Designation: D 229 – 01

An American National Standard

Standard Test Methods for Rigid Sheet and Plate Materials Used for Electrical Insulation[1]

This standard is issued under the fixed designation D 229; 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 These test methods cover procedures for testing rigid electrical insulation normally manufactured in flat sheet or plate form. They are generally used as terminal boards, spacers, voltage barriers, and circuit boards.

NOTE 1—For tests applying to vulcanized fibre reference should be made to Test Methods D 619.

NOTE 2—This standard resembles IEC 60893-2, Specification for Rigid Industrial Laminated Sheets Based On Thermosetting Resins for Electrical Purpose, Methods of Tests.

1.2 The test methods appear in the following sections:

Test	Sections	ASTM Test Method
Acetone extractable matter	83 to 84	D 494
Arc resistance	47	D 495
Ash	56 to 60	...
Bonding strength	49 to 54	...
Burning rate and flame resistance	61 to 75	...
Compressive strength	25	D 695
Conditioning	4	D 6054
Dissipation factor	34 to 40	D 669
Dielectric strength	28 to 33	D 149
Expansion (linear thermal)	76	D 696
Flexural properties	12 to 24	D 790
Hardness (Rockwell)	55	D 785
Insulation resistance and resistivity	41 to 46	D 257
Permittivity	34 to 40	D 150
Resistance to impact	26	D 256
Tensile properties	7 to 11	D 638
Thickness	5 to 6	D 374
Tracking resistance	48	D 2132
Warp or twist	77 to 82	...
Water absorption	27	D 570

1.3 The values stated in inch-pound units are to be regarded as the standard. The metric equivalents of inch-pound units given in these test methods may be approximate.

1.4 This is a fire-test-response standard. See Sections 61 through 75, which are the procedures for burning rate and flame resistance.

1.5 *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 precautionary statements are given in 31.1 and 61.5.

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[2]

D 150 Test Methods for AC Loss Characteristics and Permittivity (Dielectric Constant) of Solid Electrical Insulation[2]

D 256 Test Methods for Determining the Izod Pendulum Impact Resistance of Plastics[3]

D 257 Test Methods for DC Resistance or Conductance of Insulating Materials[2]

D 374 Test Methods for Thickness of Solid Electrical Insulation[2]

D 494 Test Method for Acetone Extraction of Phenolic Molded or Laminated Products[4]

D 495 Test Method for High-Voltage, Low-Current, Dry Arc Resistance of Solid Electrical Insulation[2]

D 570 Test Method for Water Absorption of Plastics[3]

D 617 Test Method for Punching Quality of Phenolic Laminated Sheets[2]

D 619 Test Methods for Vulcanized Fibre Used for Electrical Insulation[2]

D 638 Test Method for Tensile Properties of Plastics[3]

D 669 Test Method for Dissipation Factor and Permittivity Parallel with Laminations of Laminated Sheet and Plate Materials[2]

D 695 Test Method for Compressive Properties of Rigid Plastics[3]

[1] These test methods are under the jurisdiction of ASTM Committee D09 on Electrical and Electronic Insulating Materials and are the direct responsibility of Subcommittee D09.07 on Flexible and Rigid Insulating Materials.

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[2] *Annual Book of ASTM Standards*, Vol 10.01.

[3] *Annual Book of ASTM Standards*, Vol 08.01.

[4] *Discontinued*; see *1991 Annual Book of ASTM Standards*, Vol 10.01.

D 696 Test Method for Coefficient of Linear Thermal Expansion of Plastics Between −30°C and 30°C With a Vitreous Silica Dilatometer[3]
D 785 Test Method for Rockwell Hardness of Plastics and Electrical Insulating Materials[3]
D 790 Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials[3]
D 792 Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement[3]
D 883 Terminology Relating to Plastics[3]
D 1674 Methods of Testing Polymerizable Embedding Compounds Used for Electrical Insulation[4]
D 1711 Terminology Relating to Electrical Insulation[2]
D 1825 Practice for Etching and Cleaning Copper-Clad Electrical Insulating Materials and Thermosetting Laminates for Electrical Testing[2]
D 2132 Test Method for Dust-and-Fog Tracking and Erosion Resistance of Electrical Insulating Materials[2]
D 2303 Test Methods for Liquid-Contaminant, Inclined-Plane Tracking and Erosion of Insulating Materials[2]
D 3487 Specification for Mineral Insulating Oil Used in Electrical Apparatus[5]
D 5032 Practice for Maintaining Constant Relative Humidity by Means of Aqueous Glycerin Solutions[6]
D 6054 Practice for Conditioning Electrical Insulating Materials for Testing[6]
E 197 Specification for Enclosures and Servicing Units for Tests Above and Below Room Temperature[7]

2.2 *IEC Standard:*
IEC 60893–2 Specification for Rigid Industrial Laminated Sheets Based on Thermosetting Resins for Electrical Purpose, Methods of Tests[8]

3. Terminology

3.1 *Definitions*—Rigid electrical insulating materials are defined in these test methods in accordance with Terminology D 883. The terminology applied to materials in these test methods shall be in accordance with the terms appearing in Terminologies D 883 and D 1711.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 In referring to the cutting, application, and loading of the specimens, the following terms apply:

3.2.1.1 *crosswise (CW), adj*—in the direction of the sheet at 90° to the lengthwise direction. This is normally the weakest direction in flexure. For some materials, including the raw materials used for manufacture of materials considered herein, this direction may be designated as the cross-machine direction or the weft direction.

3.2.1.2 *edgewise loading, n*—mechanical force applied in the plane of the original sheet or plate.

3.2.1.3 *flatwise loading, n*—mechanical force applied normal to the surfaces of the original sheet or plate.

3.2.1.4 *lengthwise (LW), adj*—in the direction of the sheet which is strongest in flexure. For some materials, including the raw materials used for the manufacture of materials considered herein, this direction may be designated as the machine direction or the warp direction.

3.2.2 In referring to bonding strength, the following term applies:

3.2.2.1 *bonding strength, n*—the force required to split a prescribed specimen under the test conditions specified herein.

4. Conditioning

4.1 The properties of the materials described in these test methods are affected by the temperature and moisture exposure of the materials to a greater or lesser extent, depending on the particular material and the specific property. Control of temperature and humidity exposure is undertaken to: (*1*) obtain satisfactory test precision, or (*2*) study the behavior of the material as influenced by specific temperature and humidity conditions.

4.2 Unless otherwise specified in these test methods or by a specific ASTM material specification, or unless material behavior at a specific exposure is desired, condition test specimens in accordance with Procedure A of Practice D 6054 and test in the Standard Laboratory Atmosphere (23 ± 1.1°C, 50 ± 2 % relative humidity).

THICKNESS

5. Apparatus and Procedure

5.1 Measure thickness in accordance with Test Methods D 374.

5.2 On test specimens, the use of a machinist's micrometer as specified in Method B is satisfactory for the determination of thickness for all of the test methods that follow. Where it is convenient, the deadweight dial micrometer, Method C, may be used.

5.3 On large sheets, use Method B. Choose a micrometer with a yoke of sufficient size and rigidity to permit accurate measurements in the center of the sheet.

6. Precision and Bias

6.1 Results of comparative tests in several factories, measuring 36-in. (914-mm) square sheets by a variety of such devices, indicate that the trade is able to measure sheets 1⁄32 and 1⁄8 in. (1 and 3 mm) in thickness to accuracy of 0.0015 in. (0.0381 mm). (In the tests, σ, of 0.0005 in. (0.0127 mm) was obtained.)

6.2 This test method has no bias because the value for breaking strength is determined solely in terms of this test method itself.

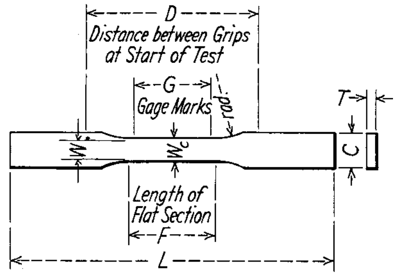
TENSILE PROPERTIES

7. Test Specimens

7.1 Machine the test specimens from sample material to conform to the dimensions of sheet and plate materials in Fig. 1.

7.2 Prepare four LW and four CW specimens.

[5] *Annual Book of ASTM Standards*, Vol 10.03.
[6] *Annual Book of ASTM Standards*, Vol 10.02.
[7] *Discontinued*; see *1979 Annual Book of ASTM Standards*, Part 40.
[8] Available from American National Standards Institute, 25 W. 43rd St., 4th Floor, New York, NY 10036.



Dimension	Nominal Thickness, *T*										Tolerance	
	¼ in. (6 mm) or Under				Over ¼ in. (6 mm) to ½ in. (13 mm), incl				Over ½ in. (13 mm) to 1 in. (25 mm), incl[A]			
	Type I		Type II[B]		Type I		Type II[B]		Type I			
	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.
C—Width over-all	19.05	0.750	19.05	0.750	28.57	1.125	28.57	1.125	38.10	1.500	±0.40 −0.00	+ 0.016 −0.000
W—Width of flat section	12.70	0.500	6.35	0.250	19.05	0.750	9.52	0.375	25.40	1.000	+ 0.12	+ 0.005
F—Length of flat section	57.1	2.25	57.1	2.250	57.1	2.25	57.1	2.25	57.1	2.25	±0.40	±0.016
G—Gage length[C]	50.8	2.00	50.8	2.00	50.8	2.00	50.8	2.00	50.8	2.00	±0.40	±0.016
D—Distance between grips	114	4½	133	5¼	114	4½	133	5¼	133	5¼	±3	±⅛
L—Length over-all	216	8½	238	9⅜	248	9¾	257	10⅛	305	12	min	min
Rad.—Radius of fillet	76	3	76	3	76	3	76	3	76	3	min	min

[A] For sheets of a nominal thickness over 1 in. (25.4 mm) machine the specimens to 1 in. (25.4 mm) ± 0.010 in. (0.25 mm) in thickness. For thickness between 1 in. (25.4 mm) and 2 in. (51 mm), machine approximately equal amounts from each surface. For thicker sheets, machine both surfaces and note the location of the specimen with reference to the original thickness.

[B] Use the type II specimen for material from which the Type I specimen does not give satisfactory failures in the gage length, such as for resin-impregnated compressed laminated wood.

[C] Test marks only.

FIG. 1 Tension Test Specimen for Sheet and Plate Insulating Materials

8. Rate of Loading

8.1 The materials covered by these test methods generally exhibit high elastic modulus. Use any crosshead speed provided that the load and strain indicators are capable of accurate measurement at the speed used, except use 0.05 in./min (1 mm/min) in matters of dispute.

9. Procedure

9.1 Measure the tensile strength and elastic modulus in accordance with Test Method D 638 except as modified in the following paragraphs.

9.2 Measure the width and thickness of the specimen to the nearest 0.001 in. (0.025 mm) at several points along the length of the flat section, which is indicated as Dimension F in Fig. 1. Record the minimum values of cross-sectional area so determined.

9.3 Place the specimen in the grips of the testing machine, taking care to align the long axis of the specimen and the grips with an imaginary line joining the points of attachment of the grips to the machine. Allow 0.25 in. (6.3 mm) between the ends of the gripping surfaces and the shoulders of the fillet of the flat test specimen; thus, the ends of the gripping surfaces should be the indicated distance apart, as shown in Fig. 1, at the start of the test. Tighten the grips evenly and firmly to the degree necessary to prevent slippage of the specimen during the test, but not to the point where the specimen would be crushed.

9.4 *Tensile Strength*—Set the rate of loading. Load the specimen at the indicated rate until the specimen ruptures. Record the maximum load (usually the load at rupture).

9.5 *Elastic Modulus*—When elastic modulus is desired, use a load-extension recorder with appropriate extension transmitter and proceed as in 9.3. Attach the extension transmitter, and proceed as in 9.4.

10. Report

10.1 Report the following information:

10.1.1 Complete identification of the material tested,

10.1.2 Type of test specimen (I or II),

10.1.3 Conditioning if other than specified,

10.1.4 Speed of testing,

10.1.5 Calculated tensile strength, average, maximum, and minimum in lb/in.^{2} (MPa), for LW and CW specimens, respectively,

10.1.6 Calculated elastic modulus when applicable, average, maximum, and minimum in lb/in.^{2} (MPa), for LW and CW specimens, respectively, and

10.1.7 Any other tensile property calculated from the measurements obtained.

11. Precision and Bias

11.1 This test method has been in use for many years, but no statement for precision has been made and no activity is planned to develop such a statement.

11.2 This test method has no bias because the value for breaking strength is determined solely in terms of this test method itself. See Test Method D 638 for a discussion of precision and bias for tensile testing of plastics.

FLEXURAL PROPERTIES

12. Test Specimens

12.1 Test four LW and four CW specimens machined from sample material in accordance with Test Methods D 790.

NOTE 3—Conventional flexure tests in a flatwise direction are not recommended for materials thinner than 1⁄32 in. (1 mm) nor in the edgewise direction for materials thinner than 1⁄4 in. (6 mm).

13. Rate of Loading

13.1 The materials covered by these test methods generally rupture during flexural testing at small deflections. Therefore, Procedure A (strain rate of 0.01/min) is specified whenever it is desired to obtain the modulus of elasticity. Any crosshead speed that produces failure in no less than 1 min may be used when flexural strength only is desired, provided that the load indicator is capable of accurately indicating the load at the speed used, and except that in all matters of dispute, a crosshead speed that produces the strain rate specified in Procedure A shall be considered to be the referee speed.

14. Procedure

14.1 Measure the flexural strength and modulus of elasticity in accordance with Procedure A of Test Methods D 790, except that where modulus of elasticity is desired use a load-deflection recorder with appropriate deflection transmitter.

15. Report

15.1 Report the following information:

15.1.1 Complete identification of the material tested,

15.1.2 Conditioning if other than specified,

15.1.3 Speed of testing if other than Procedure A speed,

15.1.4 Calculated flexural strength, average, maximum, and minimum in lb/in.^{2} (MPa), for LW and CW specimens, respectively,

15.1.5 Calculated tangent modulus of elasticity when applicable, average, maximum, and minimum, for LW and CW specimens, respectively, and

15.1.6 Any other flexural property calculated from the measurements obtained.

16. Precision and Bias

16.1 This test method has been in use for many years, but no statement for precision has been made and no activity is planned to develop such a statement.

16.2 This test method has no bias because the value for breaking strength is determined solely in terms of this test method itself. See Test Methods D 790 for a discussion of precision and bias for testing of flexural properties of plastics.

FLEXURAL PROPERTIES AT ELEVATED TEMPERATURE

17. Scope

17.1 This test method covers the determination of flexural properties at elevated temperature, and as a function of time of exposure to elevated temperature.

18. Significance and Use

18.1 This test method provides useful engineering information for evaluating the mechanical behavior of rigid electrical insulation at elevated temperature. When the proper exposure and test temperatures are chosen, depending on the material and end-use operating temperature, the test method may be used as one means of indicating relative thermal degradation of rigid insulating materials.

19. Apparatus

19.1 *Testing Machine*—A universal testing machine and accessory equipment in accordance with Test Methods D 790. Apparatus that is exposed to elevated temperature during the test shall be adjusted to function normally at the elevated temperature and, where necessary, accuracy shall be verified by calibration at the test temperature.

19.2 *Test Enclosure*—A test enclosure conforming to the Type I, Grade B, temperature requirements of Specification E 197. The test enclosure may rest on the testing machine table, in which case the top shall have a hole of sufficient size so that adequate clearance is provided for the loading nose, or the test enclosure may rest on a dolly and contain a cradle which is supported by the loading members of the machine.

19.3 *Heat Aging Oven*—A heat aging oven for conditioning specimens at the test temperature for periods of more than 1 h. The oven shall conform to the requirements for Type I, Grade A, units of Specification E 197, except with respect to the time constant.

19.4 *Specimen Transfer Device*—A means of transferring the test specimens from the heat-aging oven to the test enclosure when testing specimens exposed to elevated temperature for periods of more than 1 h. The specimens may be transferred without cooling either in a small mobile transfer oven or wrapped in previously heated thick pad of heat resistant material.

19.5 *Thermocouple*—Thermocouple made with No. 30 or 28 B & S gage thermocouple calibration wires to determine the temperature of the specimen. Any suitable indicating or recording device shall be used that provides an overall (junction and instrument) accuracy of ±2°C.

20. Test Specimen

20.1 Test the specimen flatwise and lengthwise and machine from sample material in accordance with Section 12.

20.2 Where it is desired to evaluate relative thermal degradation, specimens shall be 1⁄8 in. (3 mm) in nominal thickness.

20.3 Fit at least one specimen of each thickness for each sample material with a hole drilled into an edge that rests outside the support to a depth of at least 1⁄2 in. (13 mm). Insert the thermocouple junction in this hole and cement. Use this specimen to determine the temperature of the specimen on the support and the time required to reach the specified temperature for specimens that are tested after 15-min exposure or less.

20.4 Test five specimens at each temperature.

21. Conditioning

21.1 No special conditioning is required for specimens that are to be tested after more than 1-h exposure at elevated temperature.

22. Procedure

22.1 Adjust the rate of loading in accordance with Section 13 and test the specimen in accordance with Section 14.

22.2 Age in the flexural test enclosure the specimens that are to be tested 1 h or less after exposure to elevated temperature.

22.3 Exposures at elevated temperature for 15 min or less shall not include the time (previously determined from the specimen with the thermocouple) that is required for the specimen to reach the specified temperature. Rather, begin exposures for intervals of 15 min or less when the specimen reaches the specified temperature and end when the specified exposure period has expired.

22.4 Age in the heat-aging oven the specimens that are exposed to elevated temperature for more than 1 h. Do not allow the specimens to cool when removed from the heat-aging oven, but rather transfer them in the mobile-transfer oven or wrap them in previously heated thick pad of heat resistant material. Place them in the flexural test chamber which has been previously heated to the specified temperature.

22.5 Consider the flexural test enclosure and accessory equipment inside at equilibrium when a dummy specimen fitted with an internal thermocouple, and placed on the supports, has reached the specified temperature, as determined by the thermocouple measurement. Place test specimens in the flexural test enclosure only after equilibrium has been established.

23. Report

23.1 Report all applicable information plus the following:

23.1.1 Temperature at which the specimens were exposed and tested,

23.1.2 Time of exposure, and

23.1.3 Where sufficient measurements are made, a plot of flexural strength as ordinate and time at elevated temperature as abscissa, for each temperature chosen.

24. Precision and Bias

24.1 This test method has been in use for many years, but no statement for precision has been made and no activity is planned to develop such a statement.

24.2 A statement of bias is not available because of the lack of a standard reference material for this property.

COMPRESSIVE STRENGTH

25. Procedure

25.1 Determine the compressive strength in accordance with Test Method D 695, except test four specimens.

RESISTANCE TO IMPACT

26. Procedure

26.1 Determine the resistance to impact in accordance with Test Methods D 256, using Method A or C, whichever is applicable, except test four specimens conditioned in accordance with 4.2 of these test methods.

WATER ABSORPTION

27. Procedure

27.1 Determine the water absorption in accordance with Test Method D 570, except test all sample material for water-soluble matter unless it has been previously demonstrated by test that there is negligible water-soluble matter in the sample. Test four specimens.

DIELECTRIC STRENGTH

28. Surrounding Medium

28.1 Except as noted below, perform tests in a surrounding medium of transformer oil meeting all of the requirements for Type I mineral oil of Specification D 3487. Test at room temperature, unless otherwise specified.

NOTE 4—A liquid medium is specified to obtain breakdown of a reasonable size test specimen rather than flashover in the medium. Testing in a liquid medium limits the likelihood of flashover but may not always prevent it, especially with the tapered-pin method.

Transverse tests performed in an air medium will generally result in lower breakdown values than transverse tests performed in the liquid medium. This is particularly true when porous materials are tested. Tests performed in the liquid medium on specimens that have been thermally aged may produce misleading conclusions when change in dielectric strength is utilized as a criterion of thermal degradation.

Transverse tests in air for porous materials and thermally aged materials are encouraged. Various schemes may be utilized for potting or gasketing the electrodes to prevent flashover. Apparatus is being evaluated for use in a standard method for transverse tests in air. See the Surrounding Medium section of Test Method D 149.

28.2 In the special case of material tests on parallel-tapered-pin configuration where breakdown voltages exceed 50 kV special attention must be given to the cleanliness, dryness, and temperature of the surrounding medium. The substitution of dibutyl phthalate for transformer oil has been found to be satisfactory.

NOTE 5—Breakdown of the oil above the specified value for the material under test is not necessarily proof that actual specimen breakdown occurred during a parallel-tapered-pin test, since the specimen surface structure and its permittivity will influence the breakdown voltage of a given oil between the tapered pins with specimen in place.

29. Electrodes and Test Specimens

29.1 *Transverse Test*—Use 2-in. (51-mm) diameter electrodes (Type 1 of Test Method D 149) for voltage stress applied perpendicular to the flat side of the specimen. The test specimen shall be of such size that flashover in the oil medium does not occur before specimen breakdown. In general, a 4-in. (102-mm) square will be satisfactory.

29.2 *Parallel Test, Point-Plane Method*— The test specimens shall be ½ in. (13 mm) in width by 1 in. (25 mm) in length by the thickness of the material. Minimum thickness of the material shall be ⅛ in. (3 mm). Using a twist drill with a point angle of 60 to 90°, drill a hole in the approximate center of the 1-in. (25-mm) length in a direction parallel with the flat sides, to a depth of 7⁄16 in. (11 mm), leaving a thickness of 1⁄16 in. (1.6 mm) to be tested. Insert a snug-fitting metal pin electrode, with the end ground to conform with the shape of the drill used in the hole. Place the specimen on a flat metal plate that is at least 1½ in. (38 mm) in diameter. This plate serves as the lower electrode. Thus, in effect, the material is tested parallel with the flat sides in a point-plane dielectric gap. The diameter of the hole shall be as shown in the following table:

Nominal Thickness of Sheets	Nominal Hole Diameter for Pin Electrode
⅛ to ¼ in. (3 to 6 mm)	1⁄16 in. (1.6 mm)
>¼ in. (6 mm)	⅛ in. (3 mm)

29.3 *Parallel Test, Tapered-Pin Method*:

29.3.1 *Significance*—Sheet and plate insulation, particularly laminated sheets, are frequently used in service in a manner such that the full thickness of the insulation is exposed to a voltage stress parallel to the flat sides between pin-type inserts. This method (employing tapered-pin electrodes) is recommended, rather than the method in 29.2, when it is desired to simulate the service condition described and when the need for obtaining quantitative dielectric breakdown data is secondary to acceptance and quality control needs.

29.3.2 *Nature of Test*—The tapered-pin electrodes extend beyond the test specimen on both flat sides. Therefore, oil-medium flashover or oil-specimen interface failure may obscure specimen volume dielectric breakdown. This method is suited, consequently, for use primarily as a proof-type test, that is, to determine only that a material will withstand without failure a specified minimum electric stress applied in a prescribed manner under specified conditions. In some limited cases, however, (for example, specimens conditioned in water) it may be possible to employ the tapered-pin method to obtain quantitative specimen dielectric breakdown data. When numerous tests are made, it may prove difficult to maintain the oil-medium in such a condition as to obviate flashover (with specimen in place between pins spaced 1 in. (25 mm) apart) at voltage magnitude above 50 kV. The practical limit, therefore, when using an oil-medium is 50 kV. This limit can be increased to 80 kV by the use of dibutyl phthalate.

29.3.3 *Test Specimens and Electrodes*— The test specimen shall be 2 by 3 in. (50 by 75 mm) by the thickness of the sheet. The electrodes shall be USA Standard tapered pins (such as Morse, Brown & Sharpe, or Pratt & Whitney) having a taper of ¼ in./ft (20 mm/m). For specimen thicknesses up to and including ½ in. (13 mm), use No. 3 USA Standard tapered pins[9] 3 in. (76 mm) long and having a diameter of 7⁄32 in. (5.6 mm) at the large end. For specimen thicknesses over ½ in. (13 mm) up to and including 2 in. (51 mm), use No. 4 USA Standard Pins[9] 4 in. (102 mm) long having a diameter at the large end of ¼ in. (6 mm). Drill two 3⁄16-in. (5-mm) diameter holes, centrally located, 1 in. (25 mm) apart, center to center, and perpendicular to the faces of the specimen. Ream the holes to a sufficient depth to allow the pins to extend approximately 1 in. (25 mm) from the small ends of the holes. Insert the electrodes from opposite sides of the specimen, after the conditioning period. Metal spheres of ½ in. (13-mm) diameter placed on the extremities of the tapered pins may sometimes decrease the tendency to flashover in the oil.

30. Conditioning

30.1 Condition five specimens in accordance with Section 4. In the case of the Parallel Test, Tapered Pin Method, tests are usually performed on unconditioned specimens. However, in determining the effects of exposure to moisture or water using this test, Procedure E of Practice D 6054 is recommended.

31. Procedure

31.1 **Warning:** Lethal voltages may be present during this test. It is essential that the test apparatus, and all associated equipment that may be electrically connected to it, be properly designed and installed for safe operation. Solidly ground all electrically conductive parts that any person might come into contact with during the test. Provide means for use at the completion of any test to ground any parts which: were at high voltage during the test; may have acquired an induced charge during the test; may retain a charge even after disconnection of the voltage source. Thoroughly instruct all operators in the proper way to conduct tests safely. When making high voltage tests, particularly in compressed gas or in oil, the energy released at breakdown may be sufficient to result in fire, explosion, or rupture of the test chamber. Design test equipment, test chambers, and test specimens so as to minimize the possibility of such occurrences and to eliminate the possibility of personal injury.

31.2 Determine the dielectric strength, dielectric breakdown voltage, and dielectric proof-type test in accordance with Test Method D 149, except as follows: Make the tests perpendicular to or parallel with the flat sides, or both, depending upon whether the stress on the material when in use is to be perpendicular to or parallel with the flat sides, or both.

31.3 Make the tests by either the short-time method, the step-by-step method, or the slow-rate-of-rise method as follows:

31.3.1 *Short-Time Method*—Increase the voltage at the rate of 0.5 kV/s.

31.3.2 *Step-by-Step Method*—Apply the voltage at each step for 1 min and increase it in the following increments:

Breakdown Voltage by Short-Time Method, kV	Increment of Increase of Test Voltage, kV
25 or less	1.0
Over 25 to 50, incl	2.0
Over 50 to 100, incl	5.0
Over 100	10.0

31.3.3 *Slow-Rate-of-Rise Method*—Increase the voltage as follows:

Breakdown Voltage by Short-Time Method, kV	Rate of Test Voltage Rise, V/s
25 or less	17
Over 25 to 50, incl	33
Over 50 to 100, incl	83
Over 100	167

31.4 *Proof-Type Test*—Make the tests by either the step-by-step or the slow-rate-of-rise method as follows:

31.4.1 *Step-by-Step Method*—Starting at the prescribed percentage of the minimum failure voltage as specified in the appropriate material specification, increase the test voltage in 1-min steps. Use test voltage increments of 1.0 kV for starting

[9] For information on tapered pins, see *Kent's Mechanical Engineers' Handbook*, 12th edition, *Design and Production Volume*, Section 15, p. 14.