



Standard Test Method for Comparative Tracking Index of Electrical Insulating Materials¹

This standard is issued under the fixed designation D 3638; 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 (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method evaluates in a short period of time the low-voltage (up to 600 V) track resistance or comparative tracking index (CTI) of materials in the presence of aqueous contaminants.

1.2 The values stated in metric (SI) units are to be regarded as standard. The inch-pound equivalents of the metric units may be approximate.

1.3 *This standard does not purport to address all of the safety problems, 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 Testing²

D 647 Practice for Design of Molds for Test Specimens of Plastic Molding Materials²

D 1711 Terminology Relating to Electrical Insulation³

D 1898 Practice for Sampling of Plastics²

2.2 IEC Publication:

112, Recommended Method for Determining the Comparative Track Index of Solid Insulating Materials Under Moist Conditions, 1971 Second Edition⁴

3. Terminology

3.1 Definitions:

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

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

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

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

3.2 Definitions of Terms Specific to This Standard:

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

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 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 comparative 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

¹ 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.

Current edition approved Oct. 15, 1993. Published December 1993. Originally published as D 3638 – 77. Last previous edition D 3638 – 85 (1992) ⁴¹.

² *Annual Book of ASTM Standards*, Vol 08.01.

³ *Annual Book of ASTM Standards*, Vol 10.01.

⁴ Available from the International Electrotechnical Commission, Geneva, Switzerland.

voltages, provides a comparison of the performance of insulating materials under wet and contaminated conditions. The comparative tracking index 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 The conditions specified herein are intended, as in other tracking test methods, to produce a condition conducive to the formation of surface discharges and possible subsequent tracking. Test conditions are chosen to reproducibly and conveniently accelerate a process; for this reason, they rarely reproduce the varied conditions found in actual service. Therefore, while tracking tests serve to differentiate materials under given conditions, results of tracking tests cannot be used to infer either direct or comparative service behavior of an application design. Rather, tracking test results provide a tool for judging the suitability of materials for a given application. The suitability can only be verified through testing the design in actual end use or under conditions which simulate end use as closely as possible.

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 as follows:

6.1.1 *Variable Power Source*, consisting of a transformer type supply, such as the combination T1 and T2 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* (V1), capable of measuring the varying a-c output of the power source. A 0 to 600-V voltmeter with an accuracy of at least ± 2.5 % of full scale.

6.1.3 *Ammeter* (A1), with a range of 0 to 1 A a-c and an accuracy of at least ± 10 % of full scale.

6.1.4 *Current Limiting Resistor* (R1), continuously variable, wire wound, rated at greater than 1 A.

6.1.5 *Shorting Switch* (S1), single-pole single-throw rated at 1000 V and greater than 1 A.

NOTE 1—The need for a shorting switch can be considered 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 can be considered another option.

6.1.6 *Over-Current Relay* (R0), which has to be inserted in the circuit shall not trip at currents up to 0.1 A and the tripping time on short circuit shall be at least 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 2—Some instruments have used a Heinemann breaker, which is probably the closest standard commercial breaker to that described in the IEC Method. This breaker is Heinemann Model Series JA, Curve 2. Also the tripping action can be accomplished with electronic circuitry.

6.1.7 *Testing Fixture* (J1), adjustable platform which supports the specimen and electrode setup.

6.1.8 *Platinum Electrodes*, 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° 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 “Omm” radius electrode. Since the direction of polish may influence the results, all electrodes should be polished 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 M Ω /cm at 23°C. Allow the solution to stand overnight in a covered, but not sealed, container.

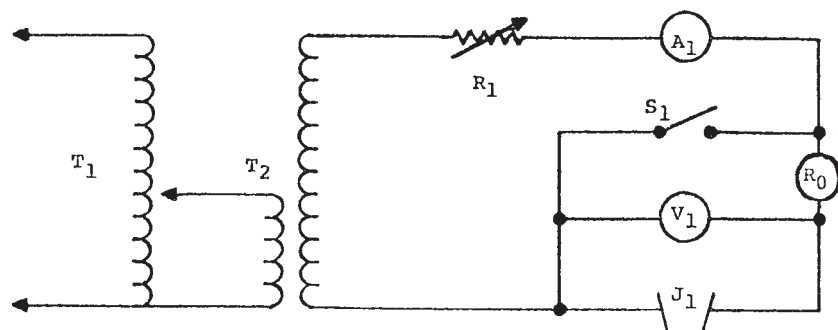


FIG. 1 Electrical Circuit Components

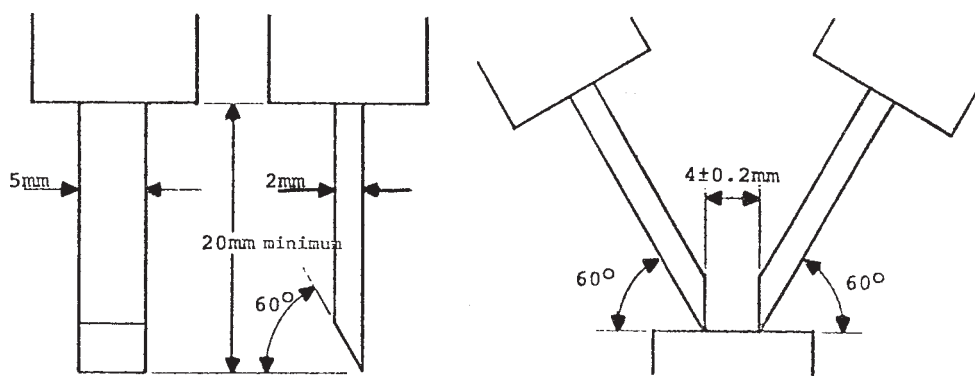


FIG. 2 Electrodes (Radius 0.05 to 0.1 mm)

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 NH_4Cl .

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 Typical test specimens can be 50-mm (2 in.) or 100-mm (4 in.) diameter disks or any other similar shape. Minimum thickness shall be 2.5 mm (0.100 in.). At least five specimens of each sample shall be tested.

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

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

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

8.5 Test thin materials by first clamping them together tightly to form a specimen having a thickness as close as possible to the recommended thickness.

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 should not be more than 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 to be $20 \pm 5 - 0 \text{ mm}^3$ (0.0015 in.³) and the drop rate is to be 1 drop/30 $\pm$ 5 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 when the edges are rounded in excess of 0.1-mm diameter or when burrs or rough edges are observable at 15 $\times$ magnification. Replace electrodes when sharpening or machining fails to restore the specific dimensions of the electrodes and the quality of the chisel edge.

9.5 Reproducibility of results is improved by cleaning the electrodes after every two or three tests.⁵

9.6 The power source is set to the desired voltage with nothing but air between the electrodes (switch open). The shorting switch is closed and the current limiting resistor adjusted to give a reading of 1 A.

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 the desired voltage and adjust in accordance with 9.6.

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° 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 3—It is recommended that 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 surface of the specimen, no light is visible between the specimen and the electrodes. If light is visible due to the electrode edges having become rounded, the edges must be reground.

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

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.

⁵ No. P13 Crystal Bay Cleaning Crocus Cloth, available from 3M Co., has been found satisfactory for this method.

10.8 A test may be repeated 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 unsplashed by a prior test.

10.9 Obtain one reading on each of five specimens of a sample to be tested at any given voltage. Repeat this process in accordance with 10.8, at different voltage levels such that at least two levels produce failures in less than 50 drops and two levels greater than 50 drops.

10.10 Test voltages should be limited to 600 V or less. Testing at higher voltages will generate 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 vaporize completely the electrolyte solution that has been placed between the electrodes. Thus, if flooding occurs, the test should be discontinued.

11. Calculation

11.1 Plot the number of drops of electrolyte at breakdown versus voltage. On the curve note the voltage which corresponds to 50 drops. This is the comparative track index (CTI) (see Fig. 3).

12. Report

12.1 Report the comparative tracking index for each material tested, and include the following:

12.1.1 Description of the material tested,

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 CTI value in volts derived in accordance with 11.1, and

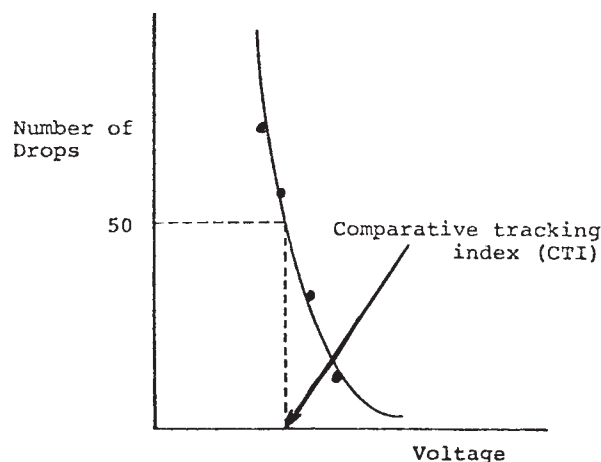


FIG. 3 Typical Tracking Voltage Curve

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 While some variance in breakdown data can be expected with this test method, particularly as the test voltage approaches an asymptotic value, CTI values derived therefrom generally show an interlaboratory range of ± 25 V, intralaboratory variation often being less. However variations in CTI approaching ± 50 V or more are likely to result if meticulous attention to the procedure is not employed.

13.2 A statement about bias cannot be made for this test method because a standard reference material of known tracking index is not currently available.

14. Keywords

14.1 CTI; comparative tracking index; tracking; contamination; 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 the wetting of the side is not evident.

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, several drops should be flushed through the system prior to starting a test.

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