

# INTERNATIONAL STANDARD



BASIC SAFETY PUBLICATION

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

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## INTERNATIONAL ELECTROTECHNICAL COMMISSION

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

## FOREWORD

- 1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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**This commented version (CMV) of the official standard IEC 60112:2020 edition 5.0 allows the user to identify the changes made to the previous edition IEC 60112:2003 +AMD1:2009 CSV edition 4.1. Furthermore, comments from IEC TC 112 experts are provided to explain the reasons of the most relevant changes.**

**A vertical bar appears in the margin wherever a change has been made. Additions are in green text, deletions are in strikethrough red text. Experts' comments are identified by a blue-background number. Mouse over a number to display a pop-up note with the comment.**

**This publication contains the CMV and the official standard. The full list of comments is available at the end of the CMV.**

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.

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# 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 **1** 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. **2**

Test results ~~cannot be used~~ are not directly suitable **3** 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*. **4**

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 ~~required~~ available **5** 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 ~~may~~ can rank materials in a different order from the drop test given in this document. **6**

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. **7**

## 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 Guide 104:1997, The preparation of safety publications and the use of basic safety publications and group safety publications~~ **8**

~~ISO 293:1986, Plastics – Compression moulding test specimens of thermoplastic materials~~ **9**

~~ISO 294-1:1996, Plastics – Injection moulding of test specimens of thermoplastic materials – Part 1: General principles, and moulding of multi-purpose and bar test specimens~~ **10**

~~ISO 294-3:2002, Plastics – Injection moulding of test specimens of thermoplastic materials – Part 3: Small plates~~ **11**



~~ISO 295:1991, Plastics—Compression moulding of test specimens of thermosetting materials~~ 12

ISO 4287, Geometrical Product Specifications (GPS) – Surface texture: Profile method – Terms, definitions and surface texture parameters 13

### 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> 14

#### 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 ~~conducting~~ conductive 15 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 ~~of at least 0,5 A for at least 2 s~~ 16 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) 17 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 persistent flame are allowed at any lower test voltage. 18

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. 19

#### 3.6

##### persistent flame

~~in case of dispute—~~one flame 20 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 **21**

## 4 Principle

The upper surface of the test specimen is supported in a ~~approximately~~ **22** 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. **23**

## 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 ~~over the edges of the test specimen~~ away from the test electrodes. **24**

NOTE 1 In general flat surfaces of not less than 20 mm × 20 mm are ~~recommended~~ used to reduce the probability of electrolyte ~~loss over the specimen edge~~ flows away from the test electrodes **25** although smaller sizes ~~may~~ can **26** be used, subject to no electrolyte loss, e.g. ISO 3167, 15 mm × 15 mm multi-purpose test specimens.

NOTE 2 ~~It is preferable to use~~ In general separate test specimens for each test are used. If several tests are to be made on the same test piece, ~~care should be taken to ensure that the~~ testing points ~~are~~ 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. **27**

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 ~~may not~~ 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 ~~allowed~~ possible. **28**

Test specimens shall have ~~nominally~~ uniformly **29** 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, 30 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 ~~may~~ can 31 lead to different levels of performance in the PTI and CTI test.

NOTE 5 Parts moulded using different flow directions ~~may~~ can 32 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). 33

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. 34

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. 35

## 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 °C ± 5 K~~ (23 ± 5) °C, 36 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. 37

### 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.

NOTE Dust, dirt, fingerprints, grease, oil, mould release or other contaminants ~~may~~ can influence the results. ~~Care should be taken~~ When cleaning the test specimen ~~to avoid~~, swelling, softening, abrasion or other damage to the material shall be avoided. 38

## 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 ~~It is recommended that~~ In general, **39** 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  $(60 \pm 5)^\circ$  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  $(4,0 \pm 0,1)$  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  $(1,00 \pm 0,05)$  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 ~~a maximum error~~ an accuracy **40** 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  $(1,0 \pm 0,1)$  A and the voltage indicated by the voltmeter shall not decrease by more than 10 % when this current flows ~~(see Figure 4)~~. **41** The instrument used to measure the value of the short-circuit current shall have ~~a maximum error~~ an accuracy **42** of  $\pm 3$  % or better for the reading.

~~The input supply voltage to the apparatus shall be adequately stable.~~

NOTE To achieve the tolerance requirement it may be necessary that the supply voltage to the apparatus is sufficiently stable. **43**

The over-current device shall operate when a current with an RMS value of ~~0,50 A with a relative tolerance of  $\pm 10$  %~~, has persisted for ~~2,00 s with a relative tolerance of  $\pm 10$  %~~  $(0,50 \pm 0,05)$  A has persisted for  $(2,00 \pm 0,20)$  s. **44**

## 7.3 Test solutions

Solution A:

Dissolve approximately 0,1 % by mass of analytical reagent grade anhydrous ammonium chloride ( $\text{NH}_4\text{Cl}$ ), of a purity of not less than 99,8 %, in de-ionized water, ~~having a conductivity of not greater than 1 mS/m~~ **45** to give a resistivity of  $(3,95 \pm 0,05)$   $\Omega\text{m}$  at  $(23 \pm 1)^\circ\text{C}$ .

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  $25^\circ\text{C}$  is  $(3,75 \pm 0,05)$   $\Omega\text{m}$ , and  $(4,25 \pm 0,05)$   $\Omega\text{m}$  at  $20^\circ\text{C}$ . **46**

## Solution B:

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

## Solution C: 47

Dissolve approximately 0,42 % by mass of analytical reagent grade anhydrous ammonium chloride ( $\text{NH}_4\text{Cl}$ ), of a purity of not less than 99,8 %, and  $(0,5 \pm 0,02)$  % by mass of ~~sodium di-butyl naphthalene sulfonate~~ a non-ionic surfactant (*t-octylphenoxypolyethoxyethanol*, CAS Registry Number 9002-93-1) in de-ionized water, ~~having a conductivity of not greater than 1 mS/m~~, to give a resistivity of  $(1,98 \pm 0,05) \Omega\text{m}$  at  $(23 \pm 1) ^\circ\text{C}$  and a surface tension of  $< 40 \text{ mN/m}$  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. 48

Solution A is normally used, but where a more aggressive contaminant is required, solution ~~B~~ C is recommended. To indicate that solution ~~B~~ C was used, the CTI or PTI value shall be followed by the letter "MC". 49 The use of solution B may be stipulated for comparability with prior results. 50

## 7.4 Dropping device

Drops of the test solution shall fall on to the specimen surface at intervals of  $(30 \pm 5) \text{ s}$ . The drops shall fall approximately centrally between the two contact areas of 51 the electrodes from a height of  $(35 \pm 5) \text{ mm}$ .

~~The time for 50 drops to fall on to the specimen shall be  $(24,5 \pm 2) \text{ min}$ .~~

The target time between single drops shall be 30 s. 52 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.

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NOTE 1 The mass of the drops ~~may~~ can 53 be determined by weighing with the appropriate laboratory balance. 2020

NOTE 2 The target mass for 50 drops is 1,07 g and for 20 drops it is 0,43 g. 54

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, 55 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 ~~The use of~~ A drop detector or counter ~~is recommended~~ can be used 56 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 ~~recommended~~ common 57 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 ~~its immediate~~ the contacting electrodes shall be mounted in an essentially draught-free space in ~~an enclosure~~ a chamber. 58

NOTE To keep the chamber reasonably free of fumes, it ~~may~~ 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 ~~enclosure may~~ chamber can be substantially higher to assist in fume removal. The air velocity ~~may~~ can be measured with an appropriately scaled hot wire anemometer. **59**

A suitable fume extraction system shall be provided to allow safe venting of the ~~enclosure~~ chamber **60** after the test.

### 7.7 Conditioning chamber **61**

The conditioning chamber shall be maintained at  $(23 \pm 2) ^\circ\text{C}$  and a relative humidity of  $(50 \pm 10) \%$ .

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  $(23 \pm 5) ^\circ\text{C}$ .

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. **62**

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 ~~it may be advisable to clean~~ the outside of the dropping device can be cleaned **63** 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  $(4,0 \pm 0,1) \text{ mm}$ . 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. **64**