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An American National Standard

Standard Test Methods for Thin Thermally Conductive Solid Materials for Electrical Insulation and Dielectric Applications[1]

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1. Scope

1.1 This standard is a compilation of test methods for evaluating properties of thermally conductive electrical insulation sheet materials to be used for dielectric applications.

1.2 Such materials are thin, compliant sheets, typically produced by mixing thermally conductive particulate fillers with organic or silicone binders. For added physical strength these materials are often reinforced with a woven or nonwoven fabric or a dielectric film.

1.3 These test methods apply to thermally conductive sheet material ranging from about 0.02 to 6-mm thickness.

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.* See also 18.1.2 and 19.1.2.

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

NOTE 1—There is no IEC publication or ISO standard equivalent to this standard.

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 Insulating Materials[2]

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

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

D 412 Test Methods for Vulcanized Rubber and Thermoplastic Rubbers and Thermoplastic Elastomers—Tension[3]

D 624 Test Method for Tear Strength of Conventional Vulcanized Rubber and Thermoplastic Elastomers[3]

D 792 Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement[4]

D 883 Terminology Relating to Plastics[4]

D 1000 Test Methods for Pressure-Sensitive Adhesive-Coated Tapes Used for Electrical and Electronic Applications[2]

D 1458 Test Methods for Fully Cured Silicone Rubber-Coated Glass Fabric and Tapes for Electrical Insulation[2]

D 1711 Terminology Relating to Electrical Insulation[2]

D 2240 Test Method for Rubber Property—Durometer Hardness[3]

D 5470 Test Method for Thermal Transmission Properties of Thin Thermally Conductive Solid Electrical Insulation Materials[5]

D 6054 Practice for Conditioning Electrical Insulating Materials for Testing[5]

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *apparent thermal conductivity, n*—the time rate of heat flow, under steady conditions, through unit area, per unit temperature gradient in the direction perpendicular to the area, for a nonhomogeneous material.

3.1.1.1 See 16.1 for a discussion of the terms *thermal conductivity* and *apparent thermal conductivity*. To avoid confusion, these test methods use *apparent thermal conductivity* for measurements of homogeneous and nonhomogeneous materials.

[1] These test methods are under the jurisdiction of ASTM Committee D-9 on Electrical and Electronic Insulating Materials and are the direct responsibility of Subcommittee D09.19 on Dielectric Sheet and Roll Products.

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

[3] *Annual Book of ASTM Standards*, Vol 09.01.

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

[5] *Annual Book of ASTM Standards*, Vol 10.02.

3.1.2 See Terminologies D 1711 and D 883 for definitions of other terms used in these test methods.

4. Significance and Use

4.1 These test methods are useful to determine compliance of thermally conductive sheet electrical insulation with specification requirements established jointly by a producer and a user.

4.2 These test methods have been found useful for quality assessment. Results of the test methods can be useful in apparatus design.

5. Specimen Preparation

5.1 From a sample of sufficient size, prepare test specimens of the dimensions and of the quantity to meet the requirements for each test procedure.

6. Conditioning

6.1 Unless otherwise specified, condition specimens in accordance with Procedure A of Practice D 6054. Perform all tests on specimens that are in equilibrium with the conditions of Procedure A of Practice D 6054. Make the tests in a chamber maintained at 23 ± 2°C and 50 ± 5 % relative humidity.

6.2 When required by a test procedure, condition specimens in accordance with Procedure D of Practice D 6054 except that either distilled or deionized water may be used. In such cases, remove the specimens from the water into air maintained at 23 ± 2°C and 50 ± 5 % relative humidity, remove surface water with a paper towel, and begin testing within 30 s.

7. Precision and Bias

7.1 No evaluation of precision or bias has been established for the test methods herein as they relate to these thin thermally conductive materials. For general guidance only, reference may be made to Precision and Bias statements in the referenced test methods as listed in Section 2.

8. Thickness

8.1 *Significance and Use*—The accurate determination of thickness is essential for design purposes for both thermal conduction and electrical insulation. Thickness enters into the calculation of thermal, electrical, and tensile properties.

8.2 *Procedure*:

8.2.1 Make thickness measurements on specimens in accordance with Test Methods D 374M, Method H. This test method uses a micrometer which applies a pressure of 26 ± 4 kPa on the specimen, using a 6.25-mm diameter presser foot.

8.2.2 Clean the surfaces where the measurements are to be made. Take five randomly spaced measurements to cover the length and width of the specimen. Take measurements at least 6 mm from the edges of the specimen.

NOTE 2—At the compressive loads of this test method, some materials will undergo compression or compression deflection. The buyer and the seller may wish to agree on other conditions of pressure, anvil and presser foot geometry, and the dwell time to be used.

8.3 *Report*—Report the thickness in millimetres as the average of the five measurements.

9. Adhesion Strength

9.1 *Significance and Use*—Materials covered by this test method are optionally coated with a pressure sensitive adhesive on one or both sides. In some cases performance in a particular application can be affected by the adhesion strength.

9.2 *Procedure*—Test three specimens of 25-mm width in accordance with Test Methods D 1000 except, clean the steel panel with isopropyl alcohol.

9.3 *Calculation*—From the 3 specimens, calculate the average adhesion strength.

9.4 *Report*—Report the average adhesion strength in newtons per metre of width.

10. Breaking Strength

10.1 *Significance and Use*—Breaking strength can be a significant limitation on methods of applying tapes. Hence it may be important to measure the tensile force they can withstand.

10.2 *Procedure*:

10.2.1 Prepare three specimens at least 500 mm long and 25 mm wide. If the material contains reinforcing fibers, cut the test specimen such that the machine direction reinforcing fibers are parallel to the long axis of the specimen. In the case of materials narrower than 25 mm, test the full width as received.

10.2.2 Test the breaking strength in accordance with Test Methods D 1458.

10.3 *Calculation*—From the test measurements on the 3 specimens, calculate the average breaking strength.

10.4 *Report*—Report the average breaking strength in newtons per metre of width.

11. Tensile Strength and Elongation

11.1 *Significance and Use*—Tensile test results with these materials will vary with specimen geometry and conditions of testing. Hence, these tensile measurements are not always reliable indicators of usefulness in a particular application. Tensile properties of glass-fiber-reinforced materials vary with the ratio of the glass-fiber thickness to the total thickness. Measurements of tensile properties vary with the direction of the glass fibers with respect to the direction in which the specimen is cut.

11.2 *Procedure*:

11.2.1 Prepare three specimens in accordance with Test Methods D 412 using Die C.

11.2.2 If the material contains reinforcing fibers, cut the test specimen such that any reinforcing fibers are at 45 ± 10° to the long axis of the specimen.

11.2.3 In accordance with Test Methods D 412, measure the tensile breaking strength and tensile elongation at a jaw separation rate of 500 mm/min (20 in./min).

11.3 *Calculation*:

11.3.1 Calculate the tensile strength in kilopascals using the initial thickness and width for each specimen. Calculate the average tensile strength from the three test measurements.

11.3.2 Similarly, calculate each elongation at break as a percentage of the initial jaw separation. Calculate the average from the three test measurements.

11.4 *Report*—Report the average tensile strength in kilopascals and the average elongation in percent.

12. Hardness

12.1 *Significance and Use*—This test method is empirical and intended for control purposes only.

12.2 *Procedure*:

12.2.1 Prepare a sufficient number of specimens to form a stack approximately 6 mm high.

12.2.2 Determine the indentation hardness in accordance with Test Method D 2240 with the following exception:

12.2.2.1 Read the scale within 2 s after the presser foot is in firm contact with the specimen.

12.3 *Calculation*—From the five measurements taken at different locations on the specimen, calculate the average hardness.

12.4 *Report*—Report the average hardness in accordance with the Shore Hardness system.

13. Specific Gravity

13.1 *Significance and Use*—Specific gravity can be a useful tool to help verify proper filler loading and distribution. This value may also be required by designers of specific applications of these materials.

13.2 *Procedure*—Prepare two specimens of at least 650 mm^2 in area and test in accordance with Test Methods D 792, Method A-1.

13.3 *Report*—Report the average of the two test measurements as the specific gravity.

14. Tear Strength

14.1 *Significance and Use*:

14.1.1 In certain applications, these materials are stressed during installation in such a way as to introduce tearing stresses on the material. Tear strength measurements provide a means of comparing or specifying materials for such applications.

14.1.2 The type of reinforcement, testing rate, and specimen size affect the tear resistance. The results obtained by this test method are predictive of performance only under certain specific conditions of use.

14.2 *Procedure*:

14.2.1 Prepare three specimens using Die C of Test Method D 624.

14.2.2 If the material contains reinforcing fibers, cut the test specimen such that any reinforcing fibers are at 45 ± 10° to the long axis of the specimen (the "A" dimension of Die C).

14.2.3 Measure the tear strength in accordance with Test Methods D 412 using a jaw separation rate of 500 mm/min (20 in./min).

14.3 *Calculation*—Calculate the tear strength for each specimen by dividing the maximum force by the specimen thickness. Calculate the average from the three test measurements.

14.4 *Report*—Report the average tear strength in newtons per millimetre.

15. Thermal Impedance

15.1 *Significance and Use*—Thermal impedance measurements are affected by applied pressure, thickness, any surface irregularities, and uniformity of heat flow. Since the results obtained by these test methods represent thermal characteristics of a material under a specific set of conditions, it is not appropriate to use these results to predict performance in an application where conditions differ from those of the test.

15.2 *Procedure*:

15.2.1 Prepare specimens for two determinations as required by either Method A or Method B of Test Method D 5470.

15.2.2 Measure the thermal impedance in accordance with Test Method D 5470, using a pressure of 3.0 ± 0.1 MPa and an average specimen temperature of 50 ± 5°C.

15.3 *Calculation*—From the two determinations, calculate the average thermal impedance.

15.4 *Report*—Report the average thermal impedance in $(m^2 \cdot K)/W$ and the test method used.

16. Apparent Thermal Conductivity

16.1 *Significance and Use*—Thermal conductivity applies only to homogeneous materials. Thermally conductive electrically insulating materials are heterogeneous since they typically include ceramic fillers and elastomeric binders, and are often reinforced with glass fiber or a layer of dielectric film. Hence the term apparent thermal conductivity is more appropriate. Because of the multilayer nature of these products, the apparent thermal conductivity will vary with material thickness.

16.2 *Procedure*:

16.2.1 Prepare specimens in accordance with either Method A or Method B of Test Method D 5470.

16.2.2 In accordance with Test Methods D 5470, determine the thermal impedance of layered stacks using 1, 2, and 3 layers of specimens at 3 ± 0.1-MPa pressure. Use either Test Method A or Test Method B of Test Method D 5470.

16.3 *Calculation*—Calculate the apparent thermal conductivity from the slope of a plot of thermal impedance against specimen stack thickness.

16.4 *Report*—Report the apparent thermal conductivity in W/(m·K) and the test method used.

17. Permittivity and Dissipation Factor

17.1 *Significance and Use*—Test Methods D 150 discuss the significance of dielectric properties and dissipation factor.

17.2 *Procedure*—Prepare four specimens. Use 75-mm diameter conducting paint opposed electrodes. Test each specimen at 1 kHz in accordance with Test Methods D 150 in air at a temperature of 23 ± 2°C.

17.3 *Report*—Report the electrodes used, the individual values, and the average value of permittivity and dissipation factor for the four specimens.

18. Volume Resistivity

18.1 *Significance and Use*:

18.1.1 Volume resistivity is important in designing an insulator for a specific application. Volume resistivity is affected by humidity and temperature. The extent of change in volume resistivity needs to be considered in developing a design for a specific application.

18.1.2 **Warning**—*Lethal voltages are a potential hazard during the performance of this test. It is essential that the test* *apparatus, and all associated equipment electrically connected to it, be properly designed and installed for safe operation. Solidly ground all electrically conductive parts which it is possible for a person to contact 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 or have the potential for acquiring an induced charge during the test or retaining a charge even after disconnection of the voltage source. Thoroughly instruct all operators as to the correct procedures for performing tests safely. When making high voltage tests, particularly in compressed gas or in oil, it is possible for the energy released at breakdown to 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. If the potential for fire exists, have fire suppression equipment available.*

18.1.3 See also Significance and Use statement in Test Methods D 257.

18.2 *Procedure*:

18.2.1 Prepare specimens in accordance with D 257. It is recommended that flat plate, guarded, and heated electrodes be used. Use electrodes which are satisfactory for electrical resistance measurement on specimens in thermal equilibrium with any specific temperature between 20 and 150°C.

18.2.2 Condition specimens in accordance with Procedure A of Practice D 6054.

18.2.3 Condition additional specimens in accordance with Procedure D of Practice D 6054. See also 6.2.

18.2.4 For each condition, measure the electrical resistance of two specimens at 500 ± 5-V dc and 60-s electrification time using the procedures of Test Methods D 257. Use the thickness as determined in Section 8 for the calculation of electrical resistivity.

18.2.5 If the results of the tests differ by a factor of more than 10, test four additional specimens.

18.3 *Calculation*:

18.3.1 From the specimens conditioned in accordance with 18.2.2, calculate the median volume resistivity.

18.3.2 From the specimens conditioned in accordance with 18.2.3, calculate the median volume resistivity.

18.4 *Report*—Report the median, maximum, and minimum volume resistivity in ohm-centimetre for each condition.

19. Dielectric Breakdown Voltage

19.1 *Significance and Use*:

19.1.1 This test method provides useful information as to the suitability of a material for a particular application. Since the conditions under which a dielectric behaves in service often differ from test conditions, the results obtained by this test method are predictive of the performance only under certain specific conditions of use and are not appropriate for applications where conditions differ from those of the test method.

19.1.2 **Warning**—*Lethal voltages are a potential hazard during the performance of this test. It is essential that the test apparatus, and all associated equipment electrically connected to it, be properly designed and installed for safe operation. Solidly ground all electrically conductive parts which it is possible for a person to contact 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 or have the potential for acquiring an induced charge during the test or retaining a charge even after disconnection of the voltage source. Thoroughly instruct all operators as to the correct procedures for performing tests safely. When making high voltage tests, particularly in compressed gas or in oil, it is possible for the energy released at breakdown to 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. If the potential for fire exists, have fire suppression equipment available.*

19.1.3 See also Significance and Use statement in Test Method D 149.

19.2 *Procedure*:

19.2.1 Prepare 10 specimens of sufficient size to prevent flashover.

19.2.2 Condition five specimens in accordance with Procedure A of Practice D 6054.

19.2.3 Condition the other five specimens in accordance with Procedure D of D 6054.

19.2.3.1 Preparatory to testing, remove surface water from each specimen and begin testing within 30 s.

19.2.4 Make breakdown voltage tests and thickness measurements in accordance with Test Method D 149 with the following conditions:

19.2.4.1 Test in air at 23 ± 2°C.

19.2.4.2 Use Type I electrodes of Table 1.

19.2.4.3 Use Method A (Short-Time Test).

19.3 *Calculation*:

19.3.1 From the 5 specimens conditioned in accordance with 19.2.2, calculate the average breakdown voltage and average thickness.

19.3.2 From the 5 specimens conditioned in accordance with 19.2.3, calculate the average breakdown voltage and average thickness.

19.4 *Report*—Report the average, maximum, and minimum breakdown voltage and average thickness for each of the different conditioning procedures.

20. Keywords

20.1 adhesion; apparent thermal conductivity; breakdown voltage; breaking strength; dissipation factor; electrical insulation; hardness; permittivity; thermal conductivity; thermal impedance; thermally conductive; thermally conductive electrical insulation; thin electrical insulation