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BASIC SAFETY PUBLICATION

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

IEC 60112:2020-10 CMV(en)

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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

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. Futhermore, 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.

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 persistant 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 ± 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 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 ± 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 ±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 suppply 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 ±10 %, has persisted for 2,00 s with a relative tolerance of ±10 % (0,50 ± 0,05) A has persisted for (2,00 ± 0,20) s. 44

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, having a conductivity of not greater than 1 mS/m 45 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. 46

Solution B:

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

Solution C: **47**

Dissolve approximately 0,~~1~~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 ~~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 ± 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. **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 "~~M~~C". **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 ± 5) s. The drops shall fall approximately centrally between the two contact areas of **51** the electrodes from a height of (35 ± 5) mm.

~~The time for 50 drops to fall on to the specimen shall be (24,5 ± 2) 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.

NOTE 1 The mass of the drops ~~may~~ can **53** 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. **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 ± 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. 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 ± 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. 64

NOTE 2 It may can 65 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. 66

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 may can 67 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 are shall be 68 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 Determination of Proof tracking index test (PTI) 69

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. The required number of specimens shall withstand the test period up to at least 25 s after the fiftieth drop has fallen without tracking failure, and without a persistent flame occurring. 70

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

NOTE The recommended 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". 71

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 ~~surface~~ specimen. 72

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. 73

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

   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. 74

   PASS EXAMPLE for solution A 'Pass PTI 250 ~~M~~ – 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, ~~this~~ 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.

~~NOTE 1 The wording of the previous edition of this standard implied that determinations of the maximum 50 drop withstand voltage had to be made before any 100 drop determinations.~~

~~NOTE 2 It is recognized that the cost of testing may be reduced by firstly determining the maximum 100 drop withstand voltage and therefore this procedure is recommended in this standard.~~ 75

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. **76**

11.2 Screening test **77**

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.

Complete the determination of the comparative tracking index according to the general procedure, and procedures 11.1, 11.3 and 11.4.

NOTE Any result of the screening test can be used for completing the general procedure to evaluate the CTI value.

This procedure is necessary because some materials can withstand high test voltages, but fails at lower test voltages.

11.3 Determination of the maximum 50 drop withstand voltage

By inference from the ~~100 drop~~ sceening **78** data, repeat the test procedure at an appropriate test voltage, using a new test specimen or site and determine whether the specimen withstands the test for the period up to at least 25 s after the fiftieth drop has fallen.

If the over-current device operated due to the occurrence of an air arc above the test specimen, the test was invalid. Repeat the test procedure at the same voltage using a new test specimen or site after cleaning the apparatus and following the procedure as described in Clause 8. If the same event occurs, repeat the test at ~~progressively lower and~~ **79** lower voltages until a valid failure or pass occurs. Report the details of the tests (see 11.5).

NOTE 1 It ~~may~~ can **80** be impossible to determine the CTI of some materials because a valid failure cannot be achieved, the characteristic behaviour moving directly from withstanding the test period at one voltage to exhibiting air arcs at the next highest test voltage.

If the over-current device operated due to the passage of an excessive current across the surface of the test specimen, or if a persistent flame occurred, the specimen failed the test at that voltage. Repeat the test on a new test specimen or site using a lower test voltage after cleaning the apparatus, etc. as described in Clause 8.

If none of the above occurred and at least 25 s elapsed after the fiftieth drop had fallen without the over-current device operating, the test is valid and the test specimen is considered to have passed.

If a hole has not formed through the test specimen during the test, repeat the test on a new test specimen or site, at ~~progressively higher and~~ **81** higher voltages until the maximum voltage is established at which no failure occurred during the test period of up to at least 25 s after the fiftieth drop has fallen in the first five tests at that voltage. Five separate **82** specimens or five sites on one plaque may be used for the tests after cleaning the apparatus and following the procedure described in Clause 8.

If a hole appeared through the test specimen, record the result, noting both that a hole was formed and the depth of the hole (the thickness of the test specimen or stack), and then continue the tests as described above.

NOTE 2 Where a hole is generated during a test, the further tests ~~may~~ can **83** be made on thicker specimens (up to a maximum thickness of 10 mm) to gain additional information after cleaning the apparatus, etc., as described in Clause 8.

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

Record, as the 50 drop result, the maximum voltage at which five specimens withstood the 50 drop period without failure.

Continue by determining the maximum 100 drop withstand voltage. **84**

11.4 Determination of the 100 drop point

Using the basic procedure described in Clause 8, set the voltage at a selected level and make the test until at least 25 s have elapsed after the one hundredth drop has fallen or until ~~previous~~ **85** failure occurs.

~~If the behaviour of the material is unknown, it is recommended that the starting voltage be 350 V.~~ **86**

If the over-current device operated due to the occurrence of an air arc above the test specimen, the test was invalid. Repeat the test procedure at the same voltage using a new test specimen or site after cleaning the apparatus and following the procedure in Clause 8. If the same event occurs, repeat the test at ~~progressively lower and~~ **87** lower voltages until a valid failure or pass occurs. Report the details of the tests (see 11.5).

NOTE 1 It ~~may~~ can **88** be impossible to determine the CTI of some materials because a valid failure cannot be achieved, the characteristic behaviour moving directly from withstanding the test period at one voltage to exhibiting air arcs at the next highest test voltage.

If the over-current device operated due to the passage of an excessive current across the surface of the test specimen, or if a persistent flame occurred, the specimen failed the test at that voltage. Repeat the test on a new test specimen or site using a lower test voltage after cleaning the apparatus, etc., as described in Clause 8.

If none of the above occurred and at least 25 s elapsed after the one hundredth drop had fallen without the over-current device operating, the test is valid and the test specimen is considered to have passed. Repeat the test on new test specimen or site at progressively higher and higher voltages until the maximum voltage is established at which no failure occurred during the test period of up to at least 25 s after the one hundredth drop has fallen in the first five tests at that voltage. Five separate specimens or five sites on one plaque may be used for the tests after cleaning the apparatus and following the procedure described in Clause 8.

If a hole appeared through the test specimen, record the result, noting both that a hole was formed and the depth of the hole (the thickness of the test specimen or stack), and then continue the tests as described above.

NOTE 2 Where a hole is generated during a test, the further tests ~~may~~ can **89** be made on thicker specimens (up to a maximum thickness of 10 mm) to gain additional information after cleaning the apparatus, etc., as described in Clause 8.

~~Where the properties of the test specimen are unknown, increases in test voltage at voltages above 400 V shall be limited to 50 V per test.~~ **90**

Record, as the 100 drop result, the maximum voltage at which five specimens withstood the 100 drop period without failure.

~~Continue by determining the maximum 50 drop withstand voltage.~~ **91**

11.5 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 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 surface.

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

e) 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 comparative tracking index test where there is no requirement for the determination of the degree of erosion as follows:

   - CTI the numerical value of the maximum 50 drop voltage, obtained in five consecutive tests (the numerical value of the highest 100 drop voltage determined in five consecutive tests, if more than 25 V below the maximum 50 drop figure), when appropriate followed by the letter "~~M~~C" to indicate that solution ~~B~~ C was used. **92**

     ~~EXAMPLE ‘CTI 175’, ‘CTI 175 M’, or ‘CTI 400(350) M’~~

     EXAMPLE for solution A 'CTI 175', or

     EXAMPLE for solution B 'CTI 175 M', or

     EXAMPLE for solution C 'CTI 175 C'.

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

   - CTI the numerical value of the maximum 50 drop voltage, obtained in five consecutive tests (the numerical value of the highest 100 drop voltage determined in five consecutive tests, if more than 25 V below the maximum 50 drop figure), when appropriate followed by the letter "~~M~~C" to indicate that solution ~~B~~ C was used – the maximum depth of erosion being in millimetres. **93**

     ~~EXAMPLE ‘CTI 275 - 1,2’, ‘CTI 375 M - 2,4,’ or ‘CTI 400(350) M - 3,4’~~

     EXAMPLE for solution A 'CTI 275 – 1,2', or

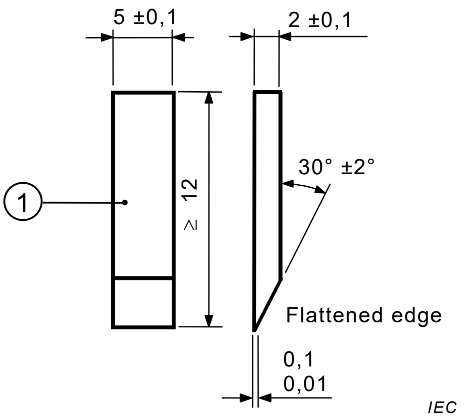
     EXAMPLE for solution B 'CTI 175 M – 2,4', or

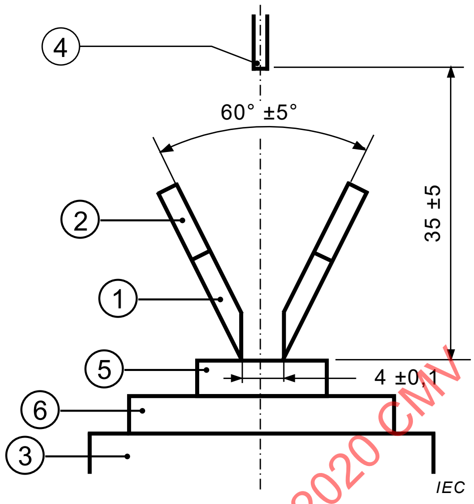
     EXAMPLE for solution C 'CTI 400(350) C – 3,4'.

If, for some reason (such as extensive flaming), the erosion cannot be measured, this shall be reported.

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

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



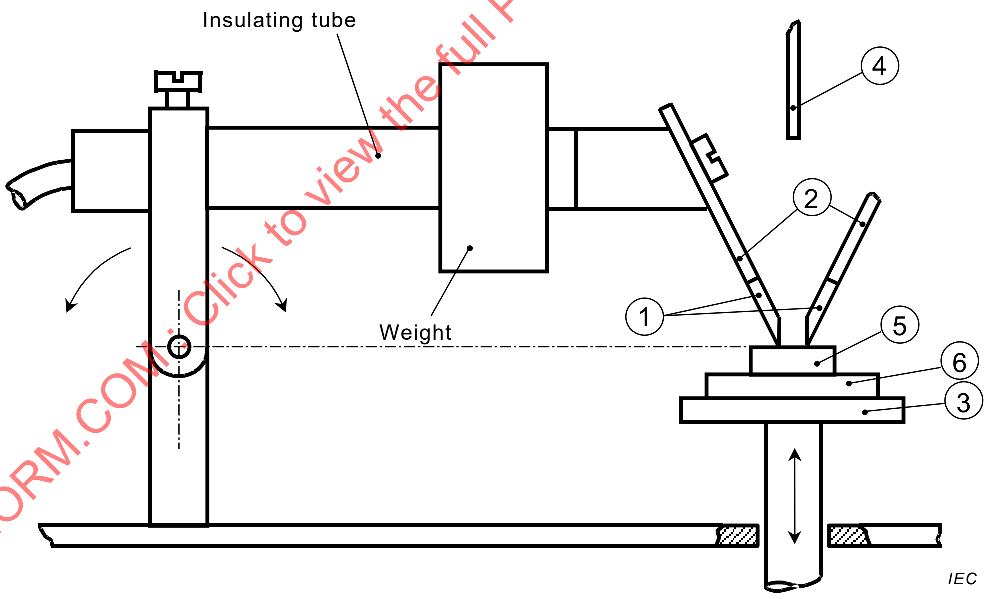


Key

1 platinum electrode
2 brass extension (optional)
3 table
4 tip of dropping device
5 specimen
6 glass specimen support

Figure 1 – Electrode

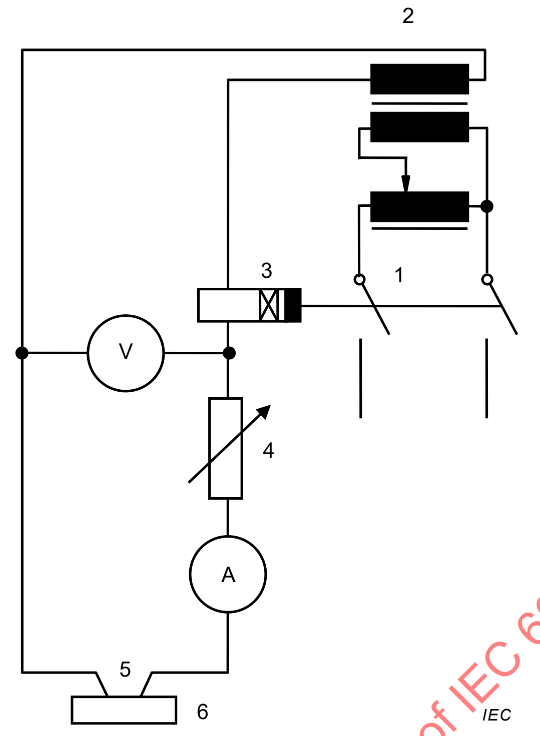
Figure 2 – Electrode/specimen arrangement



Key

1 platinum electrode
2 brass extension (optional)
3 table
4 tip of dropping device
5 specimen
6 glass specimen support

Figure 3 – Example of typical electrode mounting and specimen support



Key

1 switch

2 AC source 100 V to 600 V

3 delay over-current device

4 variable resistor

5 electrodes

6 specimen

Figure 4 – Example of test circuit

Annex A
(informative)

List of factors that should be considered by product committees

The method may be used as published but there are several areas where product committees may wish to exercise their options.

a) Whether the surface of specimens with rough surfaces may be smoothed by machining, e.g. grinding (Clause 5).

b) Specimen surface state (6.2): clean(ed) or otherwise.

c) Nature of any allowed cleaning processes (6.2).

d) Type of electrolyte to be used (solution A, or B, or C **94** (7.3)).

e) Whether any special instructions need to be given concerning the method of cleaning the apparatus between tests (Clause 8).

f) Where the material is anisotropic, results from the direction giving the lower values are usually reported unless otherwise specified (8.1).

g) Number of specimens to be used in proof tests: usually five but a different number may be preferred (10.2).

h) Required proof test voltage (10.2).

i) Whether the proof test should include a requirement for a minimum 100 drop test voltage.

j) Whether determination of erosion depth is required and, if so, the limits to be specified (Clause 9).

k) Whether, because of specific needs, the criteria for allowable flaming are not suitable for the application in mind. In those cases, alternative test methods should be developed/used.

Annex B 95
(informative)

Solution B

Solution B is difficult to produce because some ingredients are no longer available on the market. The use of solution B is still possible but not advisable. The preferred solution is solution C instead of solution B.

Solution B:

Dissolve approximately 0,1 % by mass of analytical reagent grade anhydrous ammonium chloride, of a purity of not less than 99,8 %, and (0,500 ± 0,002) % by mass of sodium-di-butyl naphthalene sulfonate in de-ionized water to give a resistivity of (1,98 ± 0,05) Ωm at (23 ± 1) °C.

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

Solution B can be used instead of solution C for back compatibility of test results.

To indicate that solution B was used, the CTI or PTI value shall be followed by the letter "M".

Annex C
(informative)

Electrode material selection

C.1 Platinum electrodes 96

Platinum electrodes have been selected for determining the comparative and proof tracking indices because platinum is the most inert material commonly available. It interacts least with the electrolyte and insulating materials used, allowing the characteristics of the insulating material under test to become the main determining factor in arriving at the tracking index.

C.2 Alternatives

In order to simulate the hardware and insulating systems used in electrical devices and to reduce the electrode cost, materials such as copper, brass, stainless steel, gold and silver are sometimes used instead of platinum for appraising the tracking characteristics of the particular electrode metal and insulating material combinations. These electrode materials interact to varying degrees both with the electrolytes used and the insulating materials, and thereby influence the test results. The results of tests made with alternatives to platinum electrodes do not qualify as either comparative or proof tracking indices.

Bibliography

IEC 60587:1984, *Electrical insulating materials used under severe ambient conditions – Test methods for evaluating resistance to tracking and erosion* **97**

IEC 60664-1, *Insulation coordination for equipment within low-voltage systems – Part 1: Principles, requirements and tests* **98**

IEC TR 62062:2002[1], *Results of the Round Robin series of tests to evaluate proposed amendments to IEC 60112*

IEC 60212, *Standard conditions for use prior to and during the testing of solid electrical insulating materials* **99**

ISO 293, *Plastics – Compression moulding of test specimens of thermoplastic materials* **100**

ISO 294-1, *Plastics – Injection moulding of test specimens of thermoplastic materials – Part 1: General principles, and moulding of multi-purpose and bar test specimens* **101**

ISO 294-3, *Plastics – Injection moulding of test specimens of thermoplastic materials – Part 3: Small plates* **102**

ISO 295, *Plastics – Compression moulding of test specimens of thermosetting materials* **103**

ISO 304, *Surface active agents – Determination of surface tension by drawing up liquid films* **104**

ISO 3167:2002, *Plastics – Multipurpose test specimens* **105**

ISO 3696, *Water for analytical laboratory use – Specification and test methods* **106**

1 Withdrawn.

List of comments

1 Editorial clarification.

2 This new paragraph highlights that the surface structure of the material has also a significant influence on the results.

3 Editorial correction.

4 Additional note to highlight that IEC 60664-1 and IEC 60112 are interconnected documents.

5 Editorial changes as no requirements are allowed in notes.

6 A general remark regarding the ongoing discussions to look at material test methods at voltages between 600 and 1000 V: It is not prohibited to run this test method at higher voltages (e.g. up to 1000 V), but you have to make sure that the test results are validated. However, this is not recommended as this would not be within the scope of this standard. Section 11.2 was added to address this. There is also currently no commercially available test equipment which enables testing at higher voltages.

7 Both new paragraphs have been added due to new ISO/IEC guideline as this document is concerned with a safety function.

8 IEC Guide 104:1997 has been removed as a normative reference because IEC Guide 104:2019 no longer requires this to be included in Clause 2.

9 Moved from normative references to the bibliography.

10 Moved from normative references to the bibliography.

11 Moved from normative references to the bibliography.

12 Moved from normative references to the bibliography.

13 ISO 4287 is added as it is required for the sample preparation.

14 Editorial addition due to new ISO/IEC guideline.

15 Editorial correction.

16 Editorial corrections as no requirements are allowed in terms and definitions.

17 Editorial addition.

18 Addition as we need to ensure we do not have failures at lower voltages although some materials can also pass criteria at higher voltages.

19 Addition as we need to ensure we do not have failures at lower voltages although some materials can also pass criteria at higher voltages.

20 Correction due to IEC rules.

21 Addition to give further information on test solution.

22 Plane needs to be horizontal to keep test liquid between electrode.

23 Addition as we need to ensure we do not have failures at lower voltages although some materials can also pass criteria at higher voltages.

24 Changes to clarify in which area the test liquid needs to remain.

25 Changes to clarify in which area the test liquid needs to remain.

26 Editorial change from may to can.

27 All editorial clarifications.

28 Editorial corrections.

29 Technical clarification that we shall have a uniform surface.

30 Addition to highlight the influence of the surface texture.

31 Editorial change from may to can.

32 Editorial change from may to can.

33 Additional reference to standardize the surface texture and for reporting. Any specific surface structures shall be mentioned in the test report.

34 Additional note to explain why grinding of the surface needs to be mentioned in the report.

35 Additional note to explain use of solution C at low surface tension and higher conductivity.

36 Editorial change (use of brackets).

37 Addition to highlight the need to test the samples quickly after conditioning before conditioning vanishes. This is consistent with other material testing standards.

38 Note converted to text in order to make it mandatory, following IEC rules.

39 Editorial change as no recommendations are allowed in notes.

40 Editorial change to use the correct technical term "accuracy" rather than "error".

41 Reference to Figure 4 is removed as it is not directly relevant to this sentence.

42 Editorial change to use the correct technical term "accuracy" rather than "error".

43 Sentence removed and converted to note.

44 10% tolerance is kept for both r.m.s. value and time and converted to absolute figures.

45 Originally quoted conductivity value is not required any more as ISO 3696 standard has been added to terms and references.

46 Additional note to provide typical room temperature values for conductivity.

47 Solution B has been moved to Annex B as there have been issues with the availability of the surfactant. There have also been significant differences in the batch to batch properties. Therefore, it is envisaged to use solution C instead of solution B. In order to keep conductivity and surface tension constant, the composition of solution C was adapted. The surfactant used in solution C is also used in the test solution in IEC 60587 (inclined plane test). The surfactant for solution C is envisaged to be mainly used in future.

48 Addition to improve clarity.

49 Use of solution C is now recommended.

50 Addition for clarification as use of solution C is now normative.

51 Addition for clarification.

52 Sentence is changed to be in line with the first sentence of the paragraph, giving a target interval time between the drops. However this sentence is not strictly necessary as the first paragraph is giving the correct time intervals.

53 Editorial change from may to can.

54 Note is added to give guidance on typical drop weights.

55 This note is also valid for solution C.

56 Editorial change as no recommendations are allowed in notes.

57 Editorial change as no recommendations are allowed in notes.

58 Editorial change to be more precise.

59 Editorial change according to IEC rules for notes.

60 Editorial change to a more technical term.

61 New subclause to describe additional requirements for test equipment plus reference to IEC 60212.

62 Addition to clarify preparation procedure.

63 Editorial change from may to can.

64 Addition for clarification.

65 Editorial change from may to can.

66 Additional sentence as advice to users that the orientation of the specimen can influence the droplet movement as the droplet should stay in the area between the electrodes.

67 Editorial change from may to can.

68 Editorial change to make it a normative requirement.

69 Clarification of the title as proof tracking index can only be tested (yes/no), but not determined. It is a requirement, but not a property.

70 Sentence is deleted and replaced by a newly added sentence below.

71 The minimum number of required test specimen is now normatively defined as five. The note is changed to allow a special agreement on the number of specimen between business partners. A clarification on the procedure on extending the number of samples for testing has been added.

72 Changed to use the correct technical term.

73 Type C is added and separate examples for each test solution is added.

74 Type C is added and separate examples for each test solution with the additional maximum depth of erosion is added.

75 Both notes are deleted as they are not relevant to this edition of the standard.

76 Addition of a new paragraph to determine if one of the samples is an outlier or not.

77 Addition of a new screening test paragraph as it is known that some materials perform better at higher voltages compared to lower voltages. Therefore a screening test is required to determine the starting voltage.

78 Editorial change to clarify that it refers to data from screening test.

79 Editorial change as use of the term "progressively lower" is not correct.

80 Editorial change from may to can.

81 Editorial change as use of the term "progressively higher" is not correct.

82 Addition to be more precise.

83 Editorial change from may to can.

84 Addition to ensure user continues to test according to 11.4 as both criteria are required (50 and 100 drops).

85 Deletion as screening test has been introduced.

86 Deletion as screening test has been introduced.

87 Editorial change as use of the term "progressively lower" is not correct.

88 Editorial change from may to can.

89 Editorial change from may to can.

90 Deletion as screening test has been introduced.

91 Deletion as this is not correct anymore.

92 Additional information to clarify the correct reporting of the results for different test solutions.

93 Additional information to clarify the correct reporting of the results with the added erosion depth results for different test solutions.

94 Addition as solution C is added.

95 Addition of new annex B as the use of solution B is now only informative in order to maintain comparability to old test reports.

96 Annex C is extended with new headlines to give information about alternative electrode materials.

97 Editorial changes to undated references.

98 Addition to the bibliography as IEC 60664-1 is referring to IEC 60112 for the comparison of the performance of different insulation materials in subclause 4.6.3.3. Table F.5 of IEC 60664-1 defines creeping distances due to failure of tracking for materials groups based on CTI tests with test solution A (in the range of 10 V to 36 kV r.m.s.). Materials groups are defined up to CTI 600 only.

99 IEC 60212 is added as it is required for the conditioning of the samples.

100 Moved from normative references to the bibliography.

101 Moved from normative references to the bibliography.

102 Moved from normative references to the bibliography.

103 Moved from normative references to the bibliography.

104 ISO 304 is added to describe the wetting properties of the solution C.

105 Editorial changes to undated references.

106 ISO 3696 is added to describe the quality of the water used for the solutions.

IEC

IEC 60112

Edition 5.0 2020-10

INTERNATIONAL STANDARD

NORME INTERNATIONALE

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)

CONTENTS

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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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.

Complete the determination of the comparative tracking index according to the general procedure, and procedures 11.1, 11.3 and 11.4.

NOTE Any result of the screening test can be used for completing the general procedure to evaluate the CTI value.

This procedure is necessary because some materials can withstand high test voltages, but fails at lower test voltages.

11.3 Determination of the maximum 50 drop withstand voltage

By inference from the sceening data, repeat the test procedure at an appropriate test voltage, using a new test specimen or site and determine whether the specimen withstands the test for the period up to at least 25 s after the fiftieth drop has fallen.

If the over-current device operated due to the occurrence of an air arc above the test specimen, the test was invalid. Repeat the test procedure at the same voltage using a new test specimen or site after cleaning the apparatus and following the procedure as described in Clause 8. If the same event occurs, repeat the test at lower voltages until a valid failure or pass occurs. Report the details of the tests (see 11.5).

NOTE 1 It can be impossible to determine the CTI of some materials because a valid failure cannot be achieved, the characteristic behaviour moving directly from withstanding the test period at one voltage to exhibiting air arcs at the next highest test voltage.

If the over-current device operated due to the passage of an excessive current across the surface of the test specimen, or if a persistent flame occurred, the specimen failed the test at that voltage. Repeat the test on a new test specimen or site using a lower test voltage after cleaning the apparatus, etc. as described in Clause 8.

If none of the above occurred and at least 25 s elapsed after the fiftieth drop had fallen without the over-current device operating, the test is valid and the test specimen is considered to have passed.

If a hole has not formed through the test specimen during the test, repeat the test on a new test specimen or site, at higher voltages until the maximum voltage is established at which no failure occurred during the test period of up to at least 25 s after the fiftieth drop has fallen in the first five tests at that voltage. Five separate specimens or five sites on one plaque may be used for the tests after cleaning the apparatus and following the procedure described in Clause 8.

If a hole appeared through the test specimen, record the result, noting both that a hole was formed and the depth of the hole (the thickness of the test specimen or stack), and then continue the tests as described above.

NOTE 2 Where a hole is generated during a test, the further tests can be made on thicker specimens (up to a maximum thickness of 10 mm) to gain additional information after cleaning the apparatus, etc., as described in Clause 8.

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

Record, as the 50 drop result, the maximum voltage at which five specimens withstood the 50 drop period without failure.

Continue by determining the maximum 100 drop withstand voltage.

11.4 Determination of the 100 drop point

Using the basic procedure described in Clause 8, set the voltage at a selected level and make the test until at least 25 s have elapsed after the one hundredth drop has fallen or until failure occurs.

If the over-current device operated due to the occurrence of an air arc above the test specimen, the test was invalid. Repeat the test procedure at the same voltage using a new test specimen or site after cleaning the apparatus and following the procedure in Clause 8. If the same event occurs, repeat the test at lower voltages until a valid failure or pass occurs. Report the details of the tests (see 11.5).

NOTE 1 It can be impossible to determine the CTI of some materials because a valid failure cannot be achieved, the characteristic behaviour moving directly from withstanding the test period at one voltage to exhibiting air arcs at the next highest test voltage.

If the over-current device operated due to the passage of an excessive current across the surface of the test specimen, or if a persistent flame occurred, the specimen failed the test at that voltage. Repeat the test on a new test specimen or site using a lower test voltage after cleaning the apparatus, etc., as described in Clause 8.

If none of the above occurred and at least 25 s elapsed after the one hundredth drop had fallen without the over-current device operating, the test is valid and the test specimen is considered to have passed. Repeat the test on new test specimen or site at progressively higher and higher voltages until the maximum voltage is established at which no failure occurred during the test period of up to at least 25 s after the one hundredth drop has fallen in the first five tests at that voltage. Five separate specimens or five sites on one plaque may be used for the tests after cleaning the apparatus and following the procedure described in Clause 8.

If a hole appeared through the test specimen, record the result, noting both that a hole was formed and the depth of the hole (the thickness of the test specimen or stack), and then continue the tests as described above.

NOTE 2 Where a hole is generated during a test, the further tests can be made on thicker specimens (up to a maximum thickness of 10 mm) to gain additional information after cleaning the apparatus, etc., as described in Clause 8.

Record, as the 100 drop result, the maximum voltage at which five specimens withstood the 100 drop period without failure.

11.5 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 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 surface.
d) State of the surface before testing, with regard to surface imperfections, e.g. scratches, blemishes, impurities, etc..
e) 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 comparative tracking index test where there is no requirement for the determination of the degree of erosion as follows:

- CTI the numerical value of the maximum 50 drop voltage, obtained in five consecutive tests (the numerical value of the highest 100 drop voltage determined in five consecutive tests, if more than 25 V below the maximum 50 drop figure), when appropriate followed by the letter "C" to indicate that solution C was used.

  EXAMPLE for solution A 'CTI 175', or

  EXAMPLE for solution B 'CTI 175 M', or

  EXAMPLE for solution C 'CTI 175 C'.

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

- CTI the numerical value of the maximum 50 drop voltage, obtained in five consecutive tests (the numerical value of the highest 100 drop voltage determined in five consecutive tests, if more than 25 V below the maximum 50 drop figure), when appropriate followed by the letter "C" to indicate that solution C was used – the maximum depth of erosion being in millimetres.

  EXAMPLE for solution A 'CTI 275 – 1,2', or

  EXAMPLE for solution B 'CTI 175 M – 2,4', or

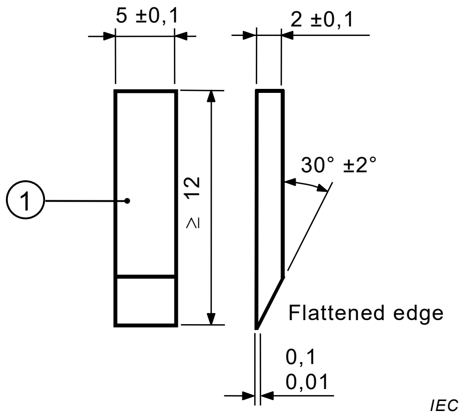
  EXAMPLE for solution C 'CTI 400(350) C – 3,4'.

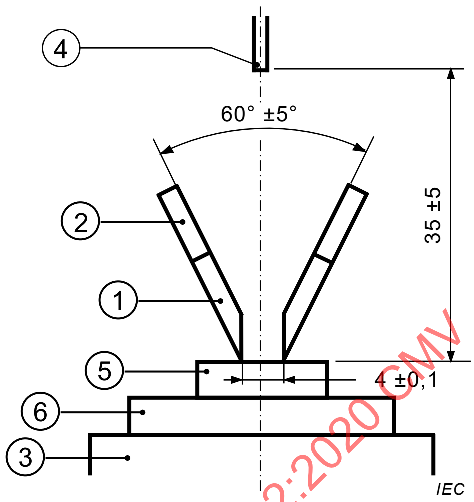
If, for some reason (such as extensive flaming), the erosion cannot be measured, this shall be reported.

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

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

Dimensions in millimetres



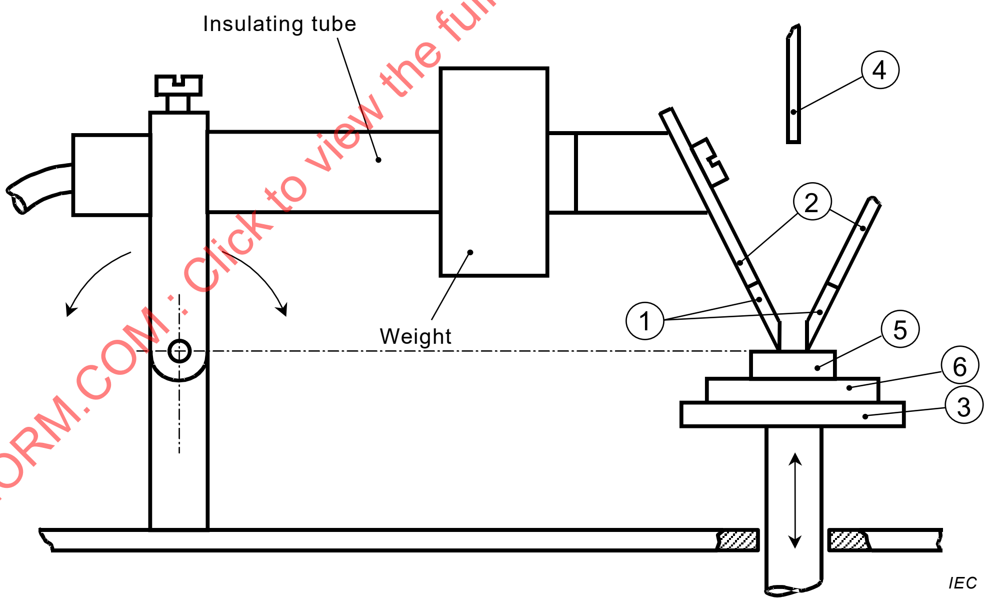


Key

1 platinum electrode
2 brass extension (optional)
3 table
4 tip of dropping device
5 specimen
6 glass specimen support

Figure 1 – Electrode

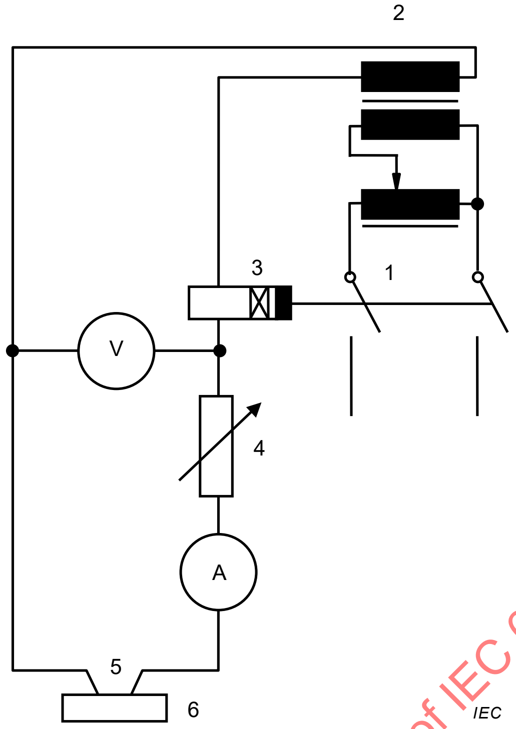
Figure 2 – Electrode/specimen arrangement



Key

1 platinum electrode
2 brass extension (optional)
3 table
4 tip of dropping device
5 specimen
6 glass specimen support

Figure 3 – Example of typical electrode mounting and specimen support



Key

1 switch

2 AC source 100 V to 600 V

3 delay over-current device

4 variable resistor

5 electrodes

6 specimen

Figure 4 – Example of test circuit

Annex A
(informative)

List of factors that should be considered by product committees

The method may be used as published but there are several areas where product committees may wish to exercise their options.

a) Whether the surface of specimens with rough surfaces may be smoothed by machining, e.g. grinding (Clause 5).

b) Specimen surface state (6.2): clean(ed) or otherwise.

c) Nature of any allowed cleaning processes (6.2).

d) Type of electrolyte to be used (solution A, or B, or C (7.3)).

e) Whether any special instructions need to be given concerning the method of cleaning the apparatus between tests (Clause 8).

f) Where the material is anisotropic, results from the direction giving the lower values are usually reported unless otherwise specified (8.1).

g) Number of specimens to be used in proof tests: usually five but a different number may be preferred (10.2).

h) Required proof test voltage (10.2).

i) Whether the proof test should include a requirement for a minimum 100 drop test voltage.

j) Whether determination of erosion depth is required and, if so, the limits to be specified (Clause 9).

k) Whether, because of specific needs, the criteria for allowable flaming are not suitable for the application in mind. In those cases, alternative test methods should be developed/used.

Annex B
(informative)

Solution B

Solution B is difficult to produce because some ingredients are no longer available on the market. The use of solution B is still possible but not advisable. The preferred solution is solution C instead of solution B.

Solution B:

Dissolve approximately 0,1 % by mass of analytical reagent grade anhydrous ammonium chloride, of a purity of not less than 99,8 %, and (0,500 ± 0,002) % by mass of sodium-di-butyl naphthalene sulfonate in de-ionized water to give a resistivity of (1,98 ± 0,05) Ωm at (23 ± 1) °C.

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

Solution B can be used instead of solution C for back compatibility of test results.

To indicate that solution B was used, the CTI or PTI value shall be followed by the letter "M".

Annex C
(informative)

Electrode material selection

C.1 Platinum electrodes

Platinum electrodes have been selected for determining the comparative and proof tracking indices because platinum is the most inert material commonly available. It interacts least with the electrolyte and insulating materials used, allowing the characteristics of the insulating material under test to become the main determining factor in arriving at the tracking index.

C.2 Alternatives

In order to simulate the hardware and insulating systems used in electrical devices and to reduce the electrode cost, materials such as copper, brass, stainless steel, gold and silver are sometimes used instead of platinum for appraising the tracking characteristics of the particular electrode metal and insulating material combinations. These electrode materials interact to varying degrees both with the electrolytes used and the insulating materials, and thereby influence the test results. The results of tests made with alternatives to platinum electrodes do not qualify as either comparative or proof tracking indices.

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1 Withdrawn.

SOMMAIRE

COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

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MÉTHODE DE DÉTERMINATION DES INDICES DE RÉSISTANCE ET DE TENUE AU CHEMINEMENT DES MATÉRIAUX ISOLANTS SOLIDES

AVANT-PROPOS

La Norme internationale IEC 60112 a été établie par le comité d'études 112 de l'IEC: Évaluation et qualification des systèmes et matériaux d'isolement électrique.

Cette cinquième édition annule et remplace la quatrième édition parue en 2003 et l'Amendement 1:2009. Cette édition constitue une révision technique.

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

- Introduction d'un nouveau contaminant, la solution C, avec un tensioactif aligné sur la méthode d'essai de l'IEC 60587. Transfert à l'Annexe B de la définition de la solution B pour référence arrière.
- Introduction d'un essai de déverminage, en tenant compte du fait que certains matériaux peuvent supporter des tensions d'essai élevées, mais pas des tensions d'essai plus basses.

Elle a le statut de publication fondamentale de sécurité, conformément au Guide IEC 104.

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

FDIS	Rapport de vote
112/479/FDIS	112/484/RVD

Le rapport de vote indiqué dans le tableau ci-dessus donne toute information sur le vote ayant abouti à l'approbation de cette Norme internationale.

Ce document a été rédigé selon les Directives ISO/IEC, Partie 2.

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1 Domaine d'application

Le présent document spécifie la méthode d'essai pour la détermination des indices de résistance et de tenue au cheminement des matériaux isolants solides sur des échantillons prélevés sur des parties d'équipement et des plaques de matériau en utilisant une tension alternative.

Le présent document fournit une procédure pour la détermination de la valeur de l'érosion quand cela est exigé.

NOTE 1 L'indice de tenue au cheminement est utilisé comme critère d'acceptation ainsi que comme critère de contrôle de la qualité des matériaux et parties fabriquées. L'indice de résistance au cheminement est principalement utilisé pour effectuer la comparaison et la caractérisation de base des propriétés des matériaux.

Cette méthode d'essai évalue la composition et la surface du matériau soumis à l'essai. La composition et les conditions de surface influencent directement les résultats de l'évaluation et sont prises en considération lors de l'utilisation des résultats au moment de la sélection des matériaux.

Les résultats d'essais tels quels ne sont pas adaptés à l'évaluation des lignes de fuite de sécurité lors de la conception des appareils électriques.

NOTE 2 Ces éléments sont conformes à l'IEC 60664-1, *Coordination de l'isolement des matériels dans les systèmes (réseaux) à basse tension – Partie 1: Principes, exigences et essais*

NOTE 3 Cet essai établit une distinction entre les matériaux ayant une tenue au cheminement relativement faible et ceux ayant une tenue moyenne ou bonne et qui peuvent être utilisés dans les équipements amenés à fonctionner sous conditions humides. Des essais plus sévères, de plus longue durée, qui utilisent des tensions plus élevées et des éprouvettes plus grandes (voir l'essai du plan incliné de l'IEC 60587), sont disponibles pour l'évaluation des performances des matériaux qui sont d'usage extérieur. D'autres méthodes d'essai comme la méthode du plan incliné peuvent classer les matériaux dans un ordre différent de celui obtenu par l'essai de gouttes donné dans le présent document.

La présente publication fondamentale de sécurité portant sur une méthode d'essai de sécurité est avant tout destinée à être utilisée par les comités d'études dans le cadre de l'élaboration de publications de sécurité, conformément aux principes établis dans le Guide IEC 104 et le Guide ISO/IEC 51.

L'une des responsabilités d'un comité d'études consiste, le cas échéant, à utiliser les publications fondamentales de sécurité dans le cadre de l'élaboration de ses publications.

2 Références normatives

Les documents suivants cités dans le texte 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).

ISO 4287, *Spécification géométrique des produits (GPS) – État de surface: Méthode du profil – Termes, définitions et paramètres d'état de surface*

3 Termes et définitions

Pour les besoins du présent document, les termes et définitions suivants s'appliquent.

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

3.1
cheminement
formation progressive de chemins conducteurs à la surface et/ou dans un isolant solide, sous l'effet combiné des contraintes électriques et de la contamination électrolytique de cette surface

3.2
défaillance par cheminement
défaillance de l'isolation due au cheminement entre les parties conductrices

Note 1 à l'article: Dans cet essai, le cheminement est indiqué par le fonctionnement d'un dispositif de protection contre les surintensités en raison du passage d'un courant à travers la surface d'essai et/ou dans l'éprouvette.

3.3
érosion électrique
disparition partielle du matériau isolant sous l'action de décharges électriques

3.4
arc électrique
arc entre les électrodes au-dessus de la surface de l'éprouvette

3.5
indice de résistance au cheminement
IRC
valeur numérique de la tension maximale exprimée en volts pour laquelle cinq éprouvettes supportent la durée d'essai correspondant au dépôt de 50 gouttes sans défaillance par cheminement, sans l'apparition d'une flamme persistante, complétée par une phrase concernant le comportement du matériau quand il est soumis à l'essai des 100 gouttes (voir 11.3)

Note 1 à l'article: Aucune défaillance par cheminement et aucune flamme persistante ne sont admises à une tension d'essai plus basse.

Note 2 à l'article: Pour les critères de l'IRC, une formulation concernant le degré d'érosion peut aussi être nécessaire.

Note 3 à l'article: Bien que l'apparition d'une flamme non persistante soit admise dans l'essai sans constituer un échec, les matériaux ne générant aucune flamme sont préférables sauf si d'autres facteurs sont considérés comme étant plus importants. Voir aussi l'Annexe A.

Note 4 à l'article: Certains matériaux peuvent supporter des tensions d'essai élevées, mais pas des tensions d'essai plus basses. Voir également 11.2.

3.6
flamme persistante
flamme qui brûle plus de 2 s

3.7
indice de tenue au cheminement
ITC
valeur numérique de la tension de tenue, exprimée en volts, pour laquelle cinq éprouvettes supportent la durée d'essai correspondant au dépôt de 50 gouttes sans défaillance par cheminement, et sans l'apparition d'une flamme persistante

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3.8
eau désionisée
eau pour laboratoire à usage analytique conformément à l'ISO 3696, qualité 3 ou équivalente

4 Principe

La surface supérieure de l'éprouvette est placée à l'horizontale et est soumise à une contrainte électrique par l'intermédiaire de deux électrodes. La surface existant entre les électrodes est soumise à une chute régulière de gouttes d'électrolyte jusqu'à ce que le dispositif de protection contre les surintensités fonctionne, ou jusqu'à ce qu'une flamme persistante apparaisse, ou jusqu'à ce que la durée de l'essai se soit écoulée.

Les essais sont de courte durée (moins de 1 h) avec jusqu'à 50 ou 100 gouttes d'environ 20 mg d'électrolyte tombant à 30 s d'intervalle entre les électrodes en platine, distantes de 4 mm à la surface de l'éprouvette.

Une tension alternative comprise entre 100 V et 600 V est appliquée entre les électrodes pendant l'essai.

Pendant l'essai, les éprouvettes peuvent aussi être érodées ou ramollies, permettant de ce fait aux électrodes de s'y enfoncer. La formation d'un trou au travers de l'éprouvette pendant un essai doit être notée, ainsi que la profondeur du trou (épaisseur de l'éprouvette). De nouveaux essais peuvent être réalisés en utilisant des éprouvettes plus épaisses, jusqu'à une épaisseur maximale de 10 mm.

NOTE Le nombre de gouttes nécessaires pour provoquer la défaillance par cheminement augmente habituellement lorsque la tension appliquée est plus faible mais, en dessous d'une valeur critique, le cheminement cesse de se produire. Il cesse également de se produire au-dessus d'une valeur critique supérieure pour certains matériaux.

5 Éprouvette

N'importe quelle surface approximativement plane peut être utilisée, sous réserve que celle-ci soit suffisante pour assurer qu'il n'y aura pas, pendant l'essai, d'écoulement de liquide depuis les électrodes d'essai.

NOTE 1 En général, des surfaces plates supérieures ou égales à 20 mm × 20 mm sont utilisées pour réduire la probabilité d'écoulement d'électrolyte depuis les électrodes d'essai, même si des surfaces de plus petite taille peuvent être utilisées, sans perte d'électrolyte (par exemple, ISO 3167, éprouvettes à usage multiple de 15 mm × 15 mm).

NOTE 2 En général, des éprouvettes distinctes sont utilisées pour chaque essai. Si plusieurs essais doivent être effectués sur le même échantillon, les points d'essai peuvent être suffisamment distants les uns des autres pour que les éclaboussures, les fumées ou l'érosion ne contaminent pas ou n'affectent pas les autres zones à soumettre à l'essai.

L'épaisseur de l'éprouvette doit être de 3 mm ou plus. Les échantillons peuvent être empilés pour atteindre l'épaisseur exigée d'au moins 3 mm.

NOTE 3 Les valeurs d'IRC obtenues sur des éprouvettes ayant une épaisseur de moins de 3 mm peuvent ne pas être comparables à celles obtenues sur des éprouvettes plus épaisses car la perte calorifique vers le support en verre est plus importante avec des éprouvettes plus fines. Pour cette raison, l'empilage des éprouvettes est possible.

Les éprouvettes doivent avoir des surfaces uniformément lisses et sans texture, exemptes d'imperfections telles que des éraflures, des taches, des impuretés, etc., sauf indication contraire dans la norme de produit. Si cela n'est pas possible, les résultats obtenus doivent être consignés avec une note décrivant la surface de l'éprouvette, car certaines caractéristiques à la surface de cette dernière pourraient contribuer à la dispersion des résultats.

Pour les essais pratiqués sur des parties de produit, s'il est impossible de découper une éprouvette adaptée, des éprouvettes découpées dans des plaques moulées avec le même matériau isolant peuvent être utilisées. Dans ce cas, il convient de veiller à ce que cette partie de produit et cette plaque soient produites si possible par le même procédé de fabrication, donnant lieu au même état de surface. Quand les détails du procédé de fabrication final sont inconnus, des méthodes données dans l'ISO 293, l'ISO 294-1, l'ISO 294-3 et l'ISO 295 peuvent être appropriées.

NOTE 4 L'utilisation de différentes conditions et/ou différents procédés de fabrication peut conduire à des niveaux de performance différents dans les essais relatifs aux IRC et ITC.

NOTE 5 Les parties moulées selon différents sens d'écoulement peuvent aussi présenter des niveaux de performance différents dans les essais relatifs aux IRC et ITC.

Dans des cas particuliers, l'éprouvette peut être meulée pour obtenir une surface plane. Dans ce cas, l'état de surface conformément à l'ISO 4287 (par exemple les valeurs R_z) doit être consigné (voir 10.2 et 11.5).

NOTE 6 Le meulage peut endommager l'éprouvette. Dans ce cas, la surface du matériau qui a été meulée présente une valeur de cheminement supérieure ou inférieure à celle de la surface d'origine.

Si le positionnement des électrodes par rapport à une caractéristique quelconque du matériau est d'importance, les mesurages doivent être pratiqués en positionnant les électrodes dans le sens de cette caractéristique et perpendiculairement. Le positionnement donnant la valeur d'IRC la plus faible doit être consigné, sauf spécification contraire.

NOTE 7 L'utilisation d'un électrolyte agressif, comme la solution C, est fréquente si le matériau possède une surface hydrophobe.

6 Conditionnement de l'éprouvette

6.1 Conditionnement environnemental

Sauf spécification contraire, les éprouvettes doivent être conditionnées pendant au moins 24 h à (23 ± 5)°C, avec une humidité relative de (50 ± 10) %. L'essai doit démarrer dans les 30 min qui suivent le retrait de l'éprouvette de la chambre de conditionnement (voir 7.7).

6.2 État de la surface de l'éprouvette

Sauf spécification contraire,

a) les essais doivent être réalisés sur des surfaces propres;

b) toute procédure de nettoyage doit être consignée. Si possible, les détails doivent faire l'objet d'un accord entre le fournisseur et le client.

La poussière, les saletés, les empreintes de doigt, la graisse, l'huile, les résidus de moulage ou les autres contaminations peuvent influencer les résultats. Lors du nettoyage des éprouvettes, gonflement, ramollissement, abrasion ou tout autre dommage au matériau doivent être évités.

7 Appareillage d'essai

7.1 Électrodes

Deux électrodes de platine de pureté minimale 99 % doivent être utilisées (voir l'Annexe C). Les deux électrodes doivent être de section rectangulaire aux dimensions (5 ± 0,1) mm × (2 ± 0,1) mm, avec une des extrémités taillée en biseau formant un angle de (30 ± 2)° (voir la Figure 1). L'arête vive doit être supprimée pour obtenir une surface approximativement plate de 0,01 mm à 0,1 mm de large.

NOTE 1 Un microscope équipé d'un oculaire calibré s'est révélé adapté pour effectuer une vérification des dimensions de la surface à l'extrémité.

NOTE 2 En général, des moyens mécaniques sont utilisés pour rétablir la forme des électrodes après un essai afin d'assurer que les électrodes respectent les tolérances exigées, en particulier pour ce qui concerne les arêtes et les coins.

Au début de l'essai, les électrodes doivent être disposées sur une surface plane et horizontale de l'éprouvette, de façon symétrique, dans un plan vertical, en faisant entre elles un angle de (60 ± 5)°, les faces verticales étant en vis à vis (voir la Figure 2). Au début de l'essai, la distance séparant les électrodes à la surface de l'éprouvette doit être de (4,0 ± 0,1) mm.

Une cale-étalon métallique rectangulaire de faible épaisseur doit être utilisée pour vérifier la distance séparant les électrodes. Les électrodes doivent se déplacer librement et la force exercée par chacune d'elles à la surface de l'éprouvette au début de l'essai doit être de (1,00 ± 0,05) N. La conception doit être telle que la force initiale est présumée invariable tout au long de l'essai.

Un dispositif pour appliquer les électrodes sur les éprouvettes est représenté à la Figure 3. La force doit être vérifiée à intervalles appropriés.

Si les essais sont effectués uniquement sur des matériaux pour lesquels la pénétration des électrodes est faible, la force exercée par l'électrode peut être générée par l'utilisation de ressorts. Cependant, sur un équipement à usage général, il convient d'utiliser le principe de gravité pour générer la force (voir la Figure 3).

NOTE 3 Sur la plupart, mais pas la totalité des équipements, si les électrodes bougent pendant l'essai à cause du ramollissement ou de l'érosion de l'éprouvette, leurs extrémités s'arquent et la distance entre électrodes change. L'amplitude et la direction du changement d'intervalle dépendent de la position relative des pivots d'électrode et des points de contact entre électrode et éprouvette. L'importance de ces changements dépend probablement du matériau et n'a pas été déterminée. Des différences de conception pourraient engendrer des écarts de résultats d'essais entre appareillages.

7.2 Circuit d'essai

Les électrodes doivent être alimentées avec une tension pratiquement sinusoïdale, variant entre 100 V et 600 V à une fréquence comprise entre 48 Hz et 62 Hz. Le dispositif de mesure de la tension doit indiquer une valeur efficace vraie et doit avoir une exactitude d'au moins 1,5 % pour la valeur lue. La puissance de la source ne doit pas être inférieure à 0,6 kVA. Un exemple de circuit d'essai adapté est représenté à la Figure 4.

Une résistance variable doit permettre d'ajuster le courant circulant entre les électrodes court-circuitées à (1,0 ± 0,1) A, et la tension indiquée par le voltmètre ne doit pas baisser de plus de 10 % quand ce courant est établi. L'appareil utilisé pour mesurer la valeur du courant de court-circuit doit avoir une exactitude d'au moins ±3 % pour la lecture.

NOTE Pour atteindre la tolérance exigée, il peut être nécessaire que la tension d'alimentation de l'appareil soit suffisamment stable.

Le dispositif de protection contre les surintensités doit fonctionner lorsqu'un courant ayant une valeur efficace de (0,50 ± 0,05) A persiste pendant (2,00 ± 0,20) s.