Standard Test Methods for Varnished Cotton Fabrics Used for Electrical Insulation[1]

This standard is issued under the fixed designation D 295; 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 the testing of varnished cotton fabrics and varnished cotton fabric tapes (Note 1) to be used as electrical insulation and are directly applicable to both "straight-cut" and "bias-cut" materials, unless otherwise stated in the test method.

NOTE 1—Methods of testing varnished glass fabrics and tapes are given in Test Methods D 902.

1.2 The procedures appear in the following order:

Procedures	Sections	ASTM Test Methods
Breaking Strength	20 to 27	...
Conditioning	5	...
Dielectric Breakdown Voltage	43 to 46	D 149
Dielectric Breakdown Voltage Under Elongation	47 to 53	D 149
Dissipation Factor and Permittivity	54 to 60	D 150
Elongation	35 to 42	...
Resistance to Oil	68 to 73	D 92
Selection of Test Specimens	4	...
Tear Resistance	28 to 34	D 689
Thickness	6 to 10	D 374
Thread Count	15 to 19	...
Volume Resistance	61 to 67	D 257
Weight	11 to 14	...

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

1.4 *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.* For specific precautionary statements, see 44.4, 51.1, 58.1, and 65.1.

NOTE 2—This standard resembles IEC 60394–2 in title only. The content is significantly different.

2. Referenced Documents

2.1 *ASTM Standards:*

D 92 Test Method for Flash and Fire Points by Cleveland Open Cup[2]

D 149 Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Electrical Insulating Materials at Commercial Power Frequencies[3]

D 150 Test Methods for AC Loss Characteristics and Permittivity (Dielectric Constant) of Solid Electrical Insulation[3]

D 257 Test Methods for DC Resistance or Conductance of Insulating Materials[3]

D 374 Test Methods for Thickness of Solid Electrical Insulation[3]

D 689 Test Method for Internal Tearing Resistance of Paper[4]

D 902 Test Methods for Flexible Resin-Coated Glass Fabrics and Glass Fabric Tapes Used for Electrical Insulation[3]

D 1711 Terminology Relating to Electrical Insulation[3]

2.2 *IEC Standard:*

IEC 60394–2 Varnished Fabrics for Electrical Purposes — Part 2: Methods of Test[5]

3. Terminology

3.1 *Definitions:* For definitions of terms used in these test methods refer to Terminology D 1711.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *weight—of varnished cloth and varnished cloth tapes*, the weight per unit area as determined in accordance with this test method. It is usually expressed in pound per square yard for a specified nominal thickness.

3.2.2 *threads per inch—of varnished cloths*, the count of the number of warp and filling yarns present in the base cloth per linear inch of width or length, respectively.

3.2.3 *elongation*—the amount of strain observed in a given length of varnished cloth or tape when subjected to prescribed loading conditions at prescribed atmospheric conditions. It is expressed as a percentage of the initial length.

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[2] *Annual Book of ASTM Standards*, Vol 05.01.

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

[4] *Annual Book of ASTM Standards*, Vol 15.09.

[5] Available from American National Standards Institute, 11 W 42nd St.,New York, NY 10036.

3.2.4 *oil resistance—of varnished cloth or tape*, the ability of the varnish film to withstand the attack of oil without excessive impairment of its physical and electrical characteristics when the varnished cloth or tape is immersed in a specified oil for a prescribed period of time at a given temperature.

4. Selection of Test Specimens

4.1 Select specimens for test from portions of material free from defects.

4.2 In the case of rolls of material other than those packed in oil, remove the outer two layers of cloth or the outer six layers of tape and prepare test specimens from the remaining material. In the case of oil-packed tape, remove the outer layer from each roll to be tested. In the case of sheets and tape strips, remove the outer six layers of material and prepare test specimens from that remaining.

NOTE 3—In the case of bias-cut materials, exclude seams and jointed selvage from test areas.

NOTE 4—If it is desired to test seams and jointed selvages for breaking strength, prepare additional test specimens so that the seams or joints are in the center of the specimens.

5. Conditioning

5.1 *Significance and Use*—Because the physical and electrical properties of most fabrics change with variation of their moisture content, it is necessary to control this property at the time of testing in order to attain reasonably good reproducibility of test values. For example, when cotton fabric absorbs moisture it tends to swell and increase in dimensions. Also, the flexibility, elongation, and tensile strength of the material normally increase with increased relative humidity, whereas, conversely, the electrical properties are depreciated when the material is subjected to these conditions. The time of exposure to the conditioned atmosphere must be long enough to permit the moisture content of the test specimen to reach a relatively stable value. If the fabric is untreated, a few hours exposure is sufficient. Treated fabrics like varnished cloth require appreciably longer time.

5.2 Where it is desired to test in a controlled atmosphere, condition the test specimens for 48 h in the Standard Laboratory Atmosphere of 50 ± 2 % relative humidity at 23 ± 1°C (73.4 ± 1.8°F). If a conditioning cabinet or chamber is used, subject the specimens to test immediately upon withdrawal from the cabinet or chamber, unless otherwise specified.

5.3 If it is desired to test the material in the condition as received by the purchaser, allow the packages containing the rolls of material from which the specimens are to be taken to reach room temperature before opening. Open the packages, remove the roll and immediately prepare such test specimens as required, unless otherwise specified.

5.4 In the case of dispute, the procedure described in 5.2 shall be the referee method.

THICKNESS

6. Significance and Use

6.1 The thickness test is necessary to determine whether the material meets specified tolerances for thickness. In addition, thickness values are essential because of the importance of space factor in designing electrical equipment.

7. Test Specimens

7.1 In the case of cloths or sheets, cut test specimens 1 in. (25.4 mm) wide across the entire width. In the case of bias-cut cloth, exclude seams or jointed selvages from the area of test.

7.2 In the case of tapes or strips, remove specimens 36 in. (910 mm) long from the sample of material selected in accordance with Section 4.

8. Procedure

8.1 Measure the thickness in accordance with Test Methods D 374, with the following modifications:

8.1.1 Either Method B or Method C may be used but Method C is to be used unless otherwise specified. Method A shall not be used.

8.1.2 In making thickness measurements, use only one layer of material.

8.1.3 In the case of cloths, take ten measurements equally spaced across the width of the specimen. The thickness of the cloth shall be the average of the ten measurements.

8.1.4 In the case of tapes, unless otherwise specified, take ten measurements equally spaced along the length of each specimen. The thickness of the tape shall be the average of ten measurements.

9. Report

9.1 Report the average, maximum, and minimum thickness in inches (or centimetres).

10. Precision and Bias

10.1 This test method has been in use for many years, but no information has been presented to ASTM upon which to base a statement of precision. No activity has been planned to develop such information.

10.2 This test method has no bias because the value for thickness is determined solely in terms of this test method itself.

WEIGHT

11. Significance and Use

11.1 Weight values are useful for estimating weight in designing electrical equipment containing a constituent part of varnished cloth or tape.

12. Procedure

12.1 Prepare either square or rectangular specimens of sufficient size to weigh not less than 0.18 oz (5 g). Accurately weigh on an analytical balance. Measure the length and width dimensions with sufficient precision to be able to compute the area within 0.3 %. Compute the weight per unit area.

13. Report

13.1 Report a description of the material and the weight in pounds per square yard or kilograms per square metre.

14. Precision and Bias

14.1 This test method has been in use for many years, but no information has been presented to ASTM upon which to base a statement of precision. No activity has been planned to develop such information.

14.2 This test method has no bias because the value for weight per unit area is determined solely in terms of this test method itself.

THREAD COUNT

15. Terminology

15.1 *Definitions of Terms Specific to This Standard:*

15.1.1 *threads per inch—of varnished cloths*, the count of the number of warp and filling yarns present in the base cloth per linear inch of width or length, respectively.

16. Significance and Use

16.1 Thread count, together with the weight and width of the cloth, is accepted as the common means for designating and identifying cloth constructions.

16.2 Certain of the physical and electrical properties of woven fabrics are dependent on thread count. That is, assuming the same size of yarn, an increase in thread count increases the weight, breaking strength, and density of the cloth. Also, the dielectric breakdown voltage and the dissipation factor of the varnished fabric may be changed by altering the thread count of the cloth.

17. Procedure

17.1 Determine separately the warp and filling threads per inch of cloth by counting in a space of not less than 1 in. (25.4 mm) in at least five different places on the specimen. The average of the five determinations shall be the thread count.

18. Report

18.1 Report the warp count and the filling count separately as threads per inch (or millimetre).

NOTE 5—The warp threads in straight-cut materials are the threads that are parallel with the length or machine-direction dimension, while in bias-cut materials the warp threads are parallel with the seams or jointed selvages.

NOTE 6—Before counting black varnished materials it will be necessary to remove the varnish film with a knife blade or other suitable instrument. Liquid varnish removers are unsuitable for this purpose as they may cause a swelling of the fibers and a shrinkage of cloth with a consequent increase in threads per inch count; therefore, the films must be removed mechanically.

19. Precision and Bias

19.1 This test method has been in use for many years, but no information has been presented to ASTM upon which to base a statement of precision. No activity has been planned to develop such information.

19.2 This test method has no bias because the value for thread count is determined solely in terms of this test method itself.

BREAKING STRENGTH

20. Significance and Use

20.1 The breaking strength of finished cloth and tape is of importance as a measure of its ability to withstand reasonable pulling without failure while being applied.

21. Apparatus

21.1 Testing machines of the dead-weight pendulum or of the constant-rate-of-elongation types shall be used, the latter being preferred.

21.2 The machine shall be graduated to read 0.5 kg or 1 lb, or less per scale division for testing specimens breaking at 50 lb (22.7 kg) or over, and to 0.25 kg, or 0.5 lb, or less for testing specimens breaking under 50 lb.

22. Test Specimens

22.1 Cut test specimens 1 in. (25.4 mm) in width and not less than 12 in. (305 mm) in length from full-width cloth or from tapes over 1 in. (25.4 mm) in width. In the case of tapes having a nominal width of 1 in. (25.4 mm) or less, prepare test specimens not less than 12 in. (305 mm) long using the original width.

NOTE 7—If it is desired to test the seams or jointed selvages of bias-cut materials for breaking strength, mount specimens obtained as described in Note 4, (4.2) in the testing machine so that the seams or jointed selvages are midway between the two jaws.

23. Number of Specimens

23.1 In the case of straight-cut cloths, cut five specimens in the direction of the warp threads and five in the direction of the filling threads from samples selected in accordance with 4.1 and 4.2.

23.2 In the case of bias-cut cloths, cut five specimens in the direction of the length from samples selected in accordance with 4.1 and 4.2.

23.3 In the case of tapes, cut five specimens from each roll selected in accordance with 4.1 and 4.2.

24. Conditioning

24.1 Condition specimens in accordance with Section 5.

25. Procedure

25.1 Adjust the clearance distance between jaws to be 6 in. (150 mm).

25.2 Select the rate of travel of the movable jaw to be constant and preferably 12 in. (305 mm)/min, but it may be within the limits of 11 and 13 in. (280 and 330 mm)/min, provided it is constant.

25.3 Reject all readings obtained when the specimens break at or in the jaws.

26. Report

26.1 Report the following information:

26.1.1 The average, maximum, and minimum breaking loads in kilograms or pounds, together with the width of the specimens and the nominal thickness, and

26.1.2 The relative humidity and temperature during the conditioning period, and at the time of the test.

26.2 In the case of straight-cut cloths, report the breaking strength of the warp threads and the filling threads separately.

27. Precision and Bias

27.1 This test method has been in use for many years, but no information has been presented to ASTM upon which to base a statement of precision. No activity has been planned to develop such information.

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

TEAR RESISTANCE

28. Significance and Use

28.1 The results of the test are suitable for acceptance, product control, research, or referee testing and for measuring the resistance of the varnished cloth to tearing while being applied in service.

28.2 Tear resistance of varnished cloth is influenced by the construction of the base cloth and the direction of tear, and the cure of the varnish.

28.3 This test method is applicable only to straight-cut varnished cloth and to tapes not less than 2¼ in. (64 mm) wide.

29. Apparatus

29.1 Conduct tests using a machine of the pendulum-impulse type as described in Test Method D 689.

30. Test Specimens

30.1 Prepare test specimens as follows from full-width cloth:

30.1.1 *Warp Threads*—Cut five specimens, 4 by 2½ in. (102 by 63.5 mm), so that the 4-in. length is parallel to the selvage edge.

30.1.2 *Filler Thread*—Cut five specimens, 4 in. by 2½ in. (102 by 63.5 mm), so that the 4-in. length is perpendicular to the selvage edge.

30.2 Cut two slits, ¹⁄₁₆ in. (1 mm) long and ¼ in. (6 mm) apart, equidistant from the center of the free side (the side not clamped in the jaws) in each specimen so that the end of the tear will fall between the two slits.

NOTE 8—Slits are cut into specimens to produce discontinuity of the outer fibers so that during the test the outer fibers unravel freely to avoid abnormal values.

31. Conditioning

31.1 Condition test specimens in accordance with Section 5.

32. Procedure

32.1 Determine the tear resistance in accordance with Test Method D 689. Place test specimens cut in accordance with Section 30, in the jaws with the longer length parallel to the jaws and the two slits on the opposite long side not clamped in the jaws. Obtain warp tears by tearing across warp direction threads and filler tears by tearing across filler direction threads.

NOTE 9—Discard test values where the end of the tear does not fall between the two slits.

33. Report

33.1 Report the following:

33.1.1 The average, minimum, and maximum tear resistance in grams, separately for warp and filler threads,

33.1.2 The nominal thickness, and

33.1.3 The relative humidity and temperature during conditioning and at the time of test.

34. Precision and Bias

34.1 This test method has been in use for many years, but no information has been presented to ASTM upon which to base a statement of precision. No activity has been planned to develop such information.

34.2 This test method has no bias because the value for tear resistance is determined solely in terms of this test method itself.

ELONGATION

35. Significance and Use

35.1 Elongation of a varnished cloth or tape insulation is important as a measure of the degree to which the insulation will conform to the contours of even and uneven surfaces without damaging the varnish film. Tapes that do not have sufficient elongation may be difficult to apply satisfactorily, whereas too much elongation may destroy the varnish film and thereby cause a decrease in its dielectric breakdown voltage.

36. Apparatus

36.1 The apparatus shall consist of a pair of clamps for gripping the ends of the specimen. The clamps shall be not less than 2 in. (50 mm) in width, and one shall be provided with a means for attaching to a fixed support and the other with means for affixing suspended weights. A suggested form of clamp is shown in Fig. 1.

37. Test Specimens

37.1 In the case of bias-cut cloth, cut test specimens not greater than 1.5 in. (38 mm) in width and in the direction of the length from the samples selected in accordance with 4.1 and 4.2.

37.2 In the case of straight-cut cloth, cut test specimens not greater than 1.5 in. (38 mm) in width and parallel to the warp yarns from samples selected in accordance with 4.1 and 4.2.

37.3 In the case of straight-cut and bias-cut tapes, cut test specimens not greater than 1.5 in. (38 mm) in width parallel to the slit edge from samples selected in accordance with 4.1 and 4.2. In the case of tapes of width greater than 1.5 in. (38 mm), cut test specimens therefrom to a width 1.5 in. (38 mm).

38. Conditioning

38.1 Condition test specimens in accordance with Section 5.

39. Procedure

39.1 Mark a gage length of 20 in. (508 mm) on the test specimen (Note 10) and fasten the specimen between two suitable clamps so that the gage length is centrally located

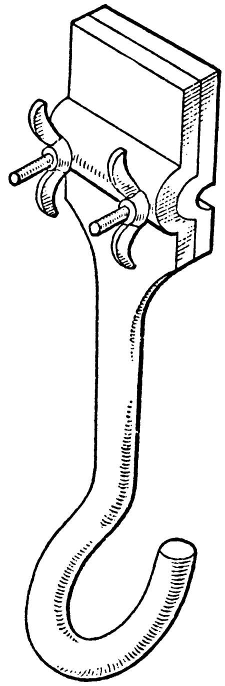

FIG. 1 Clamp for Elongation Test

between the clamps. The clearance distance between each gage line and the adjacent clamp shall be not less than 4 in. (100 mm).

NOTE 10—Strips of pressure-sensitive tape can be satisfactorily employed in marking the gage length on the elongation test specimen.

39.2 Weight the specimen with a specified load (including the weight of the clamp) for a period of 35 min for loadings of 10 lb/in. (18 kg/m) of width, and for a period of 3 min for loadings of 20 lb/in. (36 kg/m), or more, of width. At the end of the loading period measure the distance corresponding to the length between the gage lines in the elongated state before the load is removed.

40. Calculation

40.1 Calculate the percentage elongation as follows:

$$\text{Elongation, \%} = [(L_2 - L_1)/L_1] \times 100 \quad (1)$$

where:

L_1 = distance between gage lines before test, and
L_2 = distance between gage lines at the end of the test.

41. Report

41.1 Report the following information:

41.1.1 Load in pounds per inch width or kilograms per centimetre width of tape,

41.1.2 Percentage elongation, and

41.1.3 Relative humidity and temperature during the conditioning period and at the time of test.

42. Precision and Bias

42.1 This test method has been in use for many years, but no information has been presented to ASTM upon which to base a statement of precision. No activity has been planned to develop such information.

42.2 This test method has no bias because the value for elongation is determined solely in terms of this test method itself.

DIELECTRIC BREAKDOWN VOLTAGE

43. Significance and Use

43.1 Dielectric breakdown voltage of varnish cloth or tape insulating material is of significance for the following reasons:

43.1.1 This test indicates the presence of defects in the cloth or varnish in the part of the surface explored.

43.1.2 Four methods of testing for dielectric breakdown voltage are given: the short-time, step-by-step, slow-rate-of-rise, and the long-time voltage tests. Choice of the method should be based on whether the effect of time under stress is considered an important factor and the available time that can be allowed for each test.

NOTE 11—For a more detailed discussion of the significance of the dielectric breakdown voltage test, consult the general statements in Appendix X1 of Test Method D 149.

44. Short-Time, Step-by-Step, and Slow-Rate-of-Rise Tests

44.1 *Apparatus*—Select electrodes having a diameter of ¼ in. (6.35 mm), as described in Table 1 of Test Method D 149 for testing both cloths and tapes. Clamp the test specimen under pressure, using gaskets around the electrodes, in order to prevent flashover around the edges of the material. Two forms of electrode holders are described in the appendix.

44.2 *Test Specimens*:

44.2.1 In the case of cloths, cut specimens 1 in. (25.4 mm) wide across the entire width of the cloth. In the case of bias-cut cloths, exclude the seams or jointed selvages from the area of test.

44.2.2 In the case of tapes or strips, remove the specimens from a sample selected in accordance with 4.1 and 4.2.

44.3 *Conditioning*—Condition specimens in accordance with Section 5.

44.4 **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 in 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.*

44.5 *Procedure*:

44.5.1 Determine the dielectric breakdown voltage in accordance with Test Method D 149, except as specified in 44.1 to 44.6.

44.5.2 Test in air unless otherwise specified.

44.5.3 Test by either the short-time test, or by the step-by-step test or its alternative, the slow-rate-of-rise test, or by both methods, at room temperature or at 85°C (185°F) as specified.

44.5.4 In the short-time test, increase the voltage from zero at a rate of 0.5 kV/s.

44.5.5 In the step-by-step test and slow-rate-of-rise tests, increase the voltage rapidly from zero to 850 V per mil of average thickness for room temperature tests and to 600 V per mil of average thickness for 85°C (185°F) tests.

NOTE 12—In the case of materials failing to meet the starting voltages prescribed, test using the short-time test only.

44.5.6 In tests made by the step-by-step procedure, increase the applied voltage by the following increments after each 20 s of duration.

Nominal Thickness of Tape, mils	Increment, V
8 or less	250
Over 8	500

Adjust the starting voltage to the nearest even 250 or 500 V depending on the increment of increase.

44.5.7 In tests made by the slow-rate-of-rise method, increase the voltage as follows:

Nominal Thickness of Tape, mils	Rate of Rise, V/s
8 or less	12.5
Over 8	25

44.5.8 Unless otherwise specified, make ten voltage breakdown measurements equally spaced along the length of each specimen.

44.6 *Report:*

44.6.1 Report the following information:

44.6.1.1 The test procedure used,

44.6.1.2 The average thickness reported in 9.1,

44.6.1.3 The average breakdown voltage in kV,

44.6.1.4 The temperature and relative humidity at the time of test, and

44.6.1.5 The conditioning of the test specimen.

45. Long-Time Tests

45.1 *Test Specimens and Apparatus*:

45.1.1 Prepare test specimens by wrapping the material in tape form with one-quarter lap, one-half lap, or butt-jointed, or in sheet form, on brass tubes. For sheets and for tapes up to 1½ in. (38 mm) in width, use tubes 36 in. (910 mm) in length and 1 in. (25 mm) in outside diameter. For tapes wider than 1½ in. use tubes 2 in. (51 mm) in outside diameter. Build up specimens to the desired thickness, to simulate practical conditions, winding all layers of tape in the same direction.

45.1.2 Smoothly apply a layer of metal foil over the insulation for a distance of 24 in. (610 mm), leaving 6 in. (150 mm) of insulation uncovered at each end of the tube. Bind the metal foil in place with a wrapping of adhesive tape which shall extend the full length of the tube in order to protect insulation at the end from corona discharge.

45.1.3 Mount a thermocouple centrally on the metal foil and secure using adhesive tape.

45.2 *Procedure*:

45.2.1 Mount the specimen in an air oven and maintain the temperature at 100°C (212°F) during the test. Make provision for mounting the specimen so that the tube may be connected to the high-voltage side of the circuit with the foil sheath and the thermocouple both connected to ground. Where advisable or desired, alternatively immerse the test specimen in oil at the specified temperature instead of mounting in an oven.

45.2.2 Apply a voltage equal to 10 % of the breakdown voltage (to the nearest 1 kV) obtained in the short-time test and maintain it for 30 min. Then increase the voltage by steps of 20 % of the initial value until puncture occurs, the voltage being held at each step for 30 min.

45.2.3 Observe the temperature of the specimen as indicated by the thermocouple at intervals during the test and record the readings at the end of each 30-min period. It will be found that the temperature increases rapidly. During this latter period, record the temperature readings at frequent intervals.

45.3 *Report*:

45.3.1 Report the following information:

45.3.1.1 Details of the test specimen, including its preparation, thickness of insulation, and the number of layers of insulation,

45.3.1.2 The test ambient, whether air or oil,

45.3.1.3 A plot showing the time as the abscissa and the specimen temperature as the ordinate, on which is superimposed a plot showing the initially-applied voltage and its changing value as ordinates, and

45.3.1.4 The duration of the test, the breakdown voltage in kV, the temperature of the specimen at breakdown, and the overall rate of rise of temperature during the test, all taken from the plot of 45.3.1.3.

46. Precision and Bias

46.1 This test method has been in use for many years, but no information has been presented to ASTM upon which to base a statement of precision. No activity has been planned to develop such information.

46.2 This test method has no bias because the value for dielectric breakdown voltage is determined solely in terms of this test method itself.

DIELECTRIC BREAKDOWN VOLTAGE UNDER ELONGATION

NOTE 13—This test is not applicable to varnished bias tapes of less than 0.75 in. (19 mm) in nominal width.

47. Significance and Use

47.1 Varnished bias tape is elongated during normal application as an insulating material, resulting in a weave-shift of the base fabric with a triaxial distortion of the varnish impregnant and coating. This distortion is accompanied by a noticeable reduction in its voltage breakdown level as a result of strain in the insulating film or rupture of the dielectric barrier. This test serves to establish a quality definition of type, a check on production quality, and storage history of approved types.

48. Apparatus

48.1 The apparatus shall consist of a pair of clamps for gripping the ends of the specimens and some suitable means of securing the clamps so that they can be pulled away from each other at an approximately uniform rate. For this purpose, a hand- or motor-operated pulling outfit or a tension testing machine of suitable range may be used.

48.2 A special form of dielectric breakdown voltage tester, as described in 44.1 shall be used for making breakdown voltage tests. The tester shall be arranged to receive the test specimens while the latter are held in the stretched condition. Where a special pulling outfit is used, this may be so set up that the tape is pulled through the separated electrode blocks of the tester. When a tension testing machine is used, it may be more convenient to transfer the test specimen, while under tension, to a special frame which may be readily inserted into the tester.

49. Test Specimens

49.1 Prepare test specimens as described in Section 37.

50. Conditioning

50.1 Condition test specimens in accordance with Section 5.

51. Procedure

51.1 **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 in 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.*

51.2 Mark a gage length of 20 in. (510 mm) on the test specimen between the clamps, and mount the specimens centrally so that the ends of the gage length are not closer than 4 in. (100 mm) to the clamps.

51.3 Separate the clamps at a rate of approximately 2 in. (5 mm)/min until the tape has been elongated to a prescribed value. After this elongation has been reached, maintain it for 5 min and make five voltage breakdown tests by the short-time method described in Section 44. Distribute the five tests uniformly along the gage length, and complete them in not more than 10 min of elapsed time. The dielectric breakdown voltage under elongation shall be the average of the values of the five tests.

NOTE 14—If desired, calculate the dielectric strength by dividing the average breakdown voltage under elongation by the average thickness of the specimens while the specimens are elongated, and express the result as volts per mil.

52. Report

52.1 Report the following information:

52.1.1 Average dielectric breakdown voltage in kilovolts on the elongated material,

52.1.2 Percentage elongation during the test,

52.1.3 Relative humidity and temperature during the conditioning period and at the time of test, and

52.1.4 Specimen thickness in mils before and under elongation.

53. Precision and Bias

53.1 This test method has been in use for many years, but no information has been presented to ASTM upon which to base a statement of precision. No activity has been planned to develop such information.

53.2 This test method has no bias because the value for dielectric breakdown voltage under elongation is determined solely in terms of this test method itself.

DISSIPATION FACTOR AND PERMITTIVITY

54. Significance and Use

54.1 The dissipation factor test on varnished cloths and tapes is a nondestructive test. It is helpful in determining indications of product uniformity, moisture absorption, and changes in composition. The dissipation factor and permittivity determine the dielectric-loss characteristic of the material, which is of extreme importance when it is used as high-voltage insulation.

54.2 The dissipation factor test may be used for a specification acceptance test, factory control, research, or in connection with referee testing.

54.3 Permittivity is significant in that it has a direct bearing on both capacitance and the dielectric power loss of the system.

55. Electrodes

55.1 Select flat, rigid, guarded electrodes, of not over 10 in.^{2} (6500 mm^2) in area and of such size as to give the bridge sensitivity sufficient to detect readily a change in dissipation factor of 0.0005.

NOTE 15—Guarded-foil electrodes as described in Test Methods D 150 have been found suitable for measurements at room temperature.

56. Test Specimens

56.1 Prepare test specimen of any representative thickness and of such size as to extend beyond the guard electrode for a distance of at least four times the thickness of the specimen. In order to avoid ionization during the test measurement, apply a light coating of petrolatum having a dissipation factor of not more than 0.02 at 60 Hz and 80°C (176°F), or a resistivity not less than 10^{12} $\Omega \cdot$ cm at 80°C.

57. Conditioning

57.1 Condition the test specimens by one of the following methods:

57.1.1 When the greatest reproducibility of results is desired, heat the test specimens to 105 $\pm$ 3°C for 1 h without vacuum and then for 2 h at 105 $\pm$ 3°C in a vacuum having an absolute pressure not exceeding 1 torr.

57.1.2 Where the vacuum treatment is not feasible or where tests in the as-received condition are desired, or where an approximation to some conditions of use is desired, the test specimens shall be conditioned in accordance with Section 5.

57.1.3 In the event of a dispute, select the vacuum method (57.1.1) as the referee procedure.

58. Procedure

58.1 **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 in 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.*

58.2 As soon as practicable, but not later than 5 min after removal from conditioning, apply electrodes to the test specimens under a continuing pressure of not less than 10 psi (69 kPa) nor more than 20 psi (137 kPa). Apply an ac voltage across the specimen corresponding to 50 ± 5 V per mil (2 ± 0.2 kV per mm) of average thickness. Measure the dissipation factor and capacitance in accordance with the procedures described in Test Methods D 150. Compute the permittivity using the measured average thickness of each test specimen.

58.3 Conduct measurements on three specimens at one or more of the following temperatures: 23 ± 1°C, 80 ± 1°C or 100 ± 1°C, averaging the values obtained.

59. Report

59.1 Report the following information:

59.1.1 *Test Conditions*—The frequency in hertz, the temperature in degrees Celsius, the conditioning of the specimens, the size of the electrodes, the pressure on the electrodes, and the voltage gradient in the dielectric while under test.

59.1.2 *Test Specimens*—Capacitance of the specimens in picofarads, effective area of specimen electrodes, and the average thickness of specimens between electrodes.

59.1.3 Dissipation factor, permittivity, and loss index of each specimen and their average.

59.1.4 Method of measurement.

60. Precision and Bias

60.1 This test method has been in use for many years, but no information has been presented to ASTM upon which to base a statement of precision. No activity has been planned to develop such information.

60.2 This test method has no bias because the value for dissipation factor and permittivity is determined solely in terms of this test method itself.

VOLUME RESISTANCE

61. Significance and Use

61.1 The volume resistance test on varnished cloths and tapes is a nondestructive test. This test is useful in quality control, and to supplement the data derived from dissipation factor measurements.

62. Electrodes

62.1 The same type of electrodes used for dissipation factor measurements are suitable for resistance tests. In particular, the electrodes described in 55.1 are recommended for testing tapes. The total area of the measuring electrode should, however, be sufficiently large to obtain accurate readings with the particular resistance-measuring apparatus available. Electrodes of the type shown in Fig. 4 of Test Methods D 257, are also generally applicable to sheet materials.

63. Test Specimens

63.1 Prepare test specimens of any representative thickness and of such size to extend beyond the guard electrode for a distance of not less than four times the thickness of the specimen.

63.2 Where interest centers about the behavior of the insulation as a composite, prepare test specimens of two thicknesses of material plied using an appropriate and suitable slipper compound as adhesive.

64. Conditioning

64.1 Condition test specimens in accordance with Section 57.

65. Procedure

65.1 **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 in 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.*

65.2 As soon as practicable, but not later than 5 min after removal from conditioning, apply electrodes to the test specimen under a continuing pressure of not less than 10 psi (69 kPa) nor more than 20 psi (137 kPa). Impress a dc voltage across the specimen corresponding to not less than 10 V per mil (4 kV per mm) nor more than 50 V per mil (20 kV per mm). Maintain the impressed voltage for a period of 60 s. Measure the resistance in accordance with the procedure described in Test Methods D 257.

65.3 Conduct tests at 20 to 30°C (68 to 86°F) (room temperature) and at 80 ± 1°C (176 ± 2°F) on three specimens and average the values obtained.

66. Report

66.1 Report the following information:

66.1.1 The average direct voltage gradients in the dielectric under test, time of application of voltage, size of electrodes, pressure on specimen, form of the dielectric (whether one or two layers with or without compound), temperature in degrees Celsius, relative humidity in percent, and conditioning of the specimens,

66.1.2 Effective area of the specimen electrodes, and average total thickness of specimen between electrodes,

66.1.3 Volume resistance and calculated volume resistivity of each specimen and the average for all specimens, and

66.1.4 Method of measurement.

67. Precision and Bias

67.1 This test method has been in use for many years, but no information has been presented to ASTM upon which to base a statement of precision. No activity has been planned to develop such information.

67.2 This test method has no bias because the value for volume resistance is determined solely in terms of this test method itself.

RESISTANCE TO OIL

68. Significance and Use

68.1 The oil resistance of varnished cloth or tape determines the suitability of the insulation for use in oil-immersed apparatus, such as oil-filled transformers and switches, and in electric cables and cable splices. It also serves to indicate serviceability in proximity to lubricating oils. Such oils, however, usually have very little effect on a varnish film compared with transformer oils.

68.2 When immersed in oil, black varnish films usually soften and swell slightly, but may blister, wrinkle, or separate from the base fabric. Yellow varnish films are more oil-resistant and soften or swell very little, if at all. Measurement of dielectric breakdown voltage after oil immersion serves to indicate any deleterious permanent effects caused by the oil.

69. Test Specimens

69.1 Prepare one test specimen 12 in. (305 mm) long and not exceeding 1.5 in. (38 mm) in width from the material selected in accordance with Section 4.

70. Procedure

70.1 Immerse the specimens for 15 min in a specified oil maintained at 100 ± 3°C (212 ± 5°F). At the end of this time, remove the specimens from the oil, allow to cool for at least 30 min at room temperature, and remove excess oil by placing the specimens between blotters without any sliding.

70.2 Examine the varnish film for disintegration in the oil and flaking either in the oil or on the blotter. Disintegration in the oil may be detected by examination of the used oil for turbidity.

NOTE 16—The oil may be considered turbid if a sample of used oil filtered through filter paper is distinctly less transparent than an unfiltered sample of the unused oil when the two samples, in identical containers, are held in front of a diffused light. Flaking along the cut edges of tapes shall not be considered as disintegration of the varnish film.

71. Dielectric Breakdown Voltage

71.1 Determine the breakdown voltage at five points on the cooled specimen at any time within 4 h after removal from the oil, using the short-time test in accordance with Section 44.

NOTE 17—If desired, calculate the dielectric strength of the oil-immersed specimen by dividing the average voltage breakdown by the average thickness taken immediately after the breakdown test.

72. Report

72.1 Report the following information:

72.1.1 Type of oil used (preferably including the flash point as determined in accordance with Test Method D 92),

72.1.2 Temperature of the oil,

72.1.3 Results of physical examination of the film (70.2),

72.1.4 Percentage increase in average thickness due to oil immersion, and

72.1.5 Average dielectric breakdown voltage after the oil test.

73. Precision and Bias

73.1 This test method has been in use for many years, but no information has been presented to ASTM upon which to base a statement of precision. No activity has been planned to develop such information.

73.2 This test method has no bias because the value for resistance to oil is determined solely in terms of this test method itself.

74. Keywords

74.1 breaking strength; dielectric breakdown voltage; dissipation factor; permittivity; tear resistance (internal); thread count; varnished cotton fabric; volume resistance

APPENDIX

(Nonmandatory Information)

X1. APPARATUS FOR MAKING DIELECTRIC BREAKDOWN VOLTAGE TESTS ON INSULATING TAPE

X1.1 Single-Shot Tester

X1.1.1 Fig. X1.1 illustrates a single-shot tester for making dielectric breakdown voltage tests on insulating tape. In this device the tape is held under pressure between rubber washers while the voltage is applied, the pressure being supplied by compressed air operating on a piston *b* in a cylinder *a*. The piston is connected to the upper electrode *c*. The lower electrode *c′* is mounted on the insulated base. The electrodes terminate in ¼-in. (6.35-mm) brass rods having flat ends with edges rounded to a radius of 1⁄32 in. (0.79 mm). These electrode rods move against light springs. This ensures a positive contact between electrode and tape. The electrode rods are surrounded by insulating blocks *d* and *d′* having vent holes *h* for the dissipation of the gases generated by breakdown. These insulating blocks are faced with soft rubber washers *e* which can be detached and replaced as necessary.

X1.1.2 The lower electrode assembly is lined up with the upper electrode assembly by centering springs *j*, the position of which is adjustable. This lower assembly is also free to rock very slightly on a single ball support. This ensures perfect contact and equalization of pressure when the electrode assemblies come together.

X1.1.3 The upper electrode assembly is normally held clear of the lower assembly by two small springs so that tape may be readily inserted or withdrawn or moved to a new position of test. The piston *b* is smooth, without rings, and permits just enough leakage of air so that the pressure may be quickly adjusted and readily held at any desired value below the maximum available.

X1.1.4 Where compressed air is not available, pressure may be exerted by a hand-operated lever attached to the upper, or movable, electrode assembly.

X1.2 Multiple-Electrode Tester

X1.2.1 In another form of tester equipped with ten spaced opposing electrodes, a length of tape can be clamped under pressure and dielectric breakdown tests conducted sequentially and at intervals along the tape.

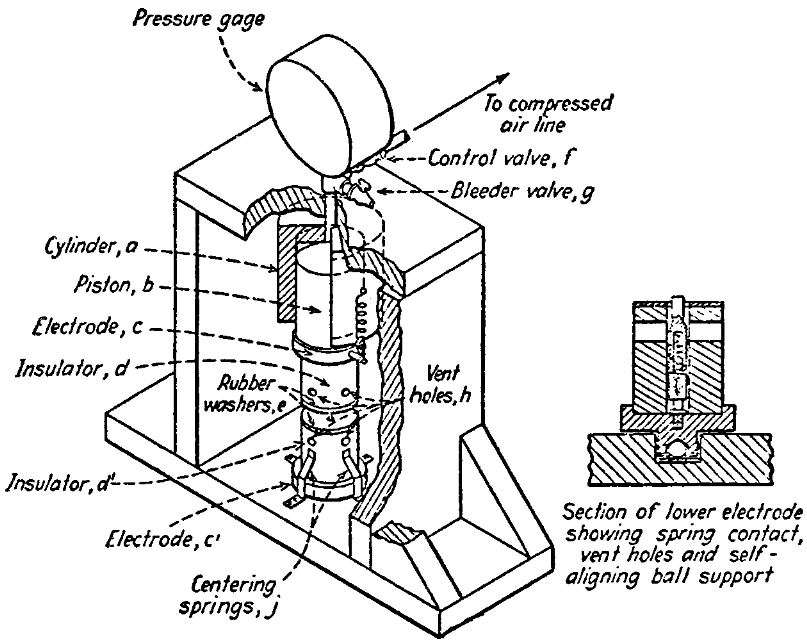

FIG. X1.1 Single-Shot Tester for Dielectric Breakdown Voltage Test on Insulating Tape