Standard Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials at Commercial Power Frequencies[1]

This standard is issued under the fixed designation D149; 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.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This test method covers procedures for the determination of dielectric strength of solid insulating materials at commercial power frequencies, under specified conditions.[2,3]

1.2 Unless otherwise specified, the tests shall be made at 60 Hz. However, this test method is suitable for use at any frequency from 25 to 800 Hz. At frequencies above 800 Hz, dielectric heating is a potential problem.

1.3 This test method is intended to be used in conjunction with any ASTM standard or other document that refers to this test method. References to this document need to specify the particular options to be used (see 5.5).

1.4 It is suitable for use at various temperatures, and in any suitable gaseous or liquid surrounding medium.

1.5 This test method is not intended for measuring the dielectric strength of materials that are fluid under the conditions of test.

1.6 This test method is not intended for use in determining intrinsic dielectric strength, direct-voltage dielectric strength, or thermal failure under electrical stress (see Test Method D3151).

1.7 This test method is most commonly used to determine the dielectric breakdown voltage through the thickness of a test specimen (puncture). It is also suitable for use to determine dielectric breakdown voltage along the interface between a solid specimen and a gaseous or liquid surrounding medium (flashover). With the addition of instructions modifying Section 12, this test method is also suitable for use for proof testing.

1.8 This test method is similar to IEC Publication 243-1. All procedures in this method are included in IEC 243-1. Differences between this method and IEC 243-1 are largely editorial.

1.9 *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.* Specific hazard statements are given in Section 7. Also see 6.4.1.

2. Referenced Documents

2.1 *ASTM Standards:*[4]

D374 Test Methods for Thickness of Solid Electrical Insulation (Withdrawn 2013)[5]
D618 Practice for Conditioning Plastics for Testing
D877 Test Method for Dielectric Breakdown Voltage of Insulating Liquids Using Disk Electrodes
D1711 Terminology Relating to Electrical Insulation
D2413 Practice for Preparation of Insulating Paper and Board Impregnated with a Liquid Dielectric
D3151 Test Method for Thermal Failure of Solid Electrical Insulating Materials Under Electric Stress (Withdrawn 2007)[5]
D3487 Specification for Mineral Insulating Oil Used in Electrical Apparatus
D5423 Specification for Forced-Convection Laboratory Ovens for Evaluation of Electrical Insulation

[1] This test method is under the jurisdiction of ASTM Committee D09 on Electrical and Electronic Insulating Materials and is the direct responsibility of Subcommittee D09.12 on Electrical Tests.

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[2] Bartnikas, R., Chapter 3, "High Voltage Measurements," *Electrical Properties of Solid Insulating Materials, Measurement Techniques* , Vol. IIB, *Engineering Dielectrics*, R. Bartnikas, Editor, *ASTM STP 926*, ASTM, Philadelphia, 1987 .

[3] Nelson, J. K., Chapter 5, "Dielectric Breakdown of Solids," *Electrical Properties of Solid Insulating Materials: Molecular Structure and Electrical Behavior,* Vol. IIA, *Engineering Dielectrics*, R. Bartnikas and R. M. Eichorn, Editors, *ASTM STP 783*, ASTM, Philadelphia, 1983

[4] 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.

[5] The last approved version of this historical standard is referenced on www.astm.org.

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

2.2 *IEC Standard:*

Pub. 243-1 Methods of Test for Electrical Strength of Solid Insulating Materials—Part 1: Tests at Power Frequencies[6]

2.3 *ANSI Standard:*

C68.1 Techniques for Dielectric Tests, IEEE Standard No. 4[7]

3. Terminology

3.1 *Definitions:*

3.1.1 *dielectric breakdown voltage (electric breakdown voltage), n*—the potential difference at which dielectric failure occurs under prescribed conditions in an electrical insulating material located between two electrodes. (See also Appendix X1.)

3.1.1.1 *Discussion*—The term *dielectric breakdown voltage* is sometimes shortened to "breakdown voltage."

3.1.2 *dielectric failure (under test), n*—an event that is evidenced by an increase in conductance in the dielectric under test limiting the electric field that can be sustained.

3.1.3 *dielectric strength, n*—the voltage gradient at which dielectric failure of the insulating material occurs under specific conditions of test.

3.1.4 *electric strength, n*—see dielectric strength.

3.1.4.1 *Discussion*—Internationally, "electric strength" is used almost universally.

3.1.5 *flashover, n*—a disruptive electrical discharge at the surface of electrical insulation or in the surrounding medium, which may or may not cause permanent damage to the insulation.

3.1.6 For definitions of other terms relating to solid insulating materials, refer to Terminology D1711.

4. Summary of Test Method

4.1 Alternating voltage at a commercial power frequency (60 Hz, unless otherwise specified) is applied to a test specimen. The voltage is increased from zero or from a level well below the breakdown voltage, in one of three prescribed methods of voltage application, until dielectric failure of the test specimen occurs.

4.2 Most commonly, the test voltage is applied using simple test electrodes on opposite faces of specimens. The options for the specimens are that they be molded or cast, or cut from flat sheet or plate. Other electrode and specimen configurations are also suitable for use to accommodate the geometry of the sample material, or to simulate a specific application for which the material is being evaluated.

5. Significance and Use

5.1 The dielectric strength of an electrical insulating material is a property of interest for any application where an electrical field will be present. In many cases the dielectric strength of a material will be the determining factor in the design of the apparatus in which it is to be used.

5.2 Tests made as specified herein are suitable for use to provide part of the information needed for determining suitability of a material for a given application; and also, for detecting changes or deviations from normal characteristics resulting from processing variables, aging conditions, or other manufacturing or environmental situations. This test method is useful for process control, acceptance or research testing.

5.3 Results obtained by this test method can seldom be used directly to determine the dielectric behavior of a material in an actual application. In most cases it is necessary that these results be evaluated by comparison with results obtained from other functional tests or from tests on other materials, or both, in order to estimate their significance for a particular material.

5.4 Three methods for voltage application are specified in Section 12: Method A, Short-Time Test; Method B, Step-by-Step Test; and Method C, Slow Rate-of-Rise Test. Method A is the most commonly-used test for quality-control tests. However, the longer-time tests, Methods B and C, which usually will give lower test results, will potentially give more meaningful results when different materials are being compared with each other. If a test set with motor-driven voltage control is available, the slow rate-of-rise test is simpler and preferable to the step-by-step test. The results obtained from Methods B and C are comparable to each other.

5.5 Documents specifying the use of this test method shall also specify:

5.5.1 Method of voltage application,

5.5.2 Voltage rate-of-rise, if slow rate-of-rise method is specified,

5.5.3 Specimen selection, preparation, and conditioning,

5.5.4 Surrounding medium and temperature during test,

5.5.5 Electrodes,

5.5.6 Wherever possible, the failure criterion of the current-sensing element, and

5.5.7 Any desired deviations from the recommended procedures as given.

5.6 If any of the requirements listed in 5.5 are missing from the specifying document, then the recommendations for the several variables shall be followed.

5.7 Unless the items listed in 5.5 are specified, tests made with such inadequate reference to this test method are not in conformance with this test method. If the items listed in 5.5 are not closely controlled during the test, it is possible that the precisions stated in 15.2 and 15.3 will not be obtained.

5.8 Variations in the failure criteria (current setting and response time) of the current sensing element significantly affect the test results.

5.9 Appendix X1. contains a more complete discussion of the significance of dielectric strength tests.

6. Apparatus

6.1 *Voltage Source*—Obtain the test voltage from a step-up transformer supplied from a variable sinusoidal low-voltage

[6] Available from International Electrotechnical Commission (IEC), 3 rue de Varembé, Case postale 131, CH-1211, Geneva 20, Switzerland, http://www.iec.ch.

[7] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

source. The transformer, its voltage source, and the associated controls shall have the following capabilities:

6.1.1 The ratio of crest to root-mean-square (rms) test voltage shall be equal to $\sqrt{2} \pm 5\ \%$ (1.34 *to* 1.48), with the test specimen in the circuit, at all voltages greater than 50 % of the breakdown voltage.

6.1.2 The capacity of the source shall be sufficient to maintain the test voltage until dielectric breakdown occurs. For most materials, using electrodes similar to those shown in Table 1, an output current capacity of 40 mA is usually satisfactory. For more complex electrode structures, or for testing high-loss materials, it is possible that higher current capacity will be needed. The power rating for most tests will vary from 0.5 kVA for testing low-capacitance specimens at voltages up to 10 kV, to 5 kVA for voltages up to 100 kV.

6.1.3 The controls on the variable low-voltage source shall be capable of varying the supply voltage and the resultant test voltage smoothly, uniformly, and without overshoots or transients, in accordance with 12.2. Do not allow the peak voltage to exceed 1.48 times the indicated rms test voltage under any circumstance. Motor-driven controls are preferable for making short-time (see 12.2.1) or slow-rate-of-rise (see 12.2.3) tests.

6.1.4 Equip the voltage source with a circuit-breaking device that will operate within three cycles. The device shall disconnect the voltage-source equipment from the power service and protect it from overload as a result of specimen breakdown causing an overload of the testing apparatus. If prolonged current follows breakdown it will result in unnecessary burning of the test specimens, pitting of the electrodes, and contamination of any liquid surrounding medium.

6.1.5 It is important for the circuit-breaking device to have an adjustable current-sensing element in the step-up transformer secondary, to allow for adjustment consistent with the specimen characteristics and arranged to sense specimen current. Set the sensing element to respond to a current that is indicative of specimen breakdown as defined in 12.3.

6.1.6 The current setting is likely to have a significant effect on the test results. Make the setting high enough that transients, such as partial discharges, will not trip the breaker but not so high that excessive burning of the specimen, with resultant electrode damage, will occur on breakdown. The optimum current setting is not the same for all specimens and depending upon the intended use of the material and the purpose of the test, it is often desirable to make tests on a given sample at more than one current setting. The electrode area is likely to have a significant effect upon the choice of current setting.

6.1.7 It is possible that the specimen current-sensing element will be in the primary of the step-up transformer. Calibrate the current-sensing dial in terms of specimen current.

6.1.8 Exercise care in setting the response of the current control. If the control is set too high, the circuit will not respond when breakdown occurs; if set too low, it is possible that it will respond to leakage currents, capacitive currents, or partial discharge (corona) currents or, when the sensing element is located in the primary, to the step-up transformer magnetizing current.

6.2 *Voltage Measurement*—A voltmeter must be provided for measuring the rms test voltage. If a peak-reading voltmeter is used, divide the reading by $\sqrt{2}$ to get rms values. The overall error of the voltage-measuring circuit shall not exceed 5 % of the measured value. In addition, the response time of

TABLE 1 Typical Electrodes for Dielectric Strength Testing of Various Types of Insulating Materials[A]

Electrode Type	Description of Electrodes[B,C]	Insulating Materials
1	Opposing cylinders 51 mm (2 in.) in diameter, 25 mm (1 in.) thick with edges rounded to 6.4 mm (0.25 in.) radius	flat sheets of paper, films, fabrics, rubber, molded plastics, laminates, boards, glass, mica, and ceramic
2	Opposing cylinders 25 mm (1 in.) in diameter, 25 mm (1 in.) thick with edges rounded to 3.2 mm (0.125 in.) radius	same as for Type 1, particularly for glass, mica, plastic, and ceramic
3	Opposing cylindrical rods 6.4 mm (0.25 in.) in diameter with edges rounded to 0.8 mm (0.0313 in.) radius[D]	same as for Type 1, particularly for varnish, plastic, and other thin film and tapes: where small specimens necessitate the use of smaller electrodes, or where testing of a small area is desired
4	Flat plates 6.4 mm (0.25 in.) wide and 108 mm (4.25 in.) long with edges square and ends rounded to 3.2 mm (0.125 in.) radius	same as for Type 1, particularly for rubber tapes and other narrow widths of thin materials
5	Hemispherical electrodes 12.7 mm (0.5 in.) in diameter[E]	filling and treating compounds, gels and semisolid compounds and greases, embedding, potting, and encapsulating materials
6	Opposing cylinders; the lower one 75 mm (3 in.) in diameter, 15 mm (0.60 in.) thick; the upper one 25 mm (1 in.) in diameter, 25 mm thick; with edges of both rounded to 3 mm (0.12 in.) radius[F]	same as for Types 1 and 2
7	Opposing circular flat plates, 150 mm diameter[G] , 10 mm thick with edges rounded to 3 to 5 mm radius[H]	flat sheet, plate, or board materials, for tests with the voltage gradient parallel to the surface

[A] These electrodes are those most commonly specified or referenced in ASTM standards. With the exception of Type 5 electrodes, no attempt has been made to suggest electrode systems for other than flat surface material. It is acceptable to use other electrodes as specified in ASTM standards or as agreed upon between seller and purchaser where none of these electrodes in the table is suitable for proper evaluation of the material being tested.
[B] Electrodes are normally made from either brass or stainless steel. Reference shall be made to the standard governing the material to be tested to determine which, if either, material is preferable.
[C] The electrodes surfaces shall be polished and free from irregularities resulting from previous testing.
[D] Refer to the appropriate standard for the load force applied by the upper electrode assembly. Unless otherwise specified the upper electrodes shall be 50 ± 2 g.
[E] Refer to the appropriate standard for the proper gap settings.
[F] The Type 6 electrodes are those given in IEC Publication 243-1 for testing of flat sheet materials. They are less critical as to concentricity of the electrodes than are the Types 1 and 2 electrodes.
[G] It is acceptable to use other diameters, provided that all parts of the test specimen are at least 15 mm inside the edges of the electrodes.
[H] The Type 7 electrodes, as described in the table and in Note[G] , are those given in IEC Publication 243-1 for making tests parallel to the surface.