



## Standard Test Method for Evaluation of Resistance to Electrical Breakdown by Treeing in Solid Dielectric Materials Using Diverging Fields<sup>1</sup>

This standard is issued under the fixed designation D 3756; 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.

### INTRODUCTION

When failure occurs in solid organic dielectrics that are subjected to very high, continuous, and nonuniform electrical gradients, it generally occurs by a mechanism called treeing. Materials of different molecular structures have different degrees of resistance to failure by treeing, and this resistance can sometimes be increased by the addition of other materials in low concentration.<sup>2</sup>

Trees that grow by a molecular degradation mechanism resulting from partial discharge (corona) are called electrical trees to distinguish them from water and electrochemical trees which are quite different.

This test method makes use of two opposing thin cylindrical electrodes, one sharpened to a point, the other with a hemispherical end. They are molded or inserted into blocks of the material to be tested. Because of the shape of the electrodes this is often called a needle test. This test provides a statistical estimate of electrical treeing initiation and propagation of solid dielectric materials in high, diverging electrical fields.

### 1. Scope

1.1 This test method covers the evaluation and comparison of the resistance of solid organic dielectric materials to the initiation or growth, or both, of tubular tree-like channels resulting from partial discharge (corona) and molecular decomposition that occur in the region of very high, diverging electric fields.<sup>3,4</sup>

1.2 This test method is primarily for use at a power frequency of 50 or 60 Hz.

1.3 The test may be carried out at room temperature or temperatures above or below room temperature. The temperature should not exceed the softening or melting point of the sample material.

1.4 This test method can be used for any solid material into which needles can be cast, molded or inserted with heat after

molding. The resistance to tree initiation is measured by the double-needle characteristic voltage, which is only applicable to non-opaque materials so that tree can be observed optically. The resistance to tree initiation and growth is reported by the double-needle voltage life, which is applicable to both opaque and non-opaque materials.

1.5 The values stated in SI units are to be regarded as the standard.

1.6 *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 149 Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials at Commercial Power Frequencies<sup>5</sup>

D 1711 Terminology Relating to Electrical Insulation<sup>5</sup>

D 1928 Practice for Preparation of Compression-Molded Test Sheets and Test Specimens<sup>6</sup>

D 2275 Test Method for Voltage Endurance of Solid Electrical Insulating Materials Subjected to Partial Discharges (Corona) on the Surface<sup>5</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> *Symposium on Engineering Dielectrics, ASTM STP 783*, ASTM, 1982, and *Symposium on Engineering Dielectrics, ASTM STP 926*, ASTM, 1986.

<sup>3</sup> W. D. Wilkens, Chapter 7, "Statistical Methods for the Evaluation of Electrical Insulating Systems," *Engineering Dielectrics, Vol IIB, Electrical Properties of Solid Insulating Materials, Measurement Techniques*, R. Bartnikas, Editor, *ASTM STP 926*, ASTM, Philadelphia, 1987.

<sup>4</sup> R. M. Eichorn, Chapter 4, "Treeing in Solid Organic Dielectric Materials," *Engineering Dielectrics, Vol IIA, Electrical Properties of Solid Insulating Materials: Molecular Structure and Electrical Behavior*, R. Bartnikas and R. M. Eichorn, Editors, *ASTM STP 783*, ASTM Philadelphia, 1983.

<sup>5</sup> *Annual Book of ASTM Standards*, Vol 10.01.

<sup>6</sup> *Annual Book of ASTM Standards*, Vol 08.01.

## 2.2 Other Document:

ANSI/IEEE 930-1987 IEEE Guide for the Statistical Analysis of Electrical Insulation Voltage Endurance Data<sup>7</sup>

## 3. Terminology

### 3.1 Definitions:

3.1.1 *partial discharge, n*—refer to D 1711.

### 3.2 Definition of Terms Specific to This Standard:

3.2.1 *characteristic voltage or DNCV (double-needle characteristic voltage), n*—that voltage which, when applied for 1 h between the ends of two thin cylindrical electrodes (one sharpened to a point, the other with a hemispherical end) in a group of replicate specimens, produces observable dielectric damage at the point of the sharp electrode in half of the specimens.

3.2.2 *median voltage life ( $t_{50}$ ), n*—the time, determined from a Weibull plot, when 50 % failure occurs from a group of 10 identical specimens subjected to the same voltage stress.

## 4. Summary of Method

4.1 In this test method, specimens are prepared and needles inserted to serve as electrodes. Voltage is applied to the needles and continued for 1 h in the double-needle characteristic voltage test or until electrical breakdown occurs in the double-needle voltage life test. Results are expressed as the voltage at which half of the specimens show dielectric damage in 1 h, or the median time to failure of a group of specimens subjected to a given continuous voltage, at a selected or predetermined temperature.

## 5. Significance and Use

5.1 This is a laboratory test designed to simulate the effects of (1) the presence of rough interfaces between conductor or semiconductive screen and primary insulation in an insulation system, (2) the presence of foreign particles (contaminants) in an insulation system, and (3) the presence of small voids or cavities within the insulation.

5.2 This test method provides comparative data. The degree of correlation with actual performance in service has not been established.

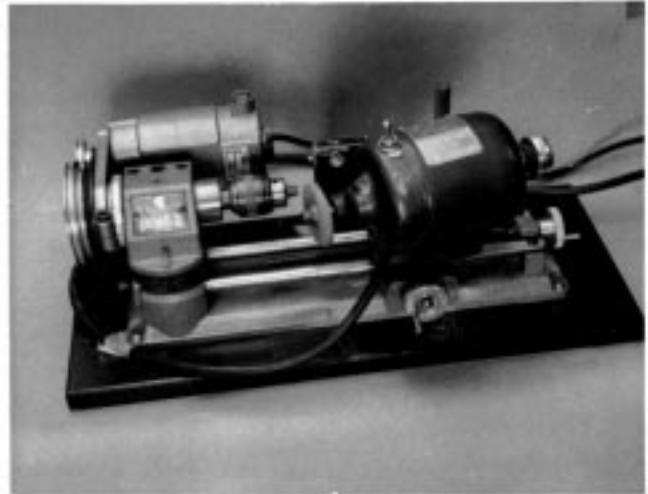
## 6. Apparatus

6.1 *Power Supply*—A high voltage supply having a sinusoidal voltage output at a power frequency equipped with continuous voltage control and an adjustable protective automatic circuit-breaking device that operates at a controllable current level. See Test Method D 149.

6.2 *Current*—Sensitive Individual Specimen Disconnect—When ten specimens are tested to failure for the voltage life test, use a disconnect circuit for each.

6.3 *Electrodes*—The critical electrode is a round steel rod, 1 mm in diameter, sharpened at one end to a controlled radius of  $3 \pm 1 \mu\text{m}$  and an included angle of  $30 \pm 1$  degrees.

6.4 *Needle-Grinding Lathe*, for preparation of the sharpened electrodes to a controlled-point sharpness and included angle. A typical lathe and grinder combination are shown in Fig. 1.



**FIG. 1 Machine Setup for Needle Sharpening**

6.5 *Specimen Molding Chase*, for single-step preparation of compression molded specimens containing needles. A typical chase is shown in Fig. 2.

6.6 *Needle-Insertion Jig*—A jig is required for slow, controlled insertion of electrodes. Fig. 3 shows a specimen insertion jig.

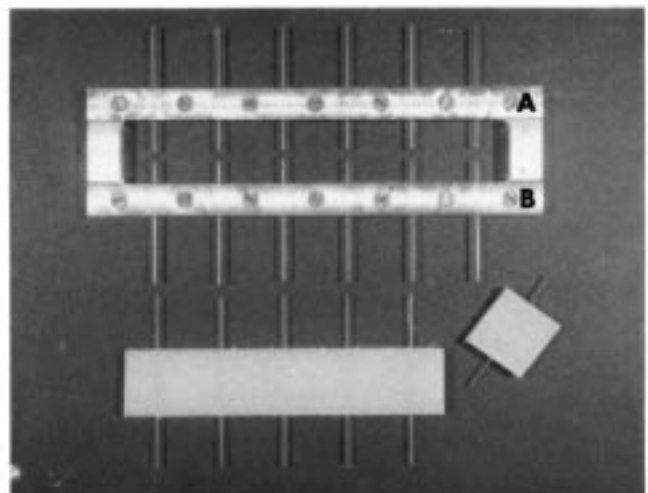
6.7 *Test Chamber*—Any temperature-controlled test chamber or enclosure, which can hold at least ten specimens and maintain uniform temperature, is appropriate for this test.

## 7. Sampling

7.1 Sample so that the specimens tested will represent the entire lot.

## 8. Test Specimens

8.1 Test specimens are approximately 25-mm<sup>2</sup> blocks, 6 mm thick, containing two needle-like electrodes as shown in Fig. 4. Prepare by compression molding, extrusion, or cutting from finished pieces. The tips of the electrodes are separated by 12.0



**FIG. 2 Chase for Preparation of Specimens Containing Electrodes**

<sup>7</sup> Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.



FIG. 3 Needle Insertion Jig

$\pm 0.5$  mm for characteristic voltage determination and  $6.5 \pm 0.5$  mm for voltage life determination. The number of test specimens is at least 24 for characteristic voltage determination (i.e. six specimens for each of at least four different testing voltages) and 10 for voltage life determination.

**8.2 Preparation of Thermoplastic and Crosslinked Specimens**—Compression-mold plaques, 6-mm thick, of the sample material, in a steam or electrically heated hydraulic press equipped for cold-water cooling of the platens. Use a positive pressure mold, which may be of either the picture-frame type or the milled-cavity type. Use parting sheets of cellophane, polyester film, or aluminum foil between the mold surfaces and the resin. The choice of parting sheet depends somewhat on the molding temperature, although aluminum sheets, washed with alcohol and thoroughly dried, are preferred. The size of the mold is not critical,  $200 \times 200$  mm is recommended. For peroxide-crosslinkable materials, the typical compression-molding conditions should follow the material manufacturers recommendation of temperature, time and pressure. The by-products of peroxide decomposition should be removed before testing by use of a vacuum oven at elevated temperatures ( $80^\circ\text{C}$  for 7 days for XLPE using dicumyl peroxide).

8.2.1 After molding, cut the plaque into 25-mm square blocks with square and smooth edges. Store the squares under standard laboratory conditions,  $23^\circ\text{C}$  and 50 % relative humidity, and protect them from dirt and atmospheric contamination until used.

**8.3 Insertion of Needles**—Insert the needle electrodes into the specimen blocks slowly and carefully to avoid orientation strains, formation of cavities, and damage to the sharp points. Use a jig, such as the one shown in Fig. 3, to ensure that every needle will be inserted under identical conditions.

8.3.1 Make the insertions as follows: Place twelve specimen blocks in the slots provided for them and lightly clamp into place. Inspect the twelve sharpened needles, after cleaning with methyl ethyl ketone; then carefully place them into the needle slots on one side so their tips just touch the specimens. Use the individual adjusting screws for positioning the needles. Slip

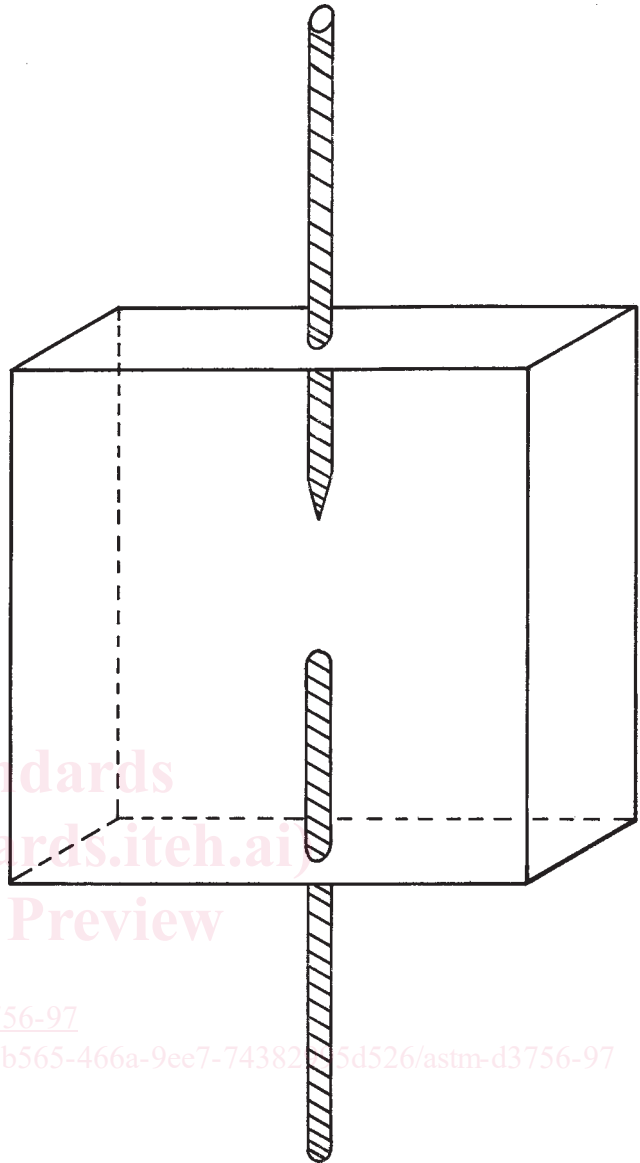


FIG. 4 Finished Specimen

shims into the needle slots above the needles, and use a cover plate to close the top of the needle slots. Secure this cover with small C-clamps at each end. The purpose of the shims and cover is to prevent the needle from cocking, and to force it to enter straight into the specimen. Place twelve electrodes with hemispheric ends in the slots on the opposite sides of the specimens in the same manner.

8.3.2 When the specimens and needles are mounted and the needles are adjusted into proper position, place the whole jig into a circulating air oven at  $105^\circ\text{C}$ , for low-density polyethylene or crosslinked materials, for a 1-h preheating period. For other partially crystalline polymeric materials use a temperature approximately  $10^\circ\text{C}$  below the thermodynamic first-order transition point. After preheating, simultaneously advance the needles 1.30 mm by making one full turn of the large lead screw. Repeat at 5-min intervals. Make sufficient turns to accomplish the insertion. Five turns are normally required for the characteristic voltage test and seven for the voltage life test.