



Standard Test Method for Comparative Tracking Index of Electrical Insulating Materials¹

This standard is issued under the fixed designation D3638; 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 are approximate.

1.3 This standard is technically equivalent to the version of IEC Publication 112 cited in 2.2. However, the 2007 version of IEC 60112 Fourth Edition yields numerical CTI values that are very likely to differ significantly from this standard.

1.4 *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:²

D1711 Terminology Relating to Electrical Insulation

D6054 Practice for Conditioning Electrical Insulating Materials for Testing

2.2 IEC Publication:

112 Recommended Method for Determining the Comparative Track Index of Solid Insulating Materials Under Moist Conditions, 1971 Second Edition³

60112 Recommended Method for Determining the Com-

parative Track Index of Solid Insulating Materials Under Moist Conditions, 2007 Fourth Edition³

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.

3.1.5 For other terminology, refer to Terminology D1711.

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.

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

3.2.2 *failure, n*—an attribute of an electrical circuit containing an electrical-current-sensing device that rapidly decreases the applied voltage to zero if the current in the circuit exceeds a predetermined limit.

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 between them exceeds a predetermined value. This condition constitutes a failure. Additional specimens are tested at other voltages so

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² For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

³ Available from the International Electrotechnical Commission, Geneva, Switzerland.

*A Summary of Changes section appears at the end of this standard.

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 index provides an indication of the relative track resistance of the material.

5. Significance and Use

5.1 Electrical equipment can 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 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. A0 to 600-V voltmeter with an accuracy of at least $\pm 2.5\%$ of full scale.

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

6.1.5.1 A shorting switch is optional. See Annex A2.

6.1.6 *Over-Current Relay* (R0), which is inserted in the circuit shall not trip at currents up to 0.1 A. Use a relay having a tripping time on short circuit of at least 0.5 s and a current limited on short circuit to 1 A with a tolerance of $\pm 10\%$ at a power factor of 0.9 to 1.0.

6.1.6.1 The tripping action can be accomplished with suitable electronic circuitry or with a commercial circuit breaker.⁴

6.1.7 *Testing Fixture*, 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). Machine the end of each electrode 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 “O mm” radius electrode. Since the direction of polish can influence the results, polish all electrodes in a direction perpendicular to the long dimension of the electrode face.

6.1.9 *Dropping Apparatus*, capable of dropping the electrolyte precisely as specified in Section 9. Include in the dropping apparatus device for 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. If necessary, adjust

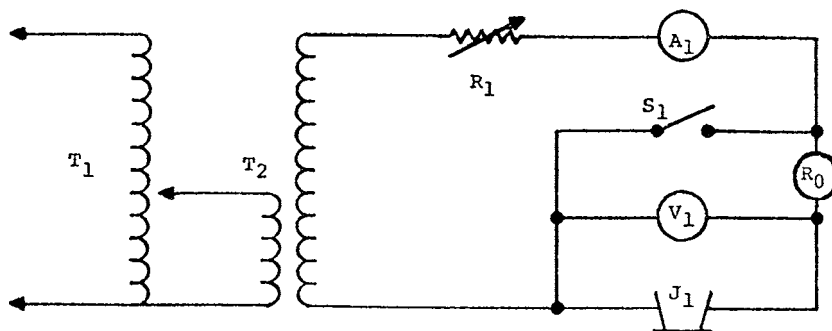


FIG. 1 Electrical Circuit Components

⁴ The committee has been informed that the closest standard commercial breaker to that described in the IEC Method is Heinemann Model Series JA, Curve 2. The committee has not independently verified this information nor does it endorse that particular breaker.

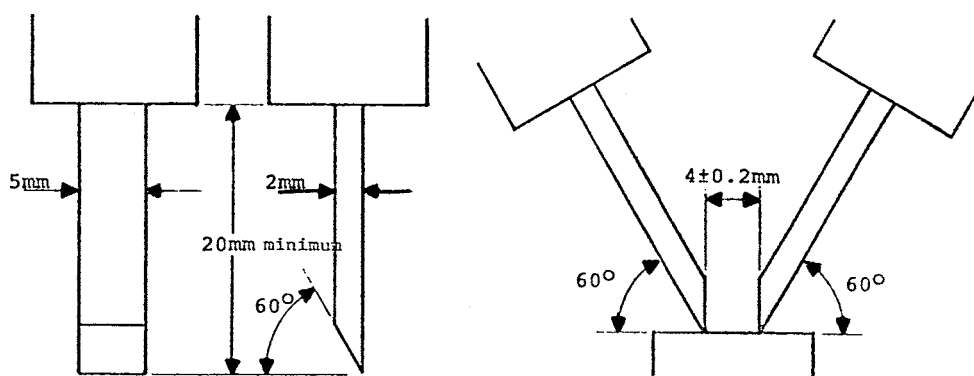


FIG. 2 Electrodes (Radius 0.05 to 0.1 mm)

this diameter so as to obtain the proper drop size in accordance with 9.2. The channel for electrolyte flow is called “the needle” in Annex A1.

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. Use water having a volume resistivity not less than 0.5 MΩ/cm at 23 °C. Allow the solution to stand overnight in a covered, but not sealed, container.

7.1.2 Calculate 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 with a minimum thickness of 2.5 mm (0.100 in.). A similar shape is any shape that has essentially a flat (not curved) planar surface that has an area of at least 2000 mm² and meets the requirements of 8.2 and 8.4. Test at least five specimens of each sample.

8.2 In as much as variations in values can result from a lack of uniformity of dispersion of the material throughout any molded specimen or from surface imperfections on any specimen, 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 Condition specimens in accordance with Procedure A of Practice D6054.

8.4 Specimens must be clean of dust, dirt, oil, or other contaminants with smooth surfaces and essentially free from scratches.

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 so that the electrodes rest on the test specimen surface as shown in Fig. 2, exerting a force of 100 g (3.5 oz).

9.2 The drop height for the electrolyte is to be not 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 $20 + 5 - 0 \text{ mm}^3$ (0.0015 in.³) and the drop rate is to be 1 drop/30 ± 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 × 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 abrasive cleaning of the electrodes after every two or three tests.

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 1—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 ± 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 A test is permitted to be repeated on a given specimen provided the electrode gap is positioned a minimum of 25 mm (1.0 in.) from any specimen area affected by a previous test or from any edge. The position of the new test must be clean and un-splashed with electrolyte from 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 Limit any test voltage 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 below 150 V, and there is not sufficient energy to vaporize completely the electrolyte solution that has been placed between the electrodes, flooding can result. If flooding occurs, discontinue the test.

11. Calculation

11.1 Plot the number of drops of electrolyte at failure 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,

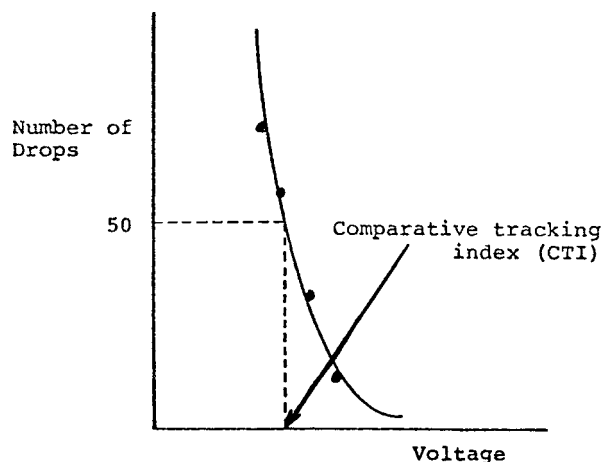


FIG. 3 Typical Tracking Voltage Curve

12.1.5 The CTI value in volts derived in accordance with 11.1, and

12.1.6 Visual observations of specimen behavior, such as melting of the specimen, 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 failure 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

ANNEXES

(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 using more acetone

and scrubbing as required. If after cleaning, the electrodes still show a dark discoloration, 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 channel through which the electrolyte drips (often called 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 will fall straight off the tip without wetting the sides of the needle only if the needle is clean. 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, flush several drops through the system prior to starting a test.

A2. OPTIONAL PROCEDURES

A2.1 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 becomes 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.

SUMMARY OF CHANGES

Committee D09 has identified the location of selected changes to this test method since the last issue, D3638 – 07, that may impact the use of this test method. (Approved January 1, 2012)

(1) Revised sections **6.1.5** and **6.1.6**, and added **Annex A2**.

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