



Designation: ~~D2671 – 13~~ D2671 – 21

Standard Test Methods for Heat-Shrinkable Tubing for Electrical Use¹

This standard is issued under the fixed designation D2671; 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 U.S. Department of Defense.

1. Scope*

1.1 These test methods cover the testing of heat-shrinkable tubing used for electrical insulation. Materials used include poly(vinyl chloride), polyolefins, fluorocarbon polymers, silicone rubber, and other plastic or elastomeric compounds.

1.2 ~~The procedures~~ These test methods appear in the following sections:

Procedure	Section(s)	Test Method(s)
Adhesive Peel Strength	<u>94 – 100</u>	
Brittleness Temperature	<u>40</u>	<u>D746</u>
Color	<u>55 and 56</u>	<u>D1535</u>
Color Stability	<u>57 – 62</u>	<u>D1535</u>
Conditioning	<u>7</u>	<u>D618</u>
Copper Stability	<u>89</u>	
Corrosion Testing	<u>85 – 91</u>	
Dielectric Breakdown	<u>20 – 25</u>	<u>D149</u>
Dimensions	<u>8 – 13</u>	<u>D876</u>
Flammability	<u>68</u>	<u>D8355</u>
		(Methods A, C, or D)
Fluid Resistance	<u>63 – 67</u>	
Fungus Resistance	<u>100 – 104</u>	
Heat Resistance	<u>49 – 54</u>	
Heat Shock	<u>26 – 30</u>	
Low-temperature Properties	<u>36 – 43</u>	
Restricted Shrinkage	<u>14 – 19</u>	
Selection of Test Specimens	<u>6</u>	
Secant Modulus	<u>77 – 80</u>	<u>D882</u>
Storage Life	<u>31 – 35</u>	
Specific Gravity	<u>69 and 70</u>	<u>D792</u>
Stress Modulus	<u>81 – 84</u>	<u>D412</u>
Tensile Strength and Ultimate Elongation	<u>44 – 48</u>	<u>D412</u>
Thermal Endurance	<u>92 and 93</u>	
Volume Resistivity	<u>71 – 74</u>	<u>D257</u>
Water Absorption	<u>75 and 76</u>	<u>D570</u>
Melting Point	<u>100 – 104</u>	<u>D3418</u>

Procedure	Sections	ASTM Method Reference
Adhesive Peel Strength	<u>98 – 104</u>	
Brittleness Temperature	<u>40</u>	<u>D746</u>
Color	<u>55 and 56</u>	<u>D1535</u>
Color Stability	<u>57 – 62</u>	<u>D1535</u>

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 Electrical Insulating Materials.

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

Conditioning	7	D618
Copper Stability	93	
Corrosion Testing	89—95	
Dielectric Breakdown	20—25	D149
Dimensions	8—13	D876
Flammability	68—72	D876
Fluid Resistance	63—67	
Fungus Resistance	104—108	
Heat Resistance	49—54	
Heat Shock	26—30	
Low-Temperature Properties	36—43	
Restricted Shrinkage	14—19	
Selection of Test Specimens	6	
Secant Modulus	81—84	D882
Storage Life	31—35	
Specific Gravity	73 and 74	D792
Stress Modulus	85—88	D412
Tensile Strength and Ultimate Elongation	44—48	D412
Thermal Endurance	96 and 97	
Volume Resistivity	75—78	D257
Water Absorption	79 and 80	D570
Melting Point	104—108	D3418

1.3 This is a fire-test-response standard.

1.3 The values stated in inch-pound units are to be regarded as standard, except for temperature, which shall be expressed in degrees Celsius. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered 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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.* For specific hazard statements, see Section 5 and 68.2 for fire test safety caveats see Test Methods D8355.

NOTE 1—These test methods are similar, but not identical to, those in IEC 60684-260684-2 (see also Note 9).

1.5 This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.

<https://standards.iteh.ai/catalog/standards/sist/d6bfe413-72c7-4571-8673-1b882a728aff/astm-d2671-21>

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
- D257 Test Methods for DC Resistance or Conductance of Insulating Materials
- D412 Test Methods for Vulcanized Rubber and Thermoplastic Elastomers—Tension
- D570 Test Method for Water Absorption of Plastics
- D618 Practice for Conditioning Plastics for Testing
- D746 Test Method for Brittleness Temperature of Plastics and Elastomers by Impact
- D792 Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement
- D876 Test Methods for Nonrigid Vinyl Chloride Polymer Tubing Used for Electrical Insulation
- D882 Test Method for Tensile Properties of Thin Plastic Sheet
- D1535 Practice for Specifying Color by the Munsell System
- D1711 Terminology Relating to Electrical Insulation
- D3418 Test Method for Transition Temperatures and Enthalpies of Fusion and Crystallization of Polymers by Differential Scanning Calorimetry
- E176 Terminology of Fire Standards
- D8355 Test Methods for Flammability of Electrical Insulating Materials Used for Sleeving or Tubing

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.

2.2 *Other Documents: IEC Standards:*

~~MIL-STD-104 Limits for Electrical Insulation Color~~³³

~~IEC Publication-216 Guide for the Determination of Thermal Endurance Properties of Electrical Insulating Materials~~

~~IEC Publication-60684 Specification for Flexible Insulating Sleeving~~

~~ISO 846 Plastics—Evaluation of the Action of Microorganisms~~⁴

2.3 *Military Standard:*⁴

~~MIL-STD-104 Limits for Electrical Insulation Color~~

2.4 *ISO Standard:*⁵

~~ISO 846 Plastics—Evaluation of the Action of Microorganisms~~

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions pertaining to electrical insulation, refer to Terminology **D1711**.

3.1.2 For definitions pertaining to fire standards, refer to Terminology **E176**.

3.1.3 *heat-shrinkable tubing, n*—tubing that will reduce in diameter from an expanded size to a predetermined size by the application of heat.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *brittleness temperature, n*—the temperature at which 50 % of the specimens fail when the specified number are tested using the apparatus and conditions specified.

3.2.2 *concentricity, n*—the ratio expressed in percent of the minimum wall thickness to the maximum wall thickness.

3.2.3 *longitudinal change, n*—the change in length, either positive or negative, that occurs when the tubing is allowed to freely recover at the recommended recovery temperature, expressed as a percentage of the as supplied or expanded length.

3.2.4 *low-temperature flexibility, n*—the resistance to cracking of tubing when wrapped around prescribed mandrels at specified temperatures.

3.2.5 *restricted shrinkage, n*—shrinkage of the tubing at a prescribed temperature over a specially designed mandrel whose smallest diameter is greater than the fully shrunk size and whose largest diameter is less than the expanded size of the tubing.

3.2.6 *storage-life, heat-shrinkable tubing, n*—the length of time that the tubing will retain its specified expanded and recovered dimensions under storage at a specified temperature.

4. Significance and Use

4.1 These test methods include most of the important tests used to characterize heat-shrinkable tubing. They are intended primarily for, but not limited to, extruded heat-shrinkable tubing.

4.2 It is acceptable to use variations in these test methods or alternate contemporary methods of measurement to determine the values for the properties in this standard provided such methods 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 without altering the result, and (2) the desire to eliminate redundant testing and use data generated during manufacturing process control, including that generated under Statistical

⁴ Available from ~~Standardization Documents Order Desk, Bldg. 4 Section D, DLA Document Services, Building 4/D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS~~<http://quicksearch.dla.mil>.

³ Available from International Electrotechnical Commission (IEC), 3, rue de Varembe, 1st floor, P.O. Box 131, CH-1211, Geneva 20, Switzerland, <https://www.iec.ch>.

⁵ Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, <http://www.ansi.org>. International Organization for Standardization (ISO), ISO Central Secretariat, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, <https://www.iso.org>.

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 ~~Warning~~**(Warning—**Lethal voltages are potentially present during this test. It is essential that the test apparatus, and all associated equipment that is potentially 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: (a) were at high voltage during the test, (b) have potentially acquired an induced charge during the test, or (c) could have retained 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, it is possible that the energy released at breakdown would 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 23.**)**Lethal voltages are potentially present during this test. It is essential that the test apparatus, and all associated equipment that is potentially 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: (a) were at high voltage during the test; (b) have potentially acquired an induced charge during the test; or (c) could have retained 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, it is possible that the energy released at breakdown would 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 23.)

5.2 Flammable Solvents:

5.2.1 Methyl ethyl ketone is a volatile, flammable solvent. It shall be handled in an area having good ventilation, such as a laboratory hood and away from sources of ignition. See Section 10096.

6. Selection of Test Specimens

6.1 Select a sufficient number of pieces of tubing in such manner as to be representative of the shipment.

6.2 Cut specimens, free of kinks, from the sample selected under 6.1. Cut perpendicular to the longitudinal axis of the tubing and in such manner that the specimen has cleanly cut square edges.

6.3 Unless otherwise stated, conduct tests on specimens in the completely shrunk condition.

7. Conditioning

7.1 When specified, condition tubing in accordance with Practice D618 using Procedure A, except that a conditioning time of 4 h shall be used. In cases where tests are performed on specimens in the shrunk state, condition the test specimens prior to testing, but after heat shrinking.

DIMENSIONS

8. Significance and Use

8.1 *Inside Diameter*—The inside diameter of tubing before and after heat-shrinking is an important factor in selecting tubing of the proper size to slip easily over an object and to conform tightly after shrinkage.

8.2 *Wall Thickness*—Wall thickness measurements are useful in providing design data and in calculating certain physical and electrical properties of the tubing.

8.3 *Concentricity*—In some cases, a thin wall area, due to variation in processing, will lead to equipment failure. It is important, therefore, both in extrusion of the tubing, and its expansion prior to shrinkage in end-use, that concentricity be held above a specified limit to ensure proper performance of the tubing.

8.4 *Length*—The length, both before and after heat-shrinking, is important in the determination of proper fit of the tubing in end-use.

9. Apparatus

9.1 *Mandrels*—Use a series of steel rods suitable for insertion into the tubing including the tapered gages described under Test Methods **D876**.

9.2 *Micrometers*, mandrel anvil and indicator set accurate to at least 0.001 in. or 0.02 mm.

9.3 *Steel Scale*, graduated in $\frac{1}{64}$ -in. or ~~0.5-mm~~ 0.5 mm divisions.

9.4 *Oven*, forced-convection type, capable of maintaining temperature to within $\pm 5^{\circ}\text{C}$; $\pm 5^{\circ}\text{C}$.

10. Test Specimens

10.1 Cut three straight lengths of expanded tubing, each 6 in. (150 mm) long, from the sample as directed in **6.2** for each test performed.

11. Procedure

11.1 *Measuring Inside Diameter:*

11.1.1 Select a mandrel that will just fit into the specimen and insert the mandrel into the expanded tubing for a distance of 1 in. (25 mm).

NOTE 3—If the tubing specimens have a tendency to adhere to the mandrels during measurement of diameter, it is recommended that the mandrels be coated with water or talc as a lubricant. However, caution must be exercised not to force the tubing on the mandrel, thereby stretching the specimens.

11.1.2 Using a machinist's micrometer, measure the outside diameter of the mandrel to the nearest 0.001 in. (0.02 mm). Record this as the expanded inside diameter.

11.1.3 Place the specimen in an oven at the temperature specified as suitable for complete shrinkage for a period of time recommended for shrinkage. Make provision for positioning the specimen horizontally in the oven so that recovery can be effected without restriction. If the tubing tends to become sticky at the shrinkage temperature, specimens can be laid in trays that have been powdered slightly with talc.

11.1.4 At the end of the specified shrinkage time, remove the specimens from the oven and allow to cool to room temperature. Measure the inside diameter as described in ~~H.1.1~~ 11.1.1 and 11.1.2 and ~~H.1.2~~, recording this as the recovered inside diameter.

11.2 *Measuring Wall Thickness:*

11.2.1 Measure the wall thickness of the expanded (as supplied) tubing using a micrometer. By means of a sufficient number of tests, locate the points on the wall corresponding to the minimum and the maximum wall thickness, and record these measurements to the nearest 0.001 in. (0.02 mm).

11.2.2 Allow the specimens to recover under heat as described in ~~H.1.3~~ 11.1.3 and 11.1.4 and ~~H.1.4~~. Measure the wall thickness as described in **11.2.1** recording these as the recovered thicknesses.

11.3 *Calculating Concentricity*—From measurements of minimum and maximum wall thickness made in accordance with ~~H.2.1~~ 11.2.1 and 11.2.2 and ~~H.2.2~~, calculate the concentricity (C) of the expanded and recovered tubing respectively, using the following equation:

$$C = 100 (M''/M') \quad (1)$$

where:

M' = maximum thickness, in. (mm), and

M = ~~minimum thickness, in. (mm).~~

"

M'' = minimum thickness, in. (mm).

11.4 Measuring Length:

11.4.1 Using the steel scale, measure the length to the nearest $\frac{1}{32}$ in. or 1 mm.

11.4.2 Allow the specimens to recover under heat as described in ~~H.1.3~~**11.1.3 and 11.1.4** and ~~H.1.4~~. Measure the length after recovery. Record the length in the expanded and recovered state.

11.5 *Calculating Longitudinal Change*—From the measurements of expanded and recovered length made in accordance with ~~H.4.1~~**11.4.1 and 11.4.2** and ~~H.4.2~~, calculate the percent longitudinal change using the following equation:

$$\text{Percent longitudinal change} = 100 (L' - L'')/L'' \quad (2)$$

$$\text{percent longitudinal change} = 100 (L' - L'')/L'' \quad (2)$$

where:

L' = recovered length, in. (mm), and

L'' = expanded length, in. (mm).

12. Report

12.1 Report the following information:

12.1.1 Identification of the tubing,

12.1.2 Inside diameter of the tubing in the expanded and in the recovered state,

12.1.3 Maximum and minimum wall thickness for each specimen in the expanded and in the recovered state,

12.1.4 Length of each specimen in the expanded and recovered state,

12.1.5 Percentage longitudinal change of each specimen (after recovery) based on the expanded state length,

12.1.6 Concentricity of each specimen in the expanded and the recovered state, and

12.1.7 Time and temperature used for shrinkage of the tubing.

13. Precision and Bias

13.1 The overall estimates of the precision within laboratories, $(S_p)_j$, and the precision between laboratories, $(S_p)_j$, are given in **Table 1** for four selected materials. These estimates are based on a round robin of three specimens, each run in six laboratories.⁶ No bias statement can be made due to the lack of a standard reference material.

RESTRICTED SHRINKAGE

14. Significance and Use

14.1 This test method covers the determination of the ability of heat-shrinkable tubing to be shrunk on a specially designed mandrel without splitting or cracking. A voltage proof test is used to ascertain splitting or cracking.

⁶ Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D09-1017.

TABLE 1 Estimated Precision of Storage Life Measurements for Selected Tubings

Property	Units	Generic Type	Nominal Value	(S_w) Estimate of Precision Within Laboratories	(S_B) Estimate of Precision Between Laboratories
Expanded inside diameter	in. (mm)	PTFE	0.11 (2.79)	0.003 (0.076)	0.003 (0.076)
		PVC	0.26 (6.60)	0.009 (0.229)	0.010 (0.254)
		Polychloroprene	0.95 (24.13)	0.006 (0.152)	0.032 (0.813)
		Polyolefin, flexible	2.0 (50.8)	0.020 (0.508)	0.025 (0.635)
		Polyolefin, flexible	2.0 (50.8)	0.020 (0.508)	0.025 (0.635)
Recovered inside diameter	in. (mm)	PTFE	0.05 (1.27)	0.001 (0.025)	0.002 (0.051)
		PVC	0.12 (3.05)	0.001 (0.025)	0.003 (0.076)
		Polychloroprene	0.42 (10.67)	0.001 (0.025)	0.005 (0.127)
		Polyolefin, flexible	0.96 (24.38)	0.005 (0.127)	0.021 (0.533)
		PTFE	0.012 (0.304)	0.0007 (0.0178)	0.0010 (0.0254)
Recovered wall thickness	in. (mm)	PVC	0.024 (0.609)	0.0007 (0.0178)	0.0011 (0.0594)
		Polyolefin, flexible	0.049 (1.245)	0.0009 (0.0229)	0.0015 (0.0381)
		Polychloroprene	0.065 (1.651)	0.0007 (0.0178)	0.0031 (0.0787)
		Polychloroprene	12.5	3.0	4.3
		Polyolefin, flexible	26	3.1	6.0
Expanded eccentricity	%	PVC	-18.4	0.6	1.7
		Polyolefin, flexible	-7.5	1.2	1.7
Longitudinal change	%	Polychloroprene	-1.9	2.3	2.3
		PVC	30	2.5	3.9
		Polyolefin, flexible			
		PTFE			

15. Apparatus

15.1 *Mandrels*—A series of mandrels having the dimensions shown in Fig. 1 and Table 2. Care shall be taken that all sharp edges are deburred.

15.2 *Oven*, forced-convection type, capable of maintaining temperature to within $\pm 5^\circ\text{C}$ $\pm 5^\circ\text{C}$ as described in 9.4.

16. Test Specimens

16.1 Cut three lengths of tubing, each 6 in. (150 mm) long, from the sample of tubing in the expanded state.

17. Procedure

17.1 Heat shrink the specimens on the mandrels shown in Fig. 1, using one of the following procedures:

17.1.1 *Procedure A*—Bring the mandrel to room temperature and thoroughly clean. The means of heat application, together with the time and method of shrinkage, shall be optional as agreed upon between the purchaser and the seller.

17.1.2 *Procedure B*—Preheat the mandrel for at least 30 min in an oven at a specified temperature. Place the tubing on the mandrel; the means of heat application to produce shrinkage shall be optional as agreed upon between the purchaser and the seller.

17.1.3 *Procedure C*—Bring the mandrel to room temperature, and position the specimen on the mandrel and place it in an oven at a prescribed temperature for a period of at least 30 min.

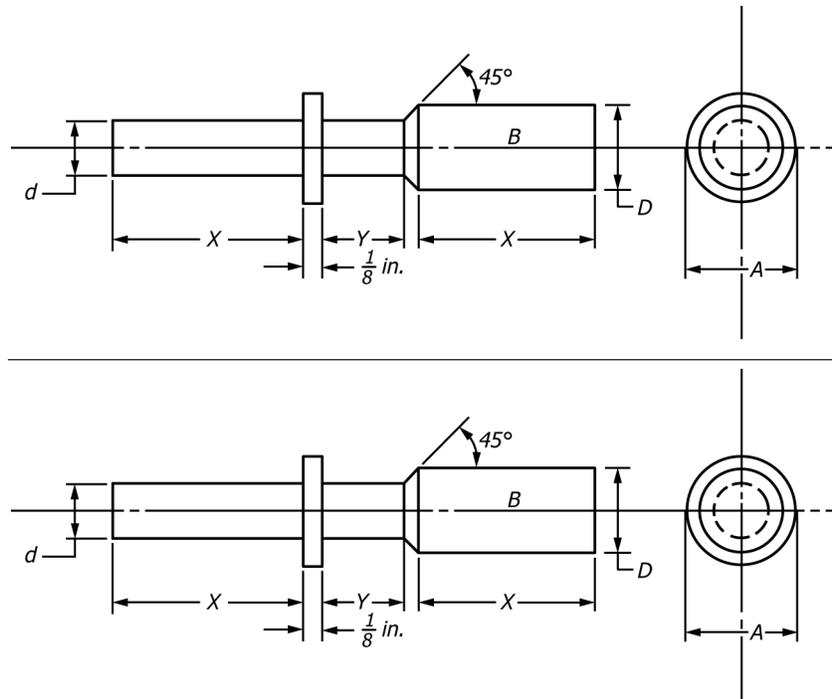
NOTE 4—Means of applying heat other than the use of ovens are acceptable as agreed upon between the purchaser and the seller.

17.2 At the end of the specified shrinkage period, remove the mandrels and specimens from the heat source, and cool to room temperature.

17.3 Examine the specimens for tightness of fit and for evidence of cracking or splitting.

NOTE 5—It is recommended that section B of the mandrel be provided with a longitudinal V-groove to permit easy removal of the shrunk specimen using a knife or razor blade.

17.4 Wrap a strip of metal foil not more than 0.001 in. (~~0.02 mm~~) (0.02 mm) thick around the specimen in the area directly over the disk (A of Fig. 1) so that the foil covers all parts of the disk. Apply a second layer of foil tightly against the tubing to ensure



- A = minimum expanded diameter of tubing as supplied.
- B = longer diameter section of the mandrel (Note 5).
- D = 75 % of diameter A .
- d = 50 % of diameter A .
- X = See Table 1.
- Y = See Table 1.
- $\frac{1}{8}$ in. = 0.13 mm.

where:

- A = minimum expanded diameter of tubing as supplied.
- B = longer diameter section of the mandrel (Note 5).
- D = 75 % of diameter A .
- d = 50 % of diameter A .
- X = see Table 1.
- Y = see Table 1, and
- $\frac{1}{8}$ in. = 0.13 mm.

FIG. 1 Mandrel for Restricted Shrinkage Test

TABLE 2 Dimensions for Restricted Shrinkage Test Mandrel

Maximum Inside Diameter of Tubing (Nominal) After Unrestricted Shrinkage, in. (mm)	Mandrel Section, in. (mm)	
	X	Y
Less than 0.050 (1.27) ^A	0.5 (13)	0.25 (6.4)
0.050 to 0.125 (1.27 to 3.18)	0.5 (13)	0.25 (6.4)
0.126 to 0.374 (3.20 to 9.50)	1 (25)	0.5 (13)
0.375 to 2.000 (9.52 to 50.80)	2 (51)	2 (51)
Greater than 2.000 (50.80)	3 (76)	3 (76)

^A For tubing sizes less than 0.050 in. (1.27 mm) in inside diameter (after unrestricted shrinkage), use a straight cylindrical mandrel having an outside diameter conforming to dimension D of Fig. 1.

contact, leaving a short length free for an electrical connection. Remove a portion of the tubing from one end of the mandrel to expose a short length for the purpose of making a second electrical connection, making sure that sufficient tubing remains between the points of connection and the foil electrode to avoid flashover during the voltage proof test.

17.5 Apply an ac voltage at a rate of 500 V/s to a specified level of voltage between the electrodes and hold for a period of 1 min.

18. Report

18.1 Report the following information:

18.1.1 Identification of the tubing,

18.1.2 Outside dimensions of the mandrel used (A , D , and d of Fig. 1),

18.1.3 Method of heat shrinking, and the time and temperature of shrinkage,

18.1.4 Brief description of the conformability of the specimen to the mandrel, together with evidence of cracking or splitting,

18.1.5 Voltage used in the proof test,

18.1.6 Results of the proof voltage test, and

18.1.7 Location of breakdown, if any.

19. Precision and Bias

19.1 No statement is made about either the precision or the bias of this test method for measuring restricted shrinkage since the result merely states whether there is conformance or nonconformance to the criteria specified in the procedure.

DIELECTRIC BREAKDOWN VOLTAGE AND DIELECTRIC STRENGTH

20. Significance and Use

20.1 By the nature of heat-shrinkable tubing, it is possible that the wall thickness will vary because of the geometry of the object on which it is shrunk. The dielectric breakdown voltage of a tubing is of importance as a measure of its ability to withstand electrical stress without failure. This value does not correspond to the dielectric breakdown voltage expected in service, but is of potential value in comparing different materials or different lots, in controlling manufacturing processes or, when coupled with experience, for a limited degree of design work. For a more complete discussion, refer to Test Method **D149**.

21. Apparatus

21.1 *Mandrels*—A series of metal mandrels having diameters larger, but not more than 15 % larger, than the nominal fully recovered diameters of tubing to be tested.

21.2 *Oven*, forced-convection type, capable of maintaining temperature to within $\pm 5^{\circ}\text{C}$; $\pm 5^{\circ}\text{C}$.

22. Test Specimens

22.1 Cut five lengths of tubing, each 6 in. (150 mm) long, from the tubing in the expanded state.

23. Procedure

Warning—High Voltage (see 5.1):

23.1 (**Warning—High Voltage**. See 5.1.)

23.2 For tubing having a recovered inside diameter of 1 in. (25 mm) or less, choose a mandrel that is slightly larger in diameter than the fully recovered inside diameter of the tubing to be tested. Heat shrink the specimen onto the mandrel by heating it in an oven at the specified time and temperature for the tubing being tested.

23.2.1 Following the heating, remove the mandrel from the oven and allow it to cool to room temperature. Apply a 1 in. (25.4 mm) wide metal-foil electrode not more than 0.001 in. (0.02 mm) thick around the center of the specimen.

23.3 For tubing having a recovered inside diameter of more than 1 in. (25.4 mm), heat shrink the specimens in an oven without a mandrel for the time and temperature specified for the tubing being tested. At the end of the heating period, remove the specimens from the oven, cut lengthwise, and while still warm, lay out flat to form a sheet. Allow to cool to room temperature.

23.4 Immerse the specimens in oil and determine the dielectric breakdown voltage of the shrunk-down specimens using the method described in Test Method **D149**. For flat test specimens, use 1-in. (25 mm) electrodes as in Test Method **D149**, Table number 1, Electrode Type 2. Make one test on each of the five specimens. Use the short-time test at a rate of rise of 500 V/s.

23.5 For determination of dielectric strength, measure the wall thickness immediately adjacent to the point of dielectric breakdown of each specimen using the method in **11.2**.

23.6 Calculate the dielectric strength by dividing the breakdown voltage by the wall thickness for each specimen.

24. Report

24.1 Report the following information:

24.1.1 Identification of the tubing,

24.1.2 Breakdown voltage in kilovolts for each specimen,

24.1.3 Average breakdown voltage for the five specimens,

24.1.4 Wall thickness of each specimen in inches or millimetres,

24.1.5 Dielectric strength in volts per mil or kilovolts per millimetre for each specimen, and

24.1.6 Average dielectric strength for the five specimens.

25. Precision and Bias

25.1 The overall estimates of the precision within laboratories, $(S_p)_j$, and the precision between laboratories, $(S_p)_j$, are given in **Table 3** for four selected materials. These estimates are based on a round robin of five specimens, each run in six laboratories.⁷ This test method has no bias because the results are expressed purely in terms of this test method.

TABLE 3 Estimated Precision of Tensile Property Measurements for Selected Tubings

Property	Units	Generic Type	Nominal Value	$(S_p)_j$ Estimate of Precision Within Laboratories	$(S_p)_j$ Estimate of Precision Between Laboratories
Dielectric breakdown voltage	kV	PVDF	11.4	1.7	1.8
		Polyolefin, semi-rigid	13.3	1.7	2.9
		Polyolefin, flexible	19.2	1.6	2.0
		Polyolefin, flexible	30	1.9	4.7
Dielectric strength	V/mil (kV/mm)	Polyolefin, semi-rigid	460 (18.11)	62 (2.44)	110 (4.33)
		Polyolefin, flexible	680 (26.77)	39 (1.54)	114 (4.49)
		Polyolefin, flexible	850 (33.46)	84 (3.31)	133 (5.24)
		PVDF	1100 (43.31)	128 (5.04)	150 (5.90)

⁷ Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D09-1025. Contact ASTM Customer Service at service@astm.org.

HEAT SHOCK

26. Significance and Use

26.1 It is not always possible to control precisely the heat source used to effect shrinkage of tubing, and for this reason, it is possible that the tubing will be exposed to temperatures in excess of those intended for shrinkage. This test method serves to evaluate the effects on the tubing of short periods of exposure to specified temperatures in excess of those normally recommended for shrinkage. This test is a means of obtaining visual evidence of the effects of elevated temperatures on heat-shrinkable tubing by visual examination, either alone or in combination with a mandrel wrap procedure following the heat exposure.

27. Test Specimens

27.1 Cut three lengths of tubing, each 6 in. (150 mm) long, from the sample of tubing in the expanded state. Cut $\frac{1}{2}$ -in. (~~13-mm~~) (13 mm) wide strips from tubing having an expanded diameter greater than 0.5 in. (12.7 mm).

28. Procedure

28.1 Attach a small piece of wire to each specimen so that the specimen is suspended vertically in the oven during the test.

28.2 Place the specimen in an oven similar to that described in 9.4, maintained at a specified temperature. After a period of 4 h, remove the specimen and allow it to cool to room temperature. When required, wrap the specimen 360° around a metal mandrel having a diameter as specified in the tubing specification in 2 to 4 s.

28.3 Examine the specimens for evidence of cracking, flowing, or dripping.

29. Report

29.1 Report the following information:

29.1.1 Identification of the tubing,

29.1.2 Temperature of the test, and

29.1.3 Record of cracking, flow, or dripping.

30. Precision and Bias

30.1 No statement is made about either the precision or the bias of this test method for measuring heat shock since the result merely states whether there is conformance or nonconformance to the criteria specified in the procedure.

STORAGE LIFE

31. Significance and Use

31.1 In the expanded form, heat-shrinkable tubing is under stress. Over a period of time there will be a tendency for this stress to relax. Potential effects of this relaxation include the following: (a) that the tubing no longer meets the minimum-expanded dimension, or (b) that it will fail to recover to the maximum-recovered dimension. This test method provides an accelerated means of evaluating the utility of heat-shrinkable tubing after a period of storage under prescribed conditions and assists in determining the need for special storage and handling requirements.

32. Test Specimens

32.1 Cut three lengths of tubing, each 6 in. (150 mm) long, from the sample of tubing in the expanded state.

33. Procedure

33.1 Measure the inside diameter of the specimens in accordance with 11.1.

33.2 Place the specimens in an oven of the forced-convection type and capable of maintaining a temperature of $40 \pm 2^{\circ}\text{C}$ ($104 \pm 4^{\circ}\text{F}$) (or other specified temperature) for a period of two weeks.

33.3 Remove the specimens and allow them to cool to room temperature. Measure the inside diameter of each specimen in accordance with 11.1.

33.4 Shrink the specimens and measure the inside diameter and wall thickness in accordance with 11.1 and 11.2.

34. Report

34.1 Report the following information:

34.1.1 Identification of the tubing,

34.1.2 Inside diameter of the tubing before conditioning, after two weeks of conditioning, and after heat shrinking,

34.1.3 Wall thickness after heat-shrinking, and

34.1.4 Temperature of the storage-life test, if other than 40°C .

35. Precision and Bias

35.1 The overall estimates of the precision within laboratories, $(S_r)_j$, and the precision between laboratories, $(S_R)_j$, are given in Table 4 for two selected materials. These estimates are based on a round robin of three specimens, each run in six laboratories.⁷ This test method has no bias because the results are expressed purely in terms of this test method.

LOW-TEMPERATURE PROPERTIES

36. Significance and Use

36.1 Flexibility of tubing at low temperatures is an important service property. Procedures A and C are low-temperature flexibility tests. Procedure A serves to evaluate tubing by a method that simulates actual use in service, but that is restricted by its physical limitations to tubing having a recovered inside diameter of less than 0.375 in. (9.5 mm). Procedure C can be used on any size tubing and the test can be performed on tubing in either the expanded or fully recovered condition. Alternatively, a brittleness temperature test (Procedure B) serves to evaluate low-temperature impact resistance of specimens of prescribed form and is not restricted to certain sizes.

37. Apparatus

37.1 *Cold Chamber*—A thermally insulated enclosure equipped to maintain an atmosphere at a specified low temperature to within $\pm 2^{\circ}\text{C}$, and of such size as to permit convenient bending of specimens around mandrels without removal from the chamber.

37.2 *Stranded Wire*, sizes AWG 0 to 30 (9.5 to 0.25 mm).

37.3 *Mandrels*, stainless steel. Sizes are to be specified in tubing specification.

TABLE 4 Estimated Precision of Storage Life Measurements for Selected Tubings

Property	Units	Generic Type	Nominal Value	$(S_r)_j$ Estimate of Precision Within Laboratories	$(S_R)_j$ Estimate of Precision Between Laboratories
Expanded inside diameter	in. (mm)	PVC	0.26 (6.60)	0.005 (0.127)	0.011 (0.279)
		Polychloroprene	0.95 (24.13)	0.002 (0.051)	0.012 (0.305)
Recovered inside diameter	in. (mm)	PVC	0.12 (3.05)	0.002 (0.051)	0.004 (0.102)
		Polychloroprene	0.43 (10.92)	0.002 (0.051)	0.008 (0.203)
Recovered wall	in. (mm)	PVC	0.023 (0.584)	0.0011 (0.028)	0.0019 (0.048)
		Polychloroprene	0.064 (1.626)	0.0011 (0.028)	0.0031 (0.079)