 General

Where the material is substantially anisotropic, tests shall be made in the direction of the features and orthogonal to them. Results from the direction giving the lower values shall be used, unless otherwise specified.

Tests shall be made at an ambient temperature of (23 ± 5) °C.

Tests shall be made on uncontaminated test specimens, unless otherwise specified.

The result of a test where a hole is formed is considered to be valid, irrespective of the test specimen thickness, but the formation of the hole shall be reported together with the depth of the hole (the thickness of the test specimen or stack).

8.2 Preparation

After each test, clean the electrodes with an appropriate solvent and then rinse and dry them with de-ionized water. If necessary, restore their shape, polish if necessary, and give a final rinse and dry before the next test.

Immediately before the test ensure, if necessary by cooling the electrodes, that their temperature is sufficiently low so that they have no adverse effect on the specimen properties.

Ensure freedom from visual contamination and ensure that the solution to be used conforms to the conductivity requirements either by regular testing, or by measurement immediately before the test.

NOTE 1 Residues on the dropping device from an earlier test will probably contaminate the solution and evaporation of the solution will increase its concentration – both of which may result in lower than true values. In such cases the outside of the dropping device can be cleaned mechanically and/or with a solvent and the inside by flushing through with conforming solution before each test. Flushing through some 10 to 20 drops depending upon the delay between tests will normally remove any non-conforming liquid.

In case of dispute, the cleaning procedures used for the electrodes and dropper tube shall be agreed between purchaser and supplier.

Place the test specimen, with the test surface uppermost and horizontal on the specimen support table. Adjust the relative height of the test specimen and electrode mounting assembly, such that on lowering the electrodes on to the specimen, the correct orientation is achieved with a separation of (4,0 ± 0,1) mm. Ensure that the chisel edges make contact with the surface of the specimen with the required force and over the full width of the chisel.

NOTE 2 It can be helpful to place a light behind the electrodes when making this check visually.

The orientation of the specimen should ensure that the droplet stays between the electrodes.

Set the test voltage to the required value which shall be an integer multiple of 25 V, and adjust the circuit parameters so that the short-circuit current is within the permitted tolerance.

8.3 Test procedure

Start the dropping system so that drops fall on to the test surface and continue the test until one of the following occurs:

a) the over-current device operates;

b) a persistent flame occurs;

c) at least 25 s have elapsed after the fiftieth (hundredth) drop has fallen without a) or b) occurring.

NOTE If there is no requirement for the determination of erosion, the 100 drop tests can be made ahead of any 50 drop tests.

After completion of the test, vent the chamber of noxious fumes and remove the test specimen.

9 Determination of erosion

When required, specimens which have not failed at the 50 drop point shall be cleaned of any debris or loosely attached degradation products and placed on the platform of a depth gauge. The maximum depth of erosion of each specimen shall be measured in millimetres to an accuracy of 0,1 mm, using a 1,0 mm nominal diameter probe having a hemispherical end. The result is the maximum of the five measured values.

Erosion depths of less than 1 mm shall be reported as < 1 mm.

In the case of tests according to Clause 10, when required the erosion shall be measured on the specimens which withstood 50 drops at the specified voltage.

In the case of tests according to Clause 11, when required the erosion shall be measured on the five specimens tested at the maximum 50 drop voltage.

10 Proof tracking index test (PTI)

10.1 Procedure

Where, in IEC standards for material or for electrical equipment specifications, or in other standards, a proof test only is required, 50 drop tests shall be made in accordance with Clause 8 but at the single voltage specified.

Operation of the over-current device by air arcs does not constitute a tracking failure.

The minimum required number of specimens is five. If one of five specimens fails at the certain test voltage, a new set of five samples may be tested unless otherwise specified. If only one of the total of ten specimens fails, the result is "pass".

A different number of specimens may be agreed by manufacturer and user, or defined in product standards.

The proof voltage shall be an integer multiple of 25 V.

10.2 Report

The report shall include the following information.

a) Identification of the material tested and details of any conditioning.

b) Thickness of the specimens and the number of layers used to achieve this thickness.

c) Nature of the test specimen surface where the original surface was not tested:

   1) details of any cleaning process;

   2) details of any machining processes, e.g. grinding;

   3) details of any coating on the tested specimen.

d) State of the surface before testing, with regard to surface imperfections, e.g. surface scratches, blemishes, impurities, etc.

e) The cleaning procedure used for the electrodes and dropper.

f) Where the measurements were not made in an essentially draught-free space, report on the approximate air flow rate.

g) Orientation of the electrodes in relation to any known characteristics of the material.

h) Report on the result of the proof tracking index test where there is no requirement for the determination of the degree of erosion as follows:

- Pass or fail at the specified voltage with an indication of the type of solution if Type C or Type B.

  EXAMPLE for solution A 'Pass PTI 175', or 'Fail PTI 175'

  EXAMPLE for solution B 'Pass PTI 225 M', or 'Fail PTI 225 M'

  EXAMPLE for solution C 'Pass PTI 175 C', or 'Fail PTI 175 C'

Where there is an erosion requirement the result shall be reported as follows:

- Pass or fail at the specified voltage with an indication of the type of solution if Type C, or Type B, and the maximum depth of erosion.

  PASS EXAMPLE for solution A 'Pass PTI 250 – 3', or 'Fail PTI 250 – 3'

  PASS EXAMPLE for solution B 'Pass PTI 375 M – 3', or 'Fail PTI 375 M – 3'

  PASS EXAMPLE for solution C 'Pass PTI 250 C – 3' or 'Fail PTI 250 C – 3'.

Where the erosion cannot be reported because the specimen flamed, both shall be reported.

Where a hole developed through the specimen, its formation shall be reported together with an indication of its depth (specimen thickness).

Where the tests were invalid due to air arcs, this shall be reported.

11 Determination of comparative tracking index (CTI)

11.1 General

Determination of the comparative tracking index requires the determination of the maximum voltage at which five specimens withstand the test period for 50 drops without failure and whether, at a voltage of 25 V lower than the maximum 50 drop figure, the specimen withstands 100 drops. If this is not the case, the maximum 100 drop withstand voltage shall be determined.

If one of five specimens fails at a certain test voltage, a new set of five samples may be tested. If only one of the total of ten specimens fails, this result qualifies for continuing the procedure with the next higher voltage.

11.2 Screening test

If the behaviour of the material is unknown, a screening test shall start with at least three specimens at a maximum starting voltage of 300 V with a minimum of 50 drops. If the material withstands the initial test without tracking failure and without a persistent flame, always using three specimens, increase the test voltage by 100 V steps until a tracking failure or a persistent flame occurs. Then reduce the test voltage by 50 V, and finally increase or reduce the test voltage by 25 V to identify the maximum test voltage for the determination of the comparative tracking index.

If the materail fails at the initial test voltage, reduce the test voltage by 100 V and follow the same iterative procedure for the determination of the comparative tracking index, always using three specimens.