



# Standard Test Method for Determining the Tracking Index of Electrical Insulating Materials Using Various Electrode Materials (Excluding Platinum)<sup>1</sup>

This standard is issued under the fixed designation D 5288; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This test method was developed using copper electrodes to evaluate the low-voltage (up to 600 V) tracking resistance of materials in the presence of aqueous contaminants.<sup>2</sup>

NOTE 1—At this time, only industrial laminates have been examined using this method which was developed at the National Manufacturers Electrical Association (NEMA) laboratory located at the University of Cincinnati. It was found that a closer end point (less scatter) was obtained than with platinum electrodes, and materials tested tended to be ranked by resin system.

1.1.1 Other electrode materials may be considered for use with this test method depending upon the application of the insulating material.

1.2 This test method is similar to Test Method D 3638, which determines the comparative tracking index of materials using platinum electrodes to produce the tracking on the specimen surface.

1.3 The values stated in metric (SI) units are the standard. The inch-pound equivalents of the metric units are approximate.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

## 2. Referenced Documents

### 2.1 ASTM Standards:

D 618 Practice for Conditioning Plastics and Electrical Insulating Materials for Testing<sup>3</sup>

D 1711 Terminology Relating to Electrical Insulation<sup>4</sup>

<sup>1</sup> This test method is under the jurisdiction of ASTM Committee D-9 on Electrical and Electronic Insulating Materials and is the direct responsibility of Subcommittee D09.12 on Electrical Tests.

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<sup>2</sup> Mathes, K. N., Chapter 4, "Surface Failure Measurements," *Engineering Dielectrics, Vol IIB, Electrical Properties of Solid Insulating Materials, Measurement Techniques*, R. Bartnikas, Editor, ASTM STP 926, ASTM, Philadelphia, 1987.

<sup>3</sup> *Annual Book of ASTM Standards*, Vol 08.01.

<sup>4</sup> *Annual Book of ASTM Standards*, Vol 10.01.

D 1898 Practice for Sampling of Plastics<sup>3</sup>

D 3638 Test Method for Comparative Tracking Index of Electrical Insulating Materials<sup>5</sup>

### 2.2 IEC Publication:

IEC 112, Recommended Method for Determining the Comparative Track Index of Solid Insulating Materials Under Moist Conditions, 1971 Second Edition<sup>6</sup>

## 3. Terminology

3.1 In addition to the definitions listed below, terminology as defined in Terminology D 1711 is assumed.

### 3.2 Definitions:

3.2.1 *track, n*—a partially conducting path of localized deterioration on the surface of an insulating material.

3.2.2 *tracking, n*—the process that produces tracks as a result of the action of electric discharges on or close to an insulation surface.

3.2.3 *tracking, contamination, n*—tracking caused by scintillations that result from the increased surface conduction due to contamination.

3.2.4 *tracking index, TI, n*—an index for electrical insulating materials which is arbitrarily defined as the numerical value of that voltage which will cause failure by tracking when the number of drops of contaminant required to cause failure is equal to 50.

3.2.4.1 *Discussion*—This value is obtained from a plot of the number of drops required to cause failure by tracking versus the applied voltage.

3.2.5 *tracking index-copper electrodes, TI-Cu, n*—a tracking index test using copper electrodes.

3.2.5.1 *Discussion*—This test is comparable to *comparative tracking index*, Test Method D 3638, with the following exceptions: (1) copper electrodes are used instead of platinum, and (2) the electrodes may have to be re-ground after every test because of the softness of copper.

<sup>5</sup> *Annual Book of ASTM Standards*, Vol 10.02.

<sup>6</sup> Available from the International Electrotechnical Commission, Geneva, Switzerland.

3.2.6 *tracking resistance, n*—the quantitative expression of the voltage and the time required to develop a track under specified conditions.

**4. Summary of Test Method**

4.1 The surface of a specimen of electrical insulating material is subjected to a low-voltage alternating stress combined with a low current which results from an aqueous contaminant (electrolyte) which is dropped between two opposing copper electrodes every 30 s. The voltage applied across these electrodes is maintained until the current flow between them exceeds a predetermined value which constitutes failure. Additional specimens are tested at other voltages so that a relationship between applied voltage and number of drops to failure can be established through graphical means. The numerical value of the voltage which causes failure with the application of 50 drops of the electrolyte is arbitrarily called the tracking index. This value provides an indication of the relative track resistance of the material.

**5. Significance and Use**

5.1 Electrical equipment may fail as a result of electrical tracking of insulating material that is exposed to various contaminating environments and surface conditions. There are a number of ASTM and other tests designed to quantify behavior of materials, especially at relatively high voltages. This method is an accelerated test which at relatively low test voltages, provides a comparison of the performance of insulating materials under wet and contaminated conditions. The Tracking Index—Copper Electrodes test is not related directly to the suitable operating voltage in service.

5.2 When organic electrical insulating materials are subjected to conduction currents between electrodes on their surfaces, many minute tree-like carbonaceous paths or tracks are developed near the electrodes. These tracks are oriented randomly, but generally propagate between the electrodes under the influence of the applied potential difference. Eventually a series of tracks spans the electrode gap, and failure occurs by shorting of the electrodes.

5.3 As in other tracking test methods, for example, IEC 112 and Test Method D 3638, this test method specifies test procedures that are intended to promote the formation of surface discharges which will produce carbon tracks in a reproducible manner. Since these conditions rarely reproduce the actual conditions encountered in service, the results of tracking tests cannot be used to infer either direct or relative service behavior of a material in a specific design application. Tracking tests can be used for screening purposes only. Suitability is verified through testing of the material in actual end use or under conditions that closely simulate actual end use.

5.4 The use of copper electrodes in this type of test was developed at the University of Cincinnati, NEMA laboratory. It is felt by the members of the Industrial Laminates Section of NEMA that using copper electrodes gives a more realistic value for a tracking index, related to the resin system used to reinforce the substrate of a laminate. In general, tracking tests made with copper electrodes tend to give lower values than

platinum electrodes in the same type of test. It is a fact that copper is more widely used than platinum for electrical conductors.<sup>7</sup>

**6. Apparatus**

6.1 The simplified electrical circuitry used in this test is illustrated in Fig. 1. For necessary information on the cleanliness of apparatus, see Annex A1. The essential components are:

6.1.1 *Variable Power Source*, consisting of a transformer type supply, such as the combination T<sub>1</sub> and T<sub>2</sub> in Fig. 1, with a variable output of 0 to 1000 V, 60 Hz capable of maintaining a current of 1 A (1 kVA).

6.1.2 *Voltmeter* (V<sub>1</sub>), capable of measuring the varying ac output of the power source. A0 to 600-V voltmeter with an accuracy of at least ±0.5 % of full scale.

6.1.3 *Ammeter* (A<sub>1</sub>), with a range of 0 to 1 A ac and an accuracy of at least ±10 % of full scale.

6.1.4 *Current Limiting Resistor* (R<sub>1</sub>), continuously variable, wire wound, rated at greater than 1 A.

6.1.5 *Shorting Switch* (S<sub>1</sub>), single-pole single-throw rated at 1000 V and greater than 1 A.

NOTE 2—The need for a shorting switch is optional. It is possible to couple the variable resistor with the autotransformer which gives an automatic setting of the current throughout the range of the instrument. Then whenever it is necessary to check the calibration of the instrument, the shorting action can be accomplished by a jumper wire placed across the electrodes. This coupling of the autotransformer with the variable resistor is another option.

6.1.6 *Over-Current Relay* (R<sub>0</sub>), shall not trip at currents up to 0.1 A and the tripping time on short circuit shall be a minimum of 0.5 s (the current shall be limited on short circuit to 1 A with a tolerance of ± 10 % at a power factor of 0.9 to 1.0).

NOTE 3—Some instruments have used a Heinemann breaker, which is probably the closest standard commercial breaker to that described in the IEC Method.<sup>8</sup> Also the tripping action can be accomplished with electronic circuitry.

<sup>7</sup> Middendorf, W. H. and Vemuri, R., "Report on Copper vs. Platinum Electrodes", 1990, Available from National Electrical Manufacturer's Association, 2101 L St. N.W., Suite 300, Washington, D.C. 20037-8400.

<sup>8</sup> Heinemann Model Series JA, Curve 2.

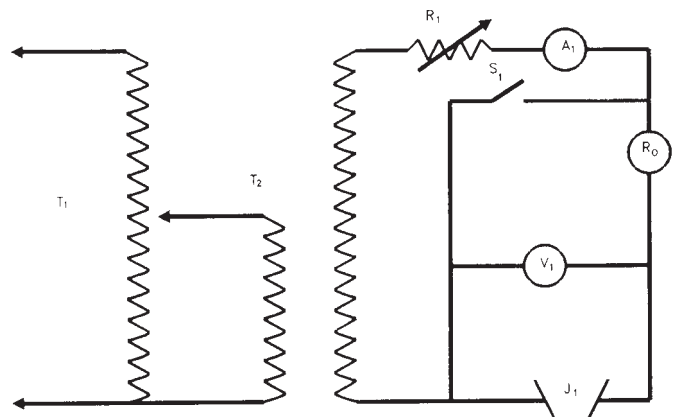


FIG. 1 Electrical Circuit Components

6.1.7 *Testing Fixture ( $J_1$ )*—adjustable platform which supports the specimen and electrode setup.

6.1.8 *Copper Electrodes*, of electrolytic copper having a rectangular cross section measuring 5 by 2 mm (0.2 by 0.08 in.), extending 20 mm (0.8 in.) minimum from suitable mounting shanks (Fig. 2). The end of each electrode is machined to form a  $30^\circ$  chisel-point edge, having a radius from 0.05 to 0.10 mm, extending along the 5-mm (0.2-in.) side of the electrode. This is the radius that generally results from polishing a “0 mm” radius electrode. Since the direction of polish may influence the results, polish all electrodes in a direction perpendicular to the long dimension of the electrode face.

6.1.9 *Dropping Apparatus*, which should drop the electrolyte precisely as specified. Included should also be a means of electrically starting and stopping the dropping of the electrolyte as well as a counting device for monitoring the number of drops. The orifice diameter of the drop mechanism is approximately 1.5 mm. However, it may be necessary to adjust this diameter somewhat so as to obtain the proper drop size in accordance with 9.2.

## 7. Reagents

### 7.1 *Electrolyte Solution of Ammonium Chloride in Water:*

7.1.1 Prepare a solution of ammonium chloride at an approximate concentration of 0.1 % by dissolving 1 g of reagent grade ammonium chloride in 1 L of water. The water used shall have a volume resistivity of no less than  $0.5 \text{ M}\Omega\text{-cm}$  at  $23^\circ\text{C}$ . Allow the solution to stand overnight in a covered, but not sealed, container.

7.1.2 Measure the resistivity of the solution using a conductivity cell and an a-c bridge, or meter, following the manufacturer’s instructions. If the resistivity is  $385 \pm 5 \Omega\text{-cm}$  at  $23 \pm \frac{1}{2}^\circ\text{C}$ , the solution is suitable for use in the test. If the resistivity is outside the above limits, adjust the concentration until these limits are observed. Adjustment is accomplished by adding water or  $\text{NH}_4\text{Cl}$ .

7.1.3 Calibrate the conductivity cell with 0.01 *N* potassium chloride calibrating solution which is available from the cell manufacturer.

## 8. Test Specimens

8.1 Samples should be selected in accordance with Practice D 1898.

8.2 Typical test specimens are 50 mm (2 in.) or 100 mm (4 in.) diameter disks or any other similar shape. The minimum thickness is 2.5 mm (0.100 in.). Test five specimens of each sample.

8.3 Variations in values can result from a lack of uniformity of dispersion of the material throughout the molded specimen or from surface imperfections. Take care to prepare specimens that are as uniform as possible, both within the particular specimen and from one specimen to another.

8.4 Conditioning should be in accordance with Procedure A of Practice D 618.

8.5 Specimens must be clean of dust, dirt, oil, or other contaminants. The molded surface must be smooth and scratch-free.

## 9. Calibration and Standardization

9.1 Partially support the electrodes by adjustable pivot arms and rest on the test specimen as shown in Fig. 2, exerting a force of 100 g (3.5 oz).

9.2 The drop height for the electrolyte is a maximum of 40 mm (1.6 in.) above the electrode gap. The holding device is designed to store an aqueous solution and deliver periodically a measured drop to the specimen. The drop size is  $20 + 5 - 0 \text{ mm}^3$  ( $0.0015 \text{ in.}^3$ ) and the drop rate is  $1 \text{ drop}/30 \pm 5 \text{ s}$ . (The drop size can be measured by using a small calibrated graduate to accumulate a number of drops to obtain an accurate reading.)

9.3 Allow approximately 15 drops of electrolyte to drop from the apparatus into a beaker or other container so as to remove any solution with a high concentration of ammonium chloride.

9.4 Reform the electrodes after every test. Replace the electrodes when sharpening or machining reduces the length to cause instability of the electrode in the holder.

9.5 Reproducibility of results is improved by reforming, polishing and washing the electrodes after each test. Wash using a stream of distilled water and dry with a clean paper based industrial towel.

## 10. Procedure

10.1 Conduct the test in a draft-free, clean environment at a temperature of  $20 \pm 5^\circ\text{C}$ .

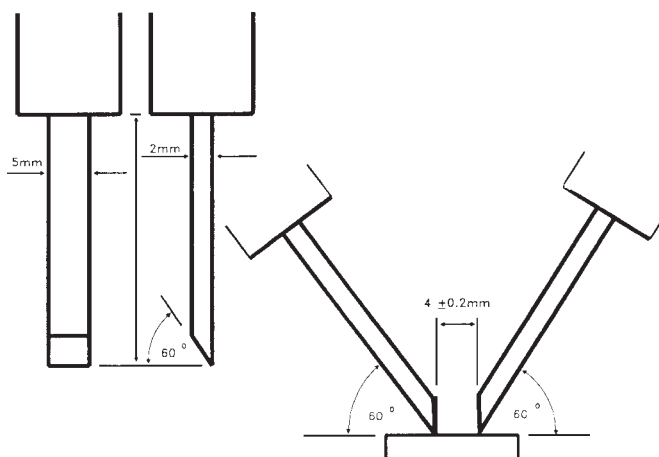
10.2 Fill the dropping assembly with solution and set the counter to 0.

10.3 Set the power source to a voltage expected to be greater than the TI-Cu value and adjust in accordance with 10.6.

10.4 Place the test specimen on the supporting platform so that the electrodes can be placed on the specimen.

10.5 Position the electrodes as shown in Fig. 2 so that the chisel edges contact the specimen at a  $60^\circ$  angle between electrodes and so that the chisel faces are parallel in the vertical plane and are separated by  $4 \pm 0.2 \text{ mm}$  (0.16 in.).

NOTE 4—Contact of the electrodes with the specimen shall be such that when a light source is so placed that the light reaches the eye along the



**FIG. 2 Electrodes (Radius 0.05 to 0.1 mm)**

surface of the specimen, no light is visible between the specimen and the electrodes. If light is visible due to the electrode edges becoming rounded, re-grind the edges.

10.6 Open the shorting switch and begin the sequence of drops with the time interval between drops set at  $30 \pm 5$  s.

10.7 Continue until tracking occurs. This condition is usually well defined with a sudden surge occurring in the current (from essentially 0 to almost 1 A) accompanied by a corresponding drop in voltage.

10.8 It is permissible to repeat a test on a given specimen provided the electrode gap is positioned a minimum of 25 mm (1.0 in.) from any area affected by a previous test or from any edge. The position of the new test must be clean and un-splashed by a prior test.

10.9 Obtain one reading using the voltage set in 10.3. If failure occurs with relatively few drops of electrolyte (fewer than 10), reduce the voltage 25 volts and repeat. If failure occurred with 10 drops or more, reduce the voltage 10 volts and repeat. When a voltage is reached that allows the test to run more than 75 drops, discontinue that test and repeat at the same voltage for verification.

10.10 Do not conduct tests at over 600 V. The use of higher voltages will result in electric discharges above the surface of the specimen, which will produce erroneous results.

10.11 When testing at voltages in the lowest range (below 150 V) there may not be sufficient energy to completely vaporize the electrolyte solution that has been placed between the electrodes. Thus, if flooding occurs, discontinue the test.

### 11. Calculation

11.1 Plot the number of drops of electrolyte at breakdown versus voltage. The data will typically appear as shown in Fig. 3. Draw a line, approximately vertical, from the test point at the lowest voltage at which the material failed in less than 50 drops, to the test point at the highest voltage at which the material did not fail in more than 50 drops. Then draw a horizontal line at 50 drops to intersect that line. The abscissa value at the intersection is the TI-Cu value.

### 12. Report

- 12.1 Report the following information:
  - 12.1.1 Description of the material tested,

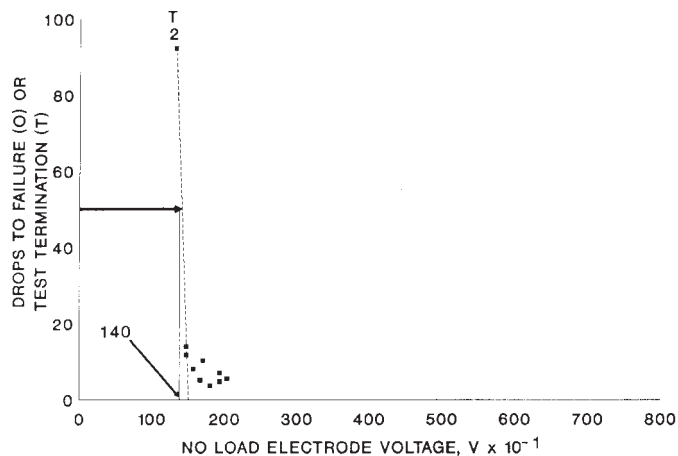


FIG. 3 Tracking Index (TI)

- 12.1.2 Resistivity of the electrolyte,
- 12.1.3 Test temperature,
- 12.1.4 Test voltage and number of drops of electrolyte to failure, for each test,
- 12.1.5 The TI-Cu value in volts derived in accordance with 11.1, and
- 12.1.6 Visual observations of specimen behavior, such as melting of the plastic, flame ignition (if it occurs), and the type of erosion that has occurred on the surface of the test specimen between the electrodes.

### 13. Precision and Bias

13.1 Results with copper electrodes are typically reproducible within  $\pm 15$  V. Furthermore, the change from failure to non-failure as the voltage is reduced occurs abruptly giving a very definite TI-Cu value.

13.2 The procedure in this standard has no bias because the value of tracking index using copper electrodes is defined in terms of this test method.

### 14. Keywords

14.1 copper electrodes; comparative tracking index; CTI; CTI-Cu; TI; track; tracking; tracking; contamination; tracking index; tracking resistance

## ANNEX

### (Mandatory Information)

#### A1. CLEANLINESS OF APPARATUS

A1.1 Cleanliness of the apparatus is essential to obtaining reproducible results. This applies especially to the hypodermic needle, the electrodes, and the contaminant liquid delivery system components.

A1.1.1 Clean the electrodes prior to each test. This is done by squirting reagent grade acetone from a laboratory wash bottle onto the electrode tips and allowing the excess acetone

to drop onto a clean facial tissue. Scrub the electrodes with the acetone-filled tissue to remove residues that might be present from a previous test. Examine the electrodes carefully to ensure complete removal of the residues. Additional acetone and scrubbing may be required. After cleaning, the electrodes

may still show a dark discoloration but it is not necessary to remove this discoloration. Rinse the electrodes with distilled water and wipe dry.

A1.1.2 It is important to clean the needle after any test in which the tracking phenomenon creates a large flame or soot that deposits on the needle. Clean the needle after any test in which the drops of contaminant liquid wet the side of the needle. Using a tissue soaked with acetone, scrub the needle, especially around the tip, to remove any residue from the previous test. Rinse the needle by squirting with distilled water.

Wipe dry. Flush several drops of contaminant liquid through the needle. The drops should fall straight off the tip without wetting the sides of the needle. If the drops wet the side, continue to repeat the cleaning steps above until there is no wetting of sides of the needle.

A1.1.3 Clean the contaminant liquid delivery system periodically by flushing with distilled water. If the apparatus has not been used within an hour, flush several drops through the system prior to starting a test.

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