Standard Test Methods for Polytetrafluoroethylene Tubing[1]

This standard is issued under the fixed designation D 1675; 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 polytetrafluoroethylene tubing for use as electrical insulation. The procedures appear in the following sections:

Procedure	Sections	ASTM Methods
Conditioning	7	...
Dielectric Breakdown Voltage	28-30	D 149, D 876
Inside Diameter	8-13	D 876
Mandrel Bend Test	46-52	D 149, D 876
Melting Point	41-45	D 3418, D 4895
Penetration Test	26 and 27	D 876
Specific Gravity	36-40	D 792, D 1505
Strain Relief	31-35	...
Volatile Loss	20-25	...
Wall Thickness	14-19	...

NOTE 1—These test methods are similar but not identical to those in IEC 60684–2.

1.2 The values stated in inch-pound units are the standard except for temperature, which is stated in degrees Celsius. Values in parentheses are for information only.

1.3 *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 warning statements, see Section 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 792 Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement[3]

D 876 Test Methods for Nonrigid Vinyl Chloride Polymer Tubing Used for Electrical Insulation[2]

D 1505 Test Method for Density of Plastics by the Density-Gradient Technique[3]

D 1711 Terminology Relating to Electrical Insulation[2]

D 3418 Test Method for Transition Temperatures of Polymers by Differential Scanning Calorimetry[4]

D 3487 Specification for Mineral Insulating Oil Used in Electrical Apparatus[5]

D 4895 Specification for Polytetrafluoroethylene (PFTE) Resins Produced from Dispersion[6]

E 176 Terminology of Fire Standards[7]

2.2 *IEC Standards*

60684–2 Flexible Insulating Sleeves—Part 2: Methods of Test[8]

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions pertaining to electrical insulation, refer to Terminology D 1711.

3.1.2 For definitions pertaining to fire standards, refer to Terminology E 176.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *apparent melting point*, *n*—the temperature at which the appearance of the plastic changes from opaque to transparent.

3.2.2 *strain relief*, *n*—a dimensional change brought about by subjecting the tubing to an elevated temperature.

3.2.3 *volatile loss*, *n*—the reduction in weight by vaporization under controlled conditions.

4. Significance and Use

4.1 The test methods in this standard are considered important to characterize polytetrafluoroethylene tubing. They are intended primarily for, but not limited to, polytetrafluoroethylene tubing.

4.2 Variations in these methods or alternate contemporary methods of measurement may be used to determine the values for the properties in this standard provided such methods

[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 March 10, 2003. Published April 2003. Originally approved in 1959. Last previous edition approved in 1998 as D 1675 – 98.

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

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

[4] *Annual Book of ASTM Standards*, Vol 08.02.

[5] *Annual Book of ASTM Standards*, Vol 10.03.

[6] *Annual Book of ASTM Standards*, Vol 08.03.

[7] *Annual Book of ASTM Standards*, Vol 04.07.

[8] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.

ensure quality levels and measurement accuracy equal to or better than those prescribed herein. It is the responsibility of the organizations using alternate test methods to be able to demonstrate this condition. In cases of dispute, the methods specified herein shall be used.

NOTE 2—Provision for alternate methods is necessary because of (1) the desire to simplify procedures for specific applications, and (2) the desire to eliminate redundant testing and use data generated during manufacturing process control, including that generated under Statistical Process Control (SPC) conditions, using equipment and methods other than those specified herein. An example would be the use of laser micrometers or optical comparators to measure dimensions.

5. Hazards

5.1 *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*. See Section 28.

5.2 *Toxic Chemicals from Thermal Decomposition*:

5.2.1 Polytetrafluoroethylene at temperatures above 200°C may produce sufficient toxic vapors to be hazardous in a confined area. Sufficient ventilation must be provided in all tests where the material is subjected to testing above 200°C. (See Sections 7, 23, 26, 33, and 43.)

6. Selection of Test Specimens

6.1 In the case of material on spools or in coils, remove and discard at least two turns of the product before selecting material for samples from which to prepare test specimens.

6.2 In the case of material offered in cut lengths, do not prepare specimens from samples of material closer than 1 in. (25 mm) from each end.

6.3 Do not use specimens with obvious defects unless the purpose of the test is to determine the effects of these defects.

7. Conditioning

7.1 (**Warning—**See 5.2.)

7.2 Unless otherwise specified, condition and test specimens at least 3 h at 23 ± 2°C (73.4 ± 4°F) and 50 ± 5 % relative humidity.

INSIDE DIAMETER

8. Significance and Use

8.1 The inside diameter is of importance in determining the proper physical fit of the tubing.

9. Apparatus

9.1 *Gage Rods*—Use standard gage steel rods with smooth surfaces and hemispherical ends having diameters within ±0.0002 in. (±0.005 mm) of the values listed as maxima and minima in Table 1. A set of two gages ("go" and "no go") is required for each size of tubing.

NOTE 3—Tapered steel gages as described in Test Methods D 876 may be used as an alternate. These gages are not practical, however, for tubing smaller than Size No. 20.

10. Test Specimens

10.1 Cut five specimens of any convenient length, but not less than 3 in. (75 mm) long, from the sample. Do not test kinked specimens.

11. Procedure

11.1 Insert the minimum gage rod for the size tubing under test into the specimen for a distance of at least 1 in. (25 mm) if possible, noting whether the rod is easily inserted and withdrawn without appreciable force. If the rod cannot be readily inserted and removed, consider the specimen as having an inside diameter less than the minimum.

11.2 Select a gage rod having the maximum size for the tubing under test. Attempt to insert the gage rod into the tubing. If the rod can be easily inserted to a distance of 1 in., the tubing has an inside diameter that exceeds the specified maximum. If the rod cannot be readily inserted, the tubing has an inside diameter less than the maximum specified.

TABLE 1 Sizes of Polytetrafluoroethylene Tubing

Size	Inside Diameter, in. (mm)		
	Maximum	Minimum	Nominal
1 in.	1.060 (26.98)	1.000 (25.40)	...
7⁄8 in.	0.927 (23.55)	0.875 (22.23)	...
3⁄4 in.	0.795 (20.19)	0.750 (19.05)	...
5⁄8 in.	0.662 (16.81)	0.625 (15.88)	...
1⁄2 in.	0.530 (13.46)	0.500 (12.70)	...
7⁄16 in.	0.464 (11.79)	0.438 (11.38)	...
3⁄8 in.	0.399 (10.13)	0.375 (9.53)	...
No. 0	0.347 (8.81)	0.325 (8.25)	0.330 (8.38)
No. 1	0.311 (7.90)	0.289 (7.34)	0.294 (7.47)
No. 2	0.278 (7.06)	0.258 (6.55)	0.263 (6.68)
No. 3	0.249 (6.32)	0.229 (5.82)	0.234 (5.94)
No. 4	0.224 (5.69)	0.204 (5.18)	0.208 (5.28)
No. 5	0.198 (5.03)	0.182 (4.62)	0.186 (4.72)
No. 6	0.178 (4.52)	0.162 (4.11)	0.166 (4.22)
No. 7	0.158 (4.01)	0.144 (3.66)	0.148 (3.76)
No. 8	0.141 (3.58)	0.129 (3.28)	0.133 (3.38)
No. 9	0.124 (3.15)	0.114 (2.90)	0.118 (3.00)
No. 10	0.112 (2.84)	0.102 (2.78)	0.106 (2.69)
No. 11	0.101 (2.57)	0.091 (2.31)	0.095 (2.41)
No. 12	0.091 (2.31)	0.081 (2.06)	0.085 (2.16)
No. 13	0.082 (2.08)	0.072 (1.83)	0.075 (1.91)
No. 14	0.074 (1.88)	0.064 (1.63)	0.066 (1.68)
No. 15	0.067 (1.70)	0.057 (1.45)	0.059 (1.50)
No. 16	0.061 (1.55)	0.051 (1.30)	0.053 (1.35)
No. 17	0.054 (1.37)	0.045 (1.14)	0.047 (1.19)
No. 18	0.049 (1.24)	0.040 (1.02)	0.042 (1.07)
No. 19	0.044 (1.12)	0.036 (0.91)	0.038 (0.97)
No. 20	0.040 (1.02)	0.032 (0.81)	0.034 (0.86)
No. 22	0.032 (0.81)	0.026 (0.66)	0.028 (0.71)
No. 24	0.027 (0.69)	0.020 (0.51)	0.022 (0.56)
No. 26	0.022 (0.56)	0.016 (0.41)	0.018 (0.46)
No. 28	0.019 (0.48)	0.013 (0.33)	0.015 (0.38)
No. 30	0.015 (0.38)	0.010 (0.25)	0.012 (0.30)

12. Report

12.1 Report the following information:

12.1.1 Nominal size or size number of the tubing, and

12.1.2 Size or size number as determined.

13. Precision and Bias

13.1 This test method has been in use for many years, but no information has been presented to ASTM International upon which to base a statement of precision. No activity has been planned to develop such information. This test method has no bias because the value for inside diameter is determined solely in terms of this test method.

WALL THICKNESS

14. Significance and Use

14.1 The wall thickness provides design data. It is also useful in computing certain physical and electrical properties of the tubing.

15. Apparatus

15.1 *Dial Micrometer*—For Size No. 22 and larger, use a dial micrometer[9] equipped with a rod support for the specimen and a chisel-edge plunger. Use a gage with a minimum graduation of 0.0005 in. (0.01 mm) and a gaging load not exceeding 25 g. Use a rod made of hardened steel 0.020 in. (0.50 mm) in diameter and 3⁄8 in. (9.5 mm) long. Ensure that the chisel edge of the plunger is flat and approximately 0.043 in. (1.1 mm) across and 5⁄16 in. (8 mm) long.

15.2 *Microscope*—For Size No. 24 and smaller, use an optical means such as a toolmaker's microscope.

16. Test Specimens

16.1 Cut five ½-in. (13-mm) specimens free from kinks from the sample. Make the cut edge perpendicular to the longitudinal axis of the sample.

17. Procedure

17.1 For Size No. 22 and larger, measure the wall thickness of the specimen using the rod and chisel apparatus by raising the chisel from the rod and placing the specimen on the rod in such a manner that the rod passes through the center of the tubing specimen and rests flatly against the upper inside wall of the specimen. Gently lower the flat chisel edge until it rests lightly on the upper outside wall of the specimen. Rotate the tubing and determine the minimum and maximum wall thickness. The average of these two readings is the wall thickness of the specimen.

17.2 For Size No. 24 and smaller, use a reference method employing optical means acceptable to both the manufacturer and the purchaser to determine the maximum and minimum wall thickness.

[9] A dial-type micrometer, Gage Model 57B-3, manufactured by Federal Products Corp., 1144 Eddy St., Providence, RI 02901, has been found satisfactory for this purpose.

18. Report

18.1 Report the following information:

18.1.1 Nominal size or number of the tubing, and

18.1.2 Minimum, maximum, and average wall thickness.

19. Precision and Bias

19.1 This test method has been in use for many years, but no information has been presented to ASTM International upon which to base a statement of precision. No activity has been planned to develop such information. This test method has no bias because the value for wall thickness is determined solely in terms of this test method.

VOLATILE LOSS

20. Significance and Use

20.1 Volatile loss is indicative of the efficiency of removal of volatiles during processing, and may indicate the presence of undesirable organic materials.

21. Apparatus

21.1 *Analytical Balance*, capable of weighing to the nearest 0.001 g.

21.2 *Oven*, forced-convection type, capable of maintaining the temperature set point to the tolerances shown in the procedure.

21.3 *Desiccator*.

22. Test Specimens

22.1 Cut three specimens in full section from the sample in a manner such that each specimen is at least 10 in. (250 mm) long and weighs at least 2 g.

23. Procedure

23.1 (**Warning—**See 5.2.)

23.2 Dry three specimens in an oven at 105 ± 2.5°C (220 ± 4.5°F) for 1 h, cool in a desiccator, and weigh immediately upon removal. Then, place the specimens on a horizontal support in an oven without touching each other or the sides of the oven, making certain to keep the specimens open throughout their entire lengths. Maintain the specimens at 300 ± 3°C (572 ± 6°F), for 2 h. At the end of this period, remove the specimens, cool in a desiccator, and weigh immediately upon removal.

24. Report

24.1 Report the following information:

24.1.1 Nominal size or size number of tubing, and

24.1.2 Change in weight calculated as a percentage of the original weight.

25. Precision and Bias

25.1 This test method has been in use for many years, but no information has been presented to ASTM International upon which to base a statement of precision. No activity has been planned to develop such information. This test method has no bias because the value for volatile loss is determined solely in terms of this test method.

PENETRATION TEST

26. Procedure

26.1 Determine the penetration temperature in accordance with Test Methods D 876 with the following exception:

26.1.1 (**Warning—**See 5.2.)

26.1.2 To facilitate testing, the initial starting temperature may be taken at 150°C (302°F) instead of room temperature. For convenience, five penetration testers may be constructed to test simultaneously the required number of specimens.

27. Precision and Bias

27.1 This test method has been in use for many years, but no information has been presented to ASTM International upon which to base a statement of precision. No activity has been planned to develop such information. This test method has no bias because the value for penetration is determined solely in terms of this test method.

DIELECTRIC BREAKDOWN VOLTAGE

28. Procedure

28.1 (**Warning—**See 5.1.)

28.2 Determine the breakdown voltage in accordance with Test Methods D 876, using the apparatus described for tubing sizes No. 20 to ½ in. but modified as follows:

28.2.1 Cut ten specimens approximately 6 in. (150 mm) long from each sample.

28.2.2 Select a straight metal rod or tube for the inner electrode of such size as to provide a tight fit without stretching the tubing. Place the tubing over the inner electrode so that one end of the electrode is exposed for an electrical connection while the other end extends about 1 in. (25 mm) beyond the specimen. Apply metal foil as an outer electrode centrally about the mounted specimen, applying the first turn of foil with a tight wrap, and then winding two more turns over the first, allowing a free end of about ½ in. (13 mm) for an electrical connection.

28.2.3 Using the short-time test of Test Method D 149, conduct breakdown tests in mineral oil meeting the requirements shown under Type 1 in Table 1 of Specification D 3487. Apply the voltage between the electrodes and increase it at a rate of 0.5 kV/s. Make ten tests, using one specimen per test.

29. Report

29.1 Report the following information:

29.1.1 Nominal size or size number of the tubing,

29.1.2 Individual breakdown voltage at each puncture,

29.1.3 Average dielectric breakdown voltage for all ten punctures, and

29.1.4 Average volts per mil computed by dividing the average breakdown voltage for the ten specimens by the average wall thickness.

30. Precision and Bias

30.1 This test method has been in use for many years, but no information has been presented to ASTM International upon which to base a statement of precision. No activity has been planned to develop such information. This test method has no bias because the value for dielectric breakdown voltage is determined solely in terms of this test method.

STRAIN RELIEF

31. Significance and Use

31.1 The strain relief test gives an indication of the amount of lengthwise shrinkage that may occur when an assembly is exposed to heat in the process of manufacture or in service. This shrinkage is due to release of residual processing strains.

32. Test Specimens

32.1 Prepare three straight lengths of tubing 10 ± 0.01 in. (250 ± 0.25 mm) long; cut the tubing so that the ends are perpendicular to the longitudinal axis of the tubing.

33. Procedure

33.1 (**Warning—**See 5.2.)

33.2 Mount the specimens on wires of at least two sizes smaller than the tubing, and support the mounted wires horizontally in a forced-circulation type oven maintained at 300 ± 3°C (572 ± 6°F) for 2 h. At the end of this period remove the specimens from the oven and measure the length of each specimen.

34. Report

34.1 Report the following information:

34.1.1 Nominal size or size number of the tubing,

34.1.2 Length of tubing after completion of the test,

34.1.3 Percentage change in length (strain relief) of each specimen based on the 10-in. (250-mm) length, and

34.1.4 Average percentage change in length (stress relief).

35. Precision and Bias

35.1 This test method has been in use for many years, but no information has been presented to ASTM International upon which to base a statement of precision. No activity has been planned to develop such information. This test method has no bias because the value for strain relief is determined solely in terms of this test method.

SPECIFIC GRAVITY

36. Significance and Use

36.1 Specific gravity is useful in determining variations in the physical state and purity of the resin.

37. Test Specimens

37.1 Prepare three test specimens by cutting lengths of tubing in a manner prescribed by either of the methods referred to in Section 38.

38. Procedure

38.1 Determine the specific gravity in accordance with either Method A-1 of Test Methods D 792 (using a wetting agent not exceeding an amount of 0.1 % added to the boiled water), or Test Method D 1505.

39. Report

39.1 Report the following information:

39.1.1 Nominal size or size number of the tubing,

39.1.2 Specific gravity of each specimen tested,

39.1.3 Average specific gravity, and

39.1.4 Test method used.

40. Precision and Bias

40.1 The precision and bias of this test method are described in Test Methods D 792 and Test Methods D 1505.

MELTING POINT

41. Significance and Use

41.1 The melting point of a polymer, as determined by differential scanning calorimetry (DSC), is a valuable characteristic for identifying or verifying the type of polymer under test.

41.2 Commercial polymers, or in certain cases, the components of a polymer mixture may be identified by this method. Research polymers may be characterized by this method.

41.3 For the purposes of this standard, the terms *melting point* and *melting peak temperature* (in Specification D 4895) are used interchangeably.

41.4 This test is useful for both specification acceptance and for research.

42. Test Specimens

42.1 Cut a specimen with a mass between 10 ± 2 mg from the tubing.

43. Procedure

43.1 (**Warning—**See 5.2.)

43.2 Determine the apparent melting point in accordance with Specification D 4895; only a single determination is necessary.

44. Report

44.1 Report the following information:

44.1.1 Nominal size or size number of the tubing, and

44.1.2 Melting point

45. Precision and Bias

45.1 The precision and bias of this test method is described in Test Method D 3418.

MANDREL BEND TEST

46. Significance and Use

46.1 The mandrel bend test is useful in determining the relative ability of the tubing to withstand crazing or cracking on bending. Since the tendency toward crazing and cracking is illustrative of improper sintering, this test also serves as a means of checking whether the tubing has been sintered to a desired level.

47. Apparatus

47.1 *Mandrels*—Use the following mandrels:

Tubing Size No.	Mandrel Diameter
28 to 6	2 × nominal ID of tubing
5 to 0	3 × nominal ID of tubing
Over 0	5 × nominal ID of tubing

48. Reagent

48.1 *Sodium Chloride Solution* (5 %)—Prepare a 5 % solution by dissolving 5 g of sodium chloride (NaCl) in 100 g of tap water.

49. Test Specimens

49.1 Cut five specimens each 12 in. (300 mm) long from the tubing.

50. Procedure

50.1 Tightly wrap the central portion of the test specimen a minimum of four turns about a mandrel having a diameter as specified in 47.1.

50.2 Unwrap the specimen, straighten it out, rotate the specimen 180° about its axis so as to wind the specimen in the exact opposite direction to the previous wind, and repeat the procedure given in 50.1.

50.3 Remove the specimen from the mandrel, straighten out, and bend it into a U-shape configuration. Immerse the bent portion of the specimen in 5 % NaCl solution for a period of 10 min.

50.4 Remove the specimen, wipe the surface free of liquid, and determine the breakdown voltage in accordance with the method given in 28.2. For this test, apply the outer electrode over the central part of the specimen which was bent on the mandrel.

51. Report

51.1 Report the following information:

51.1.1 Nominal size or size number of the tubing,

51.1.2 Dielectric breakdown voltage of each specimen, and

51.1.3 Average dielectric breakdown voltage.

52. Precision and Bias

52.1 This test method has been in use for many years, but no information has been presented to ASTM International upon which to base a statement of precision. No activity has been planned to develop such information. This test method has no bias because the value for the mandrel bend test is determined solely in terms of this test method.

53. Keywords

53.1 ac breakdown voltage; bending effects; inside diameter; melting point; penetration resistance; polytetrafluoroethylene; PTFE; specific gravity; strain relief (shrinkage); tubes; volatile content; wall thickness