Designation: D349 – 13

Standard Test Methods for Laminated Round Rods Used for Electrical Insulation[1]

This standard is issued under the fixed designation D349; 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.

1. Scope*

1.1 These test methods cover the procedures for testing rigid round rods used in electrical insulation. These round rods include many types made from fibrous sheets of basic materials, such as cellulose, glass, or nylon in the form of paper, woven fabrics, or mats, bonded together by natural or synthetic resins, or by adhesives. Such round rods include vulcanized fiber and thermosetting laminates as well as round rods made from cast, molded, or extruded natural or synthetic resins, with or without fillers or reinforcing materials.

1.2 The procedures appear in the following sections:

	Section
Compressive strength (axial)	20 – 25
Density	28 – 30
Dielectric strength	31 – 39
Flexural strength	13 – 19
Tensile strength	7 – 12
Water absorption	26-27

1.3 The values stated in inch-pound units are to be regarded as the standard.

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 a specific warning statement see 36.2.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D149 Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials at Commercial Power Frequencies

D570 Test Method for Water Absorption of Plastics

D668 Test Methods of Measuring Dimensions of Rigid Rods and Tubes Used for Electrical Insulation

D792 Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement

D1711 Terminology Relating to Electrical Insulation

D6054 Practice for Conditioning Electrical Insulating Materials for Testing (Withdrawn 2012)[3]

3. Terminology

3.1 *Definitions*—Use Terminology D1711 for definitions of terms used in these test methods and associated with electrical or electronic insulation materials.

4. Selection of Test Specimens

4.1 Specimens for tests shall be selected from portions of material that are free of obvious defects unless the purpose of the test is to evaluate the effect of these defects.

5. Conditioning

5.1 In order to eliminate the effects of previous history of humidity exposure and to obtain reproducible results (Note 1), in all cases of dispute give the test specimens of laminated rods a conditioning treatment for physical test as follows:

5.1.1 *Tensile, Flexural, and Compressive Strengths, and Density*—Prior to test, condition the machined specimens in accordance with Procedure B of Practice D6054. All specimens shall be tested at room temperature maintained at 23 ± 5 °C.

NOTE 1—The following are potential reasons to undertake conditioning of specimens: (*a*) for the purpose of bringing the material into equilibrium with normal or average room conditions of 23 °C and 50 % relative humidity; (*b*) simply to obtain reproducible results, irrespective of previous history of exposure; or (*c*) to subject the material to abnormal conditions of temperature or humidity in order to predict its service behavior.

The conditions given here to obtain reproducible results will give physical values which could be somewhat higher or somewhat lower than values under equilibrium at normal conditions, depending upon the particular material and test. To ensure substantial equilibrium under normal conditions of humidity and temperature, however, will require from 20 to 100 days or more depending upon thickness and type of material and its previous history. Consequently, conditioning for reproducibility must of necessity be used for general purchase specifications and product control tests.

[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.

Current edition approved Nov. 1, 2013. Published November 2013. Originally approved in 1932. Last previous edition approved in 2007 as D349 – 07. DOI: 10.1520/D0349-13.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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

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

6. Dimensional Measurements

6.1 Make dimensional measurements of rods in accordance with Test Methods D668.

TENSILE STRENGTH

7. Significance and Use

7.1 This test method is designed to provide data for the control and specification of materials and for characterization purposes in research and development of new materials. It is possible that the tensile properties will vary with the size of specimens and the speed of testing. Consequently, these factors along with others noted herein must be controlled where precise comparative results are desired.

8. Apparatus

8.1 Any testing machine is acceptable for use provided it is accurate to 1 % of the lowest breaking force to be applied. Use jaws which tighten under load, such as wedge grip jaws, with the specimen properly aligned.

9. Test Specimens

9.1 Prepare the test specimen as shown in Fig. 1. The length, *L*, is as shown in Table 1. Machine a groove around the specimen at the center of its length so that the diameter of the machined portion is 60 % of the original nominal diameter. This groove consists of a straight section 2 ¼ in. (57 mm) in length with a radius of 3 in. (76 mm) at each end joining it to the outside diameter.

10. Procedure

10.1 Adjust the crosshead speed of the testing machine not to exceed 0.050 in. (1.27 mm)/min when running idle and test five specimens.

11. Report

11.1 Report the following information:

11.1.1 The average diameter of the specimen, expressed to the nearest 0.001 in. (0.0254 mm), determined from at least two measurements 90° apart,

11.1.2 The average diameter of the reduced section, expressed to the nearest 0.001 in. (0.025 mm), determined from at least two measurements 90° apart,

11.1.3 Crosshead speed in inches per minute (or millimetres).

11.1.4 The breaking load of each specimen in pounds-force (or newtons),

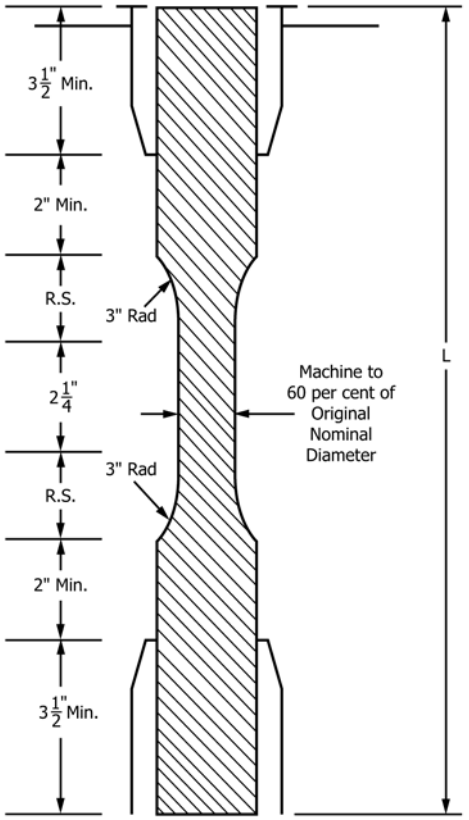
11.1.5 The tensile strength of each specimen in pounds-force per square inch, (or pascals), and

11.1.6 The room temperature in degrees Celsius.

12. Precision and Bias

12.1 *Precision*—This test method has been in use for many years, but no statement of precision has been available and no activity is planned to develop such a statement.

12.2 *Bias*—A statement of bias is not applicable in view of the lack of a standard reference material for this property.



Metric Equivalents

in.	mm
2	50.8
2¼	57.1
3	76.2
3½	88.9

FIG. 1 Diagram Showing Location of Rod Tension Test Specimen in Testing Machine

FLEXURAL STRENGTH

13. Significance and Use

13.1 Flexural strength data are useful for the control and specification of materials and to provide guidance in the design of electrical equipment. Flexural properties have the potential to vary with the size of the specimens and the speed of testing. Consequently, these factors, together with others noted herein, must be controlled where precise comparative results are desired.

14. Apparatus

14.1 Any testing machine is acceptable for use provided it is accurate to 1 % of the lowest breaking force to be applied.

15. Test Specimens

15.1 Prepare the test specimen with a diameter equal to that of the rod and a length eight times the diameter, plus 1 in. (25.4 mm) for rods under ½ in. (12.7 mm) in diameter. For rods over ½ in. and up to 2 in. (50.8 mm) in diameter, machine specimens to a diameter of ½ in. and cut to a length of 6 in. (152.4 mm).

TABLE 1 Dimensions of Rod Specimens

Nominal Diameter, in. (mm)	Length of Radial Sections 2 RS, in. (mm)	Total Calculated Minimum Length of Specimen, in. (mm)	Standard Length, *L*, of Specimen to be Used for 3 ½ in. (88.9 mm) Jaws[A]
⅛ (3.2)	0.773 (19.63)	14.02 (35.61)	15 (381.0)
3⁄16 (4.8)	0.946 (24.03)	14.20 (36.06)	15 (381.0)
¼ (6.4)	1.091 (27.71)	14.34 (36.42)	15 (381.0)
⅜ (9.5)	1.333 (33.86)	14.58 (37.03)	15 (381.0)
½ (12.7)	1.563 (38.01)	14.79 (37.56)	15.75 (400.0)
⅝ (15.9)	1.714 (43.56)	14.96 (37.99)	15.75 (400.0)
¾ (19.0)	1.813 (46.05)	15.12 (38.40)	15.75 (400.0)
⅞ (22.1)	2.019 (51.28)	15.27 (38.78)	15.75 (400.0)
1 (25.4)	2.154 (54.71)	15.40 (39.11)	16.5 (414.0)
1¼ (31.8)	2.398 (60.90)	15.65 (39.75)	16.5 (414.0)
1½ (38.0)	2.615 (66.42)	15.87 (40.31)	16.5 (414.0)
1¾ (44.5)	2.812 (70.41)	16.06 (40.79)	16.5 (414.0)
2 (50.8)	2.993 (76.02)	16.24 (41.25)	17 (432.0)

[A]For other jaws greater than 3 ½ in. (88.9 mm), the standard length shall be increased by twice the length of the jaw minus 7 in. (177.8 mm). The standard length permits a slippage of approximately ¼ to ½ in. (6.35 to 12.7 mm) in each jaw while maintaining maximum length of jaw grip.

15.2 When the rod being tested is not circumferentially isotropic, prepare specimens for testing in both of the principal directions, and identify them as to directionality. This particularly includes rods machined from stripmolded or sheet stock.

16. Procedure

16.1 Test five specimens for each laminate orientation, each as a simple beam loaded at the center. The distance between the supports shall be eight times the diameter of the rod. The supports shall have contact edges rounded to a radius of ⅛ in. (3.2 mm). Adjust the crosshead speed of the testing machine not to exceed an idle speed of 0.050 in./min (1.27 mm/min) and apply the load through a steel block having a semi-circular contact edge of the same radius as the rod, with edges rounded to a radius of ⅛ in. (3.2 mm).

17. Calculation

17.1 Calculate the maximum fiber stress, *S*, as follows:

$$S = 8\ WL/\pi d^{3} \quad (1)$$

where:

W = breaking load, lbf (N),
L = distance between supports, in. (mm), and
d = diameter, in (mm).

18. Report

18.1 Report the following information:

18.1.1 The diameter of the specimen expressed to the nearest 0.001 in. (0.0254 mm), determined from at least two measurements 90° apart,

18.1.2 Crosshead speed in inches per minute (or millimetres),

18.1.3 The breaking load of each specimen in pounds-force (or newtons),

18.1.4 The maximum fiber stress *S*, in pounds-force per square inch (pascals), and

18.1.5 The direction of loading relative to the direction of the laminate if the rods are ground from strip-molded stock, sheet stock, and vulcanized fiber.

19. Precision and Bias

19.1 *Precision*—This test method has been in use for many years, but no statement of precision has been available and no activity is planned to develop such a statement.

19.2 *Bias*—A statement of bias is not applicable in view of the lack of a standard reference material for this property.

COMPRESSIVE STRENGTH (AXIAL)

20. Significance and Use

20.1 Compression tests, properly interpreted, provide reasonably accurate information with regard to the compressive properties of rigid round rods when employed under conditions approximating those under which the tests are made. The compressive strength values have the potential to vary with the size of the rigid round rod, and with temperature and atmospheric conditions. Compression tests provide data potentially useful for research and development, engineering design, quality control, and acceptance or rejection under specifications.

21. Apparatus

21.1 Any testing machine is acceptable for use provided it is accurate to 1 % of the lowest breaking force to be applied. One end of the specimen shall bear upon an accurately centered spherical bearing block, located, whenever practicable, at the top. The metal bearing plates shall be directly in contact with the ends of the test specimen.

22. Test Specimens

22.1 Unless otherwise specified in the test method or specification for that material, test the samples as received. For rods ⅛ to 1 in. (3.2 to 25.4 mm) in diameter, prepare the test specimen with a diameter equal to the diameter of the rod, and length conforming to the following requirements:

Diameter, in. (mm)	Length, in. (mm)	Slenderness Ratio
⅛ to ¼ (3.2 to 6.4) incl	½ (12.7)	16 to 8
Over ¼ to ½ (6.4 to 12.7) incl	1 (25.4)	16 to 8
Over ½ to 1 (12.7 to 25.4) incl	2 (50.8)	16 to 8

22.2 For rods over 1 in. (25.4 mm) in diameter, specimens are standard ½ by ½ by 1-in. (12.7 by 12.7 by 25.4-mm) right parallelepiped, cut from the rods so as to be representative of their cross sections both at the center and near the edges.

22.3 Accurately cut or grind the ends of each specimen parallel to each other.

23. Procedure

23.1 Adjust the crosshead speed of the testing machine not to exceed an idle speed of 0.050 in./min (1.27 mm/min), and test five specimens with the load applied perpendicular to the faces or ends of the specimen.

23.2 Discard specimens that break at some obvious flaw and make retests unless such flaws constitute a variable, the effect of which it is desired to study.

24. Report

24.1 Report the following information:

24.1.1 The diameter of the specimen expressed to the nearest 0.001 in. (0.0254 mm), determined from at least two measurements 90° apart,

24.1.2 The load on each specimen in pounds at the first sign of rupture, and

24.1.3 The compressive strength in pounds-force per square inch (or pascals) calculated from the data obtained on the application of the load perpendicular to the face of the specimen.

25. Precision and Bias

25.1 *Precision*—This test method has been in use for many years, but no statement of precision has been available and no activity is planned to develop such a statement.

25.2 *Bias*—A statement of bias is not applicable in view of the lack of a standard reference material for this property.

WATER ABSORPTION

26. Significance and Use

26.1 The moisture content of a rigid round rod has a definite influence on the electrical properties, mechanical strength, dimensional stability, and appearance. The effect upon these properties of changes in moisture content, due to water absorption, depends largely upon the inherent properties of the rigid round rod. It is possible that the rate of water absorption will be widely different through each edge and surface. A water absorption determination will provide data useful for research and development, engineering design, quality control, and acceptance or rejection under specifications.

27. Procedure

27.1 Determine and report the rate of water absorption in accordance with Test Method D570, immersing specimens for 24 h in distilled water at 23 ± 1 °C after preliminary conditioning for 1 h at 105 to 110 °C.

27.2 For some types of materials, or for special applications, it will be desirable to employ longer periods of water immersion in order to evaluate performance. In these cases, the report shall indicate the exact conditioning procedure.

DENSITY

28. Significance and Use

28.1 Density measurements are convenient means of identifying materials in terms of composition. As such, these data are found useful in research, design, quality control, and specification compliance.

29. Procedure

29.1 Determine the density in accordance with Method A of Test Methods D792.

30. Report

30.1 Report the following information:

30.1.1 Complete identification of the material tested, and

30.1.2 Average density in grams per cubic centimetre.

DIELECTRIC STRENGTH

31. Significance and Use

31.1 The dielectric strength of a rigid round rod will depend upon a number of factors such as rod diameter, which determines the electrode diameter to be used in the test; direction of applied dielectric stress, whether transverse or parallel to the axis; rate of application and the frequency of the voltage; temperature, and surrounding atmospheric humidity. The test values for dielectric strength determined by standard procedure, which stresses a rod section 1⁄16 in. (1.6 mm) in a direction parallel to the axis, may not necessarily indicate the safe operation in service. In actual service, it is acceptable to apply the voltage over a considerably greater rod section than 1⁄16 in. (1.6 mm) or the voltage stress may be applied in a direction perpendicular to the axis. Test values for dielectric strength usually give only some indication of insulating quality under service conditions. Dielectric strength tests provide data for research and development, engineering design, quality control, and acceptance or rejection under specifications.

32. Dielectric Strength

32.1 Except as specified in Sections 33 – 37, determine the dielectric strength in accordance with Test Method D149. Make tests parallel with the major axis of the rod.

33. Electrodes and Test Specimens

33.1 Prepare the test specimens ½ in. (12.7 mm) in length. Drill a hole into one end of the test specimen in the approximate center of the rod parallel with the major axis of the rod to a depth of 7⁄16 in. (11.1 mm), leaving a section 1⁄16 in. (1.6 mm) in thickness 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, circular metal plate having a diameter at least ½ in. (12.7 mm) greater than that of the specimen. This plate serves as the lower electrode. Thus, in effect, the material is tested parallel with laminations in a point-plane gap. Make the diameter of the hole as shown in the following table:

Nominal Diameter of Rod, in. (mm)	Nominal Hole Diameter for Pin Electrode, in. (mm)
⅛ to ¼ (3.2 to 6.4), incl	1/16 (1.6)
Over ¼ (6.4)	⅛ (3.2)

NOTE 2—It is acceptable to measure the thickness of the section by measuring the length of the electrode, then the combined length of the specimen and electrode with the electrode inserted in place.

34. Conditioning

34.1 Unless otherwise specified, condition all test specimens for 48 h at 50 ± 3 °C in a circulating air oven prior to testing. After removing the specimens from the oven, permit the specimens to cool to room temperature in a desiccator over anhydrous $CaCl_2$ or other suitable desiccant.

34.2 If tests are to be conducted at other than room temperature, then, prior to the test expose specimens previously conditioned as described in 34.1 to each test temperature in a suitable temperature-controlled chamber for a period in minutes equal to one half the diameter of the specimen in mils.

35. Surrounding Medium

35.1 In the case of flashover during breakdown voltage tests, conduct the tests in a suitable liquid medium that has been determined not to damage the specimens.

36. Procedure

36.1 Conduct the tests using either the short-time method or the step-by-step method.

36.1.1 In tests made using the short-time method, increase the voltage at the rate of 500 V/s.

36.1.2 In tests made using the step-by-step method, apply the voltage at each step for 1 min. Increase the voltage in increments as follows:

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

36.2 **Warning—***It is possible that lethal voltages will be present during this test. It is essential that the test apparatus and all associated equipment potentially electrically connected to it be properly designed and installed for safe operation. Solidly ground all metal parts that any person might come into contact with during the test. Thoroughly instruct all operators in the proper way to conduct the test safely. When making high voltage tests, particularly in compressed gas or in oil, it is possible that the energy released at breakdown will be sufficient to result in fire, explosion, or rupture of the test chamber. Design of test equipment, test chambers, and test specimens shall be such as to minimize the possibility of such occurrences, and to eliminate the possibility of personal injury.*

37. Number of Tests

37.1 Conduct at least five tests at each temperature using the short-time method, and at least three tests at each temperature using the step-by-step method. When a graphical relationship of dielectric strength with temperature is desired, make tests at no less than five test temperatures when the range of temperature is considerable.

38. Report

38.1 Report the following information:

38.1.1 A description of the material, including the brand name, type, grade, color, size, and the name of the manufacturer,

38.1.2 A statement of the procedure used, whether short-time method, or step-by-step method,

38.1.3 The maximum, minimum, and average puncture voltage in kilovolts and the average dielectric strength, using the average measured thickness of the specimens prior to breakdown,

38.1.4 Duration of the test if step-by-step method, including the initially applied voltage in kilovolts,

38.1.5 The temperature at which the test is made,

38.1.6 The size and type of electrodes,

38.1.7 The type of liquid medium used, and

38.1.8 The thickness of the section.

39. Precision and Bias

39.1 *Precision*—This test method has been in use for many years, but no statement of precision has been available and no activity is planned to develop such a statement.

39.2 *Bias*—A statement of bias is not applicable in view of the lack of a standard reference material for this property.

40. Keywords

40.1 compressive strength; dielectric strength; flexural strength; rigid rods; tensile strength; thermosetting laminate; vulcanized fibre; water absorption

SUMMARY OF CHANGES

Committee D09 has identified the location of selected changes to these test methods since the last issue, D349 – 07, that may impact the use of these test methods. (Approved Nov. 1, 2013)

(*1*) Changes made in Notes 1 and 2, as well as in sections 5.1.1, 7.1, 8.1, 13.1, 14.1, 20.1, 21.1, 26.1, 27.2, 31.1, 33.1, 36.2.