Designation: D 2671 – 9900

An American National Standard

Standard Test Methods for Heat-Shrinkable Tubing for Electrical Use[1]

This standard is issued under the fixed designation D 2671; 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 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 values stated in inch-pound units are the standard except for temperature, which shall be expressed in degrees Celsius. Values stated in parentheses are for information only.

1.3 The procedures appear in the following sections:

Procedure	Sections	ASTM Method Reference
Adhesive Peel Strength	98 to 104	
Brittleness Temperature	40	D 746
Color	55 to 56	D 1535
Color Stability	57 to 62	D 1535
Conditioning	7	D 618
Copper Stability	93	
Corrosion Testing	89 to 95	
Dielectric Breakdown	20 to 25	D 149
Dimensions	8 to 13	D 876
Flammability	68 to 72	D 876
Fluid Resistance	63 to 67	
Fungus Resistance	104 to 108	
Heat Resistance	49 to 54	
Heat Shock	26 to 30	
Low-Temperature Properties	36 to 43	
Restricted Shrinkage	14 to 19	
Selection of Test Specimens	6	
Secant Modulus	81 to 84	D 882
Storage Life	31 to 35	
Specific Gravity	73 to 74	D 792
Stress Modulus	85 to 88	D 412
Tensile Strength and Ultimate Elongation	44 to 48	D 412
Thermal Endurance	96 to 97	
Volume Resistivity	75 to 78	D 257
Water Absorption	79 to 80	D 570
Melting Point	104 to 108	D 3418

1.4 This is a fire-test-response standard.

1.5 *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 hazard statements, see Sections 5 and 68.2.

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

2. Referenced Documents

2.1 *ASTM Standards:*

[1] These test methods are under the jurisdiction of ASTM Committee ~~D-9~~ D09 on Electrical and Electronic Insulating Materials and are the direct responsibility of Subcommittee D09.07 on Flexible and Rigid Insulating Materials.

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D 149 Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials at Commercial Power Frequencies[2]
D 257 Test Methods for D-C Resistance or Conductance of Insulating Materials[2]
D 412 Test Methods for Vulcanized Rubber and Thermoplastic Rubbers and Thermoplastic Elastomers—Tension[3]
D 570 Test Method for Water Absorption of Plastics[4]
D 618 Practice for Conditioning Plastics and Electrical Insulating Materials for Testing[4]
D 746 Test Method for Brittleness Temperature of Plastics and Elastomers by Impact[4]
D 792 Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement[4]
D 876 Test Methods for Nonrigid Vinyl Chloride Polymer Tubing Used for Electrical Insulation[2]
D 882 Test Methods for Tensile Properties of Thin Plastic Sheeting[4]
D 1535 Practice for Specifying Color by the Munsell System[5]
D 1711 Terminology Relating to Electrical Insulation[2]
D 3418 Test Method for Transition Temperatures of Polymers by Thermal Analysis[6]
E 176 Terminology of Fire Standards[7]

2.2 *Other Documents:*

MIL-STD 104 Limits for Electrical Insulation Color[8]
IEC Publication 216 Guide for the Determination of Thermal Endurance Properties of Electrical Insulating Materials[9]
IEC Publication 60684 Specification for Flexible Insulating Sleeving[9]
ISO 846 Plastics—Evaluation of the Action of Microorganisms[9]

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.

3.1.3 *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 Variations in these test methods or alternate contemporary methods of measurement may be used 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 ~~1~~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 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.

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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 06.01.
[6] *Annual Book of ASTM Standards*, Vol 08.02.
[7] *Annual Book of ASTM Standards*, Vol 04.07.
[8] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.
[9] Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

5. Hazards

5.1 **Warning**— *Lethal voltages may be present during this test. It is essential that the test apparatus, and all associated equipment that may be electrically connected to it, be properly designed and installed for safe operation. Solidly ground all electrically conductive parts that any person might come in contact with during the test. Provide means for use at the completion of any test to ground any parts which: were at high voltage during the test; may have acquired an induced charge during the test; may retain a charge even after disconnection of the voltage source. Thoroughly instruct all operators in the proper way to conduct tests safely. When making high voltage tests, particularly in compressed gas or in oil, the energy released at breakdown may be sufficient to result in fire, explosion, or rupture of the test chamber. Design test equipment, test chambers, and test specimens so as to minimize the possibility of such occurrences and to eliminate the possibility of personal injury. (See Section 23.)*

5.2 *Flammable Solvents*:

5.2.1 Methyl ethyl ketone is a volatile, flammable solvent. It should be handled in an area having good ventilation, such as a laboratory hood and away from sources of ignition. See Section 100.

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, test specimens in the completely shrunk condition.

7. Conditioning

7.1 When specified, condition tubing in accordance with Practice D 618 using Procedure A, except use a conditioning time of 4 h. In cases where tests are performed on specimens in the shrunk state, condition 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*—A thin wall area, due to variation in processing, may 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*—A series of steel rods suitable for insertion into the tubing including the tapered gages described under Test Methods D 876, may be used.

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 1⁄64-in. or 0.5-mm divisions.

9.4 *Oven*, forced-convection type, capable of maintaining temperature to within ±5°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 ~~2~~3—Should the tubing specimens tend to adhere to the mandrels during measurement of diameter, the mandrels may 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 11.1.1 and 11.1.2, 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 11.1.3 and 11.1.4. 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 11.2.1 and 11.2.2, calculate the concentricity (C) of the expanded and recovered tubing respectively, using the following equation:

$$C = 100\ (M''/M')\tag{1}$$

where:

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

11.4 *Measuring Length*:

11.4.1 Using the steel scale, measure the length to the nearest 1/32 in. or 1 mm.

11.4.2 Allow the specimens to recover under heat as described in 11.1.3 and 11.1.4. 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 11.4.1 and 11.4.2, calculate the percent longitudinal change using the following equation:

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

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, $(S_r)\ j$, and the precision between laboratories, $(S_r)j$, 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.[10] 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.

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 ±5°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.

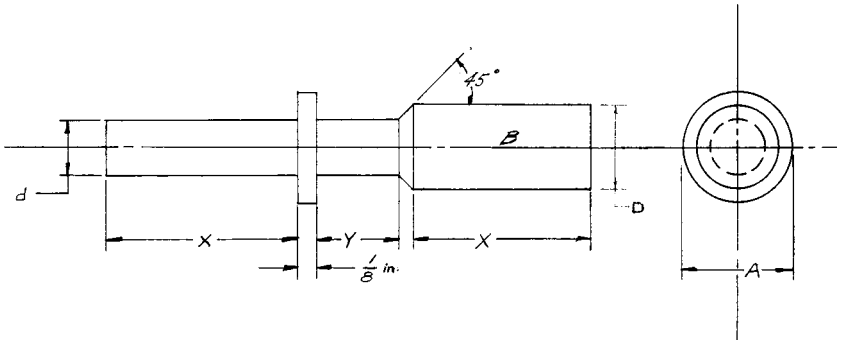
17. Procedure

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

[10] Supporting data are available from ASTM Headquarters. Request RR: D-9-1017.

TABLE 1 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)	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)
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)
Recovered wall thickness	in. (mm)	PTFE	0.012 (0.304)	0.0007 (0.0178)	0.0010 (0.0254)
		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)
Expanded eccentricity	%	Polychloroprene	12.5	3.0	4.3
		Polyolefin, flexible	26	3.1	6.0
Longitudinal change	%	PVC	−18.4	0.6	1.7
		Polyolefin, flexible	−7.5	1.2	1.7
		Polychloroprene	−1.9	2.3	2.3
		PTFE	30	2.5	3.9



A = minimum expanded diameter of tubing as supplied.
~~*B* = longer diameter section of the mandrel (Note 4).~~
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.
⅛ 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), a straight cylindrical mandrel may be used having an outside diameter conforming to dimension *D* of Fig. 1.

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 ~~3~~4—Means of applying heat other than the use of ovens may be used 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 45—Section B of the mandrel may 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) 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 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, the wall thickness may 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 may be of considerable 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 D 149.

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 ±5°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 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.

23.1.1 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.

23.2 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.

23.3 Immerse the specimens in oil and determine the dielectric breakdown voltage of the shrunk-down specimens using the method described in Test Method D 149. For flat test specimens, use 1-in. (25-mm) electrodes as in Test Method D 149, 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.

23.4 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.

23.5 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_r) *j*, and the precision between laboratories, $(S_r)j$, 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.[11] This test method has no bias because the results are expressed purely in terms of this test method.

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, tubing may 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 ½-in. (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 may be 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.

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[11] 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.

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TABLE 3 Estimated Precision of Tensile Property 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
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)

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. The effect of this relaxation is that the tubing may no longer meet the minimum-expanded dimension, or that it may 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 ± 2°C (104± 4°F) (or other specified temperature) for a period of 2 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 2 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.[11] 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± 2°C, and of such size as to permit convenient bending of specimens around mandrels without removal from the chamber.

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)

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.

38. Test Specimens

38.1 *Procedure A*—Cut three lengths of tubing, each 18 in. (460 mm) long, from the sample of tubing in the expanded state.

38.2 *Procedure B*—Cut ten 1.5-in. (38-mm) lengths of tubing from the sample of tubing in the recovered (shrunk) state. For tubing of inside diameter 0.148 in. (3.76 mm) or less, specimens are to be in full-section form; for tubing of inside diameter greater than 0.148 in., specimens are to be in the form of strips 0.25 in. (6.4 mm) wide by 1.5 in. long.

38.3 *Procedure C*—Cut three specimens each 12 in. (300 mm) long from the sample. For tubing having a recovered diameter greater than 0.4 in. (10 mm) the specimens shall be ¼-in. (6.4-mm) wide strips cut from the 12-in. length of tubing.

NOTE 56—Because no flexible mandrel is readily available that can be conveniently used to test tubing of inside diameter greater than AWG 0 (10 mm), Procedure A is restricted to tubing of inside diameter in the recovered state of less than 0.40 in. (10 mm).

39. Procedure A—Low-Temperature Flexibility

39.1 Select a stranded wire that is the nearest AWG size which is larger than the specified fully recovered diameter of the specimen being tested. See Table 5 for stranded wire sizes suitable for use with common fractional inch tubing sizes.

39.2 Locate the specimen centrally on a 24-in. (610-mm) length of stranded wire and heat shrink the tubing in accordance with 11.1.3.

39.3 Condition the specimens in the cold chamber for a period of 1 h at the specified temperature along with mandrels of the specified diameter.

39.4 After the conditioning period, and while at the specified low temperature, and without removing the specimens from the chamber, bend the tubing around the mandrel for not less than one complete wrap (360°) at a uniform speed of 10 ± 2 s per wrap.

39.5 Remove the specimens and the mandrels from the cold chamber and immediately examine them for evidences of cracking of the tubing.

40. Procedure B—Brittleness Temperature

40.1 Using Procedure A of Test Method D 746, conduct brittleness temperature tests at a specified low temperature.

41. Procedure C—Low-Temperature Flexibility

41.1 Condition the specimens in the cold chamber for 4 h at the specified temperature along with mandrels of the specified diameter.

41.2 Upon completion of this conditioning and at this same temperature, wrap the specimens not less than 360° about the mandrel in approximately 10 ± 2 s. Visually examine the specimens for cracks after removal from the cold chamber.

42. Report

42.1 Report the following information on low-temperature flexibility (Procedure A):

42.1.1 Identification of the tubing,

42.1.2 Specified inside diameter of the tubing specimens,

42.1.3 Size of the wire used,

42.1.4 Size of the mandrel used,

42.1.5 Temperature of the cold chamber, and

42.1.6 Record of cracking of the tubing after flexing.

42.2 Report the following information on brittleness temperature (Procedure B):

42.2.1 Identification of the tubing,

42.2.2 Form of the specimens tested,

TABLE 5 Stranded Wire Flexible Mandrel Sizes for Procedure A Low-Temperature Flexibility

Specified Diameter of Recovered Tubing,		AWG Wire Size
in.	(mm)	
0.023	(0.59)	24
0.031	(0.76)	22
0.047	(1.16)	18
0.062	(1.60)	14
0.093	(2.34)	10
0.125	(3.18)	8
0.187	(4.75)	6
0.250	(6.35)	4
0.312	(7.92)	2
0.375	(9.53)	0

42.2.3 Temperature of the cold chamber, and
42.2.4 Number of specimens failed.
42.3 Report the following information on low-temperature flexibility (Procedure C):
42.3.1 Identification of the tubing,
42.3.2 Nominal size of the tubing,
42.3.3 Size of the mandrel used,
42.3.4 Temperature of the cold chamber, and
42.3.5 Record of cracking of the tubing after wrapping.

43. Precision and Bias

43.1 No statement is made about either the precision or the bias of this test method for measuring low-temperature properties since the result merely states whether there is conformance or nonconformance to the criteria specified in the procedure.

TENSILE STRENGTH AND ULTIMATE ELONGATION

44. Test Specimens

44.1 For tubing of recovered inside diameter not greater than 0.33 in. (8.4 mm), cut five lengths, each 4 in. (100 mm) long, from the tubing in the recovered state.

44.2 For tubing of recovered inside diameter greater than 0.33 in. (8.4 mm), prepare five specimens from tubing in the recovered state by die cutting in accordance with Test Methods D 412, with the long dimension of the die parallel to the longitudinal axis of the tubing.

44.2.1 Prepare elastomeric and flexible plastic tubing with a secant modulus of up to 25 000 psi in the form of Die C of Test Methods D 412.

44.2.2 Prepare all other plastic tubing in the form of Die D of Test Methods D 412.

45. Procedure

45.1 For use in determining elongation, mark two parallel gage lines on the tubing or die specimens, 1 in. (25 mm) apart and centrally located on the specimen. Alternatively, an extensiometer apparatus may be used for this measurement.

45.2 For purposes of calculating tensile strength, measure the inside diameter and wall thickness of the specimens in accordance with the methods in 11.1 and 11.2, selecting those measurements which will provide the minimum cross-sectional area for each specimen.

45.3 For elastomeric and flexible tubing (44.2.1), set the grips of the testing machine 2 in. (50 mm) apart for tubing specimens and 2.5 in. (65 mm) for die cut specimens, and locate the specimens so that the bench marks are centrally spaced between the grips.

45.4 For all other tubing (44.2.2), perform the test as in Section 45 using grips spaced 1 in. (25 mm) apart.

45.5 Determine the breaking force and ultimate elongation in accordance with Test Methods D 412, except use a rate of jaw separation as specified in the tubing specification for the material being tested. Retest any specimen that breaks outside the bench marks.

45.6 A retest is not required for specimens that break outside the benchmark when (*1*) the actual value of elongation is not required (for example, in a pass-fail quality control application) and (*2*) the minimum specified value is achieved prior to break.

46. Calculation

46.1 Calculate the tensile strength and ultimate elongation in accordance with Test Methods D 412.

47. Report

47.1 Report the following information:
47.1.1 Identification of tubing,
47.1.2 Rate of jaw separation used,
47.1.3 Individual and averaged values for tensile strength in pounds-force per square inch (megapascals), and
47.1.4 Individual and averaged values for ultimate elongation in percent.

48. Precision and Bias

48.1 The overall estimates of the precision within laboratories, (S_r) *j*, and the precision between laboratories, (S_r)*j*, are given in Table 6 for four selected materials. These estimates are based on a round robin of five specimens, each run in six laboratories.[11] No bias statement can be made due to the lack of a standard reference material.

HEAT RESISTANCE

49. Significance and Use

49.1 The reduction of tensile strength or ultimate elongation due to exposure to elevated temperatures is indicative of loss of volatile constituents or of chemical changes in the tubing. The specified temperature is sufficiently high to permit the use of a

TABLE 6 Estimated Precision of Dielectric Property 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
Tensile strength	psi (MPa)	Polyolefin, flexible	1600 (11.0)	70 (0.48)	100 (0.69)
		Polychloroprene	1700 (11.7)	60 (0.41)	150 (1.03)
		Polyolefin, semi-rigid	2300 (15.9)	110 (0.76)	260 (1.79)
		PVC	3100 (21.4)	130 (0.90)	260 (1.79)
Ultimate elongation	%	PVC	270	30	30
		Polyolefin, flexible	370	20	20
		Polyolefin, semi-rigid	410	30	40
		Polychloroprene	430	20	50
Stress modulus (tensile stress) at 200 %	psi (MPa)	Polychloroprene	870 (6.0)	40 (0.28)	110 (0.76)
		PTFE	5500 (37.9)	600 (4.14)	670 (4.62)

relatively short exposure period so that the test may be used as an acceptance test for process control. Longer exposure times at other temperatures may be desirable for research purposes.

50. Apparatus

50.1 *Oven*, forced-convection type with an air velocity of between 100 and 200 ft/min (0.5 and 1 m/s), capable of maintaining temperature within ±2.5°C.

51. Test Specimens

51.1 Prepare five specimens in accordance with Section 44.

52. Procedure

52.1 Suspend the specimens in the oven for a specified period of time and at the selected temperature.

52.2 Remove the specimens, allow them to cool to room temperature, and determine the tensile strength and ultimate elongation as required in accordance with Sections 44 to 47, disregarding any change in color of the specimens after heat aging.

53. Report

53.1 Report the following information:

53.1.1 Identification of the tubing,

53.1.2 Oven temperature,

53.1.3 Period of exposure to heat,

53.1.4 Tensile strength in pounds-force per square inch (megapascals) for the aged specimens when required together with the value reported in 47.1.3, and

53.1.5 Ultimate elongation, in percent, for the aged specimens, together with the value reported in 47.1.4.

54. Precision and Bias

54.1 The overall estimates of the precision within laboratories, $(S_r)j$, and the precision between laboratories, $(S_R)j$, are given in Table 7 for four materials. These estimates are based on a round robin of five specimens, each run in five laboratories.[12] This test method has no bias because the results are expressed purely in terms of this test method.

COLOR

55. Color

55.1 Determine the color of the tubing in the expanded condition in accordance with Test Method D 1535. As an alternative method when permitted, the procedure described under Military Specification MIL-STD-104 may be used, employing color chips.

[12] Supporting data are available from ASTM Headquarters. Request RR: D-9-1028.

TABLE 7 Estimated Precision for Heat Resistance Property Measurements for Four Tubings

Property	Units	Tubing Type	Nominal Value	$(S_r)_j$	$(S_R)_j$
Tensile strength	psi (MPa)	Polyolefin, flexible whole tube specimen	2260 (15.6)	117 (0.81)	156 (1.08)
		Polyolefin, flexible die cut specimen	2220 (15.3)	84 (0.58)	183 (1.26)
		PVC	3130 (21.6)	68 (0.47)	155 (1.07)
		Polychloroprene	1610 (11.1)	53 (0.37)	70 (0.48)
Ultimate elongation	%	Polyolefin, flexible whole tube specimen	320	19	25
		Polyolefin, flexible die cut specimen	380	16	32
		PVC	220	18	35
		Polychloroprene	340	19	26

56. Precision and Bias

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

COLOR STABILITY

57. Significance and Use

57.1 For purposes of coding, it is important that the color of tubing shall be sufficiently stable during service life so that one color cannot be mistaken for another. By means of an accelerated aging test at an elevated temperature in the absence of light, this test method indicates the extent of the change, if any, in the color of tubing by reference to standard color notations or to standard colors.

58. Apparatus

58.1 *Oven*, forced-convection type, capable of maintaining temperature to within ±2.5°C (±4.5°F).

59. Test Specimens

59.1 Cut three lengths of tubing, each 4 in. (100 mm) long, from the sample of tubing in the expanded state.

60. Procedure

60.1 Place the specimens in an oven for the time and temperature specified. If the time is not specified, it shall be for a period of 24 h.

60.2 Remove the specimens, allow them to cool to room temperature, and determine the color in accordance with 55.1.

61. Report

61.1 Report the following information:

61.1.1 Identification of the tubing,

61.1.2 Aging temperature and time, and

61.1.3 Color designation of the specimens, both before and after aging.

62. Precision and Bias

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

FLUID RESISTANCE

63. Significance and Use

63.1 Resistance of tubing to attack by fluid is dependent on the nature of the compound and the processing conditions used in the manufacture of the tubing, the composition of the fluid, and the time and temperature of exposure. This test serves to evaluate the effects of fluid immersion on tubing by means of determining changes, if any, in tensile strength, ultimate elongation, breakdown voltage or dielectric strength, of treated specimens.

64. Test Specimens

64.1 For each fluid evaluated, cut ten lengths, each 6 in. (150 mm) long, from the sample of tubing.

64.1.1 Prepare five of these specimens for the tensile strength test in accordance with Section 44. If weight change is to be determined, weigh each of the fully prepared tensile specimens using an analytical balance capable of reading 0.0001g.

64.1.2 Prepare the other five specimens for the dielectric breakdown or dielectric strength test, in accordance with Section 22. Recover specimens which have a recovered diameter of 1 in. (25.4 mm) or less without mandrels using the procedure of 11.1.3. Recover larger size specimens using the procedure of 23.2.

65. Procedure

65.1 Immerse ten specimens in each fluid for a period of 24 ± 2 h at a specified temperature, using a volume of fluid not less than 20 times that of the specimens, and making sure that the container is not affected by the fluid under the conditions of the test.

65.2 Remove the specimens from the fluid, lightly wipe dry, and allow them to air dry for 45 ± 15 min at room temperature.

65.3 When weight change is being determined, weigh each of the tensile specimens before performing the tensile test and determine the change in weight as a percentage of the original weight.

65.4 Determine the tensile strength of five specimens in accordance with Sections 44 to 56, using the dimensions obtained on specimens prior to immersion as a basis of calculating tensile strength.

65.5 For specimens being tested as tubes, insert metal mandrels, choosing a mandrel diameter that will snugly fit the specimen. Determine the breakdown voltage or dielectric strength on the five specimens in accordance with Section 23.

66. Report

66.1 Report the following information:
66.1.1 Identification of the tubing,
66.1.2 Identification of fluids used (composition, purity, etc.),
66.1.3 Immersion temperature and time,
66.1.4 Average tensile strength of tubing in pounds-force per square inch (megapascals) of tubing after exposure to solvent,
66.1.5 Average ultimate elongation,
66.1.6 Average breakdown voltage, in kilovolts, of specimens after exposure to fluid, together with values obtained in 24.1.3,
66.1.7 Wall thickness of each specimen in inches or millimetres,
66.1.8 Average dielectric strength in volts per mil or kilovolts per millimetre, and
66.1.9 Average change in weight as a percentage of the original weight.

67. Precision and Bias

67.1 The overall estimates of the precision within laboratories, $(S_r)_j$, and the precision between laboratories, $(S_R)_j$, are given in Table 8 for four selected materials. These estimates are based on a round robin of the four materials with six laboratories participating.[11]

FLAMMABILITY

68. Scope

68.1 This is a fire-test-response standard. The test procedures measure the resistance of the tubing to ignition and propagation of flame after ignition under prescribed conditions of test.

68.2 *This standard should be used to measure and describe the properties of materials, products, or assemblies to heat and flame under controlled laboratory conditions and should not be used to describe or appraise the fire-hazard or fire-risk of materials, products, or assemblies under actual fire conditions. However, results of this test may be used as elements of a fire hazard or a fire-risk assessment which takes into account all of the factors which are pertinent to an assessment of the fire hazard or fire risk of a particular end use.*

69. Significance and Use

69.1 These procedures may be used to compare the flammability of different tubings having the same dimensions.

69.2 Procedure A provides a test geometry in which the test flame is applied to the under side of the specimen and is particularly useful in determining the ignitability of the tubing.

69.3 Procedure B provides a test condition in which the specimen is in contact with an internal metallic conductor simulating a common end use condition. The persistence of burning and the propagation of the flame in an upward direction are readily determined by this test.

69.4 Procedure C differs from Procedure B in that there is only a fine support wire instead of the larger metallic conductor which contacts the inner wall. In addition, this procedure determines the tendency to ignite nearby flammable materials by the occurrence of falling flaming particles. These variations make Procedure C generally a more severe test than Procedure B.

70. Procedure A

70.1 Determine the flammability in accordance with Test Methods D 876.

71. Procedure B

71.1 *Scope*:

TABLE 8 Estimated Precision of Fluid Resistance Property Measurements for Selected Tubings

Property	Units	Generic Type	Nominal Value	$(S_r)_j$	$(S_R)_j$
Tensile strength	psi (mPa)	Polyolefin, flexible[A] die cut specimen	1500 (10.3)	102 (0.70)	127 (0.88)
		PVDF[A]	6835 (47.1)	483 (3.33)	1108 (7.63)
		PVC[B]	2730 (18.8)	178 (1.23)	185 (1.27)
		Polyolefin, flexible[B] whole section specimen	1980 (13.6)	126 (0.87)	175 (1.21)
Ultimate elongation	%	Polyolefin, flexible die cut specimen	345	8	24
		PVDF	365	35	67
		PVC	250	19	27
		Polyolefin, flexible whole section specimen	365	26	35
Dielectric strength	V/mil (kV/mm)	Polyolefin, flexible 1-in. tube	685 (27.0)	85 (3.3)	95 (3.7)
		PVDF	650 (25.5)	85 (3.3)	98 (3.9)
		PVC	735 (28.9)	53 (2.1)	81 (3.2)
		Polyolefin, flexible ¼-in. tube	850 (33.5)	105 (4.0)	129 (5.1)

[A] Immersed 24 hr at room temperature in MIL-H-5606 hydraulic fluid.
[B] Immersed 24 hr at room temperature in MIL-L-7808 lubricating oil.

71.1.1 This test covers the determination of the extent and rate of flame travel from the site of initial ignition under the prescribed conditions of the test.

71.2 *Significance and Use*:

71.2.1 This test may be used to compare flammability of different tubings having the same dimensions. It simulates to some extent an end-use condition, in that tests are conducted on tubing fitted with a metallic core and an evaluation is made of the tendency of the tubing to convey flame along its length.

71.2.2 This test does not duplicate conditions in a fire and cannot be used to certify whether or not a material is fire-resistant.

71.3 *Apparatus*:

71.3.1 *Sheet-Metal Enclosure*—A three-walled enclosure, 12 in. (300 mm) wide by 14 in. (360 mm) deep by 24 in. (610 mm) high, open at the top and front, and having a provision for centering a vertical specimen of tubing 21 in. (530 mm) long.

71.3.2 *Burner*—A gas burner with a 0.38-in. (9.5-mm) bore, equipped with a pilot-flame device. The barrel of the burner shall be from 3.5 to 4 in. (90 to 100 mm) long above the primary inlet. It shall be mounted on a hinged support so that its base can be tilted 20° from the horizontal during the period that the flame is applied to the specimen, and so that the flame will impinge on the specimen at an angle of 70°. The burner shall be fitted with a gas-regulating valve and a shut-off valve.

71.3.3 *Gas Supply*—Public utility or methane gas may be used. For referee purposes, commercial-grade methane gas having a nominal heating value of 1000 Btu/ft^3(3.7×10^7 J/m^3) shall be used at a line pressure of 7 in. (175 mm) of water.

71.3.4 *Timepiece*—A timing device, graduated in seconds.

71.3.5 *Flame Indicators*—Strips of ½-in. (13-mm) wide gummed paper.

71.3.6 *Specimen Support Mandrels*—Lengths of metal conductors or rods, 21 in. (530 mm) in length to be used for supporting specimens during the test. Diameters of the mandrels shall be equal to the specified maximum recovered diameters of the specimens under test. Types of mandrels to be used will be as specified in the applicable material specification.

71.4 *Test Specimens*:

71.4.1 Cut five lengths of tubing, approximately 18 in. (460 mm) long, from the tubing sample in the expanded state.

71.5 *Procedure*:

71.5.1 Place the metal enclosure in a hood or cabinet free from drafts. Support the specimen centrally on a mandrel, shrink the tubing, and secure it with its longitudinal axis vertical in the center of the enclosure. Attach a gummed paper indicator to the specimen so that its lower edge is 10 in. (250 mm) above the point of flame impingement, and trim the paper to provide a flag 0.5 in. (13 mm) wide that projects 0.75 in. (19 mm) from the specimen directly toward the rear of the enclosure.

71.5.2 With the burner upright, adjust the flame height to 5 in. (130 mm) with the inner core of the flame at 1.5 in. (40 mm). The distance between the edge of the burner and the edge of the specimen shall be 1.5 in., measured along the axis of the burner. Turn off the gas supply and set the burner against the specimen at the required angle. Light the pilot flame.

71.5.3 Open the gas supply to the burner, permitting the pilot flame to ignite the burner. Apply the flame to the specimen for 15 s, after which time extinguish the flame by closing the gas supply for 15 s. Repeat this for a total of five times.

71.5.4 Determine the duration of burning of the specimen following the fifth cycle of flame application. Observe whether the paper indicator is burned, and if so, determine the percentage of charred or burned area, ignoring soot that can be removed by wiping. Observe whether flaming or glowing particles fall from the specimen during the test.

71.6 *Report*:

71.6.1 Report the following information:

71.6.2 Identification of the tubing,

71.6.3 Inside diameter and wall thickness of the specimens, after shrinking,

71.6.4 Percentage of burned or charred area of the paper indicator,

71.6.5 Duration of burning in seconds of all specimens following the fifth cycle of flame application, and

71.6.6 Occurrence, if any, of falling, burning particles from any of the specimens at any time during the test.

71.7 *Precision and Bias*:

71.7.1 A precision statement has not been determined. This test method has no bias because the results are expressed purely in terms of this test method.

72. Procedure C

72.1 *Apparatus*:

72.1.1 The apparatus for Procedure C is the same as for Procedure B with the exception of the specimen support mandrels. For specimens having a nominal inside diameter of 0.032 in. (0.8 mm) or larger, a 0.029 in. (0.077 mm) spring-steel music wire shall be used to support the specimen during the test. For specimens having a nominal inside diameter between 0.019 in. (0.049 mm) and 0.032 in. the support wire shall be 0.016 in. (0.041 mm) in diameter. For specimens smaller than 0.019 in. the support wire shall be 0.010 in. (0.025 mm) in diameter.

72.1.2 *Cotton*—Untreated surgical cotton approximately ⅛ in. (3 mm) thick.

72.2 *Test Specimens*:

72.2.1 Cut five lengths of tubing approximately 26 in. (660 mm) long. Completely heat recover the specimens in accordance with 11.1.3.

72.3 *Procedure*:

72.3.1 Draw the specimen onto a length of support wire sufficient to permit the attachment of the wire to the upper and lower supports. The upper end of the tubing shall be clamped so as to be completely closed to prevent chimney effects. Attach a paper indicator flag as in Procedure B. Place a flat horizontal layer of untreated surgical cotton over the burner wedge and the floor of the test enclosure. The upper surface of the cotton is to be no more than 9.5 in. (241 mm) below the point at which the tip of the blue inner cone of the flame touches the specimen.

72.3.2 Set up and operate the burner as in Procedure B. Open the gas valve to apply the gas flame to the specimen for a period of 15 s and then close the valve to remove the flame. Do not reapply the flame until all flaming and glowing of the specimen has ceased or for 15 s, whichever is greater. Repeat this cycle until the specimen has received a total of five 15-s flame applications with appropriate delays between applications.

72.3.3 Determine the total of flaming plus glowing time of the specimen after each of the five gas flame applications. Observe whether the paper indicator is burned, and if so, determine the percentage of charred or burned area, ignoring soot that can be removed by wiping. Observe whether falling particles have ignited the cotton.

72.4 *Report*—Report the following information:

72.4.1 Identification of the tubing,

72.4.2 Inside diameter of the specimens after shrinking,

72.4.3 Maximum duration of burning and glowing in seconds after any of the five flame applications for each specimen,

72.4.4 Percentage of burned or charred area of the paper indicator, and

72.4.5 Any flaming ignition of the cotton caused by particles falling from the specimen during the test.

72.5 *Precision and Bias*:

72.5.1 A precision statement is under development. This test method has no bias because the results are expressed purely in terms of this test method.

SPECIFIC GRAVITY

73. Procedure

73.1 Determine the specific gravity of tubing in the expanded state in accordance with Test Methods D 792, Method A 1 at 23°C.

74. Precision and Bias

74.1 The precision and bias of Test Methods D 792 is applicable.

VOLUME RESISTIVITY

75. Test Specimens

75.1 Cut three lengths of tubing, each 10 in. (250 mm) long, from the tubing in the expanded state.

75.2 Heat shrink the tubing prior to testing in accordance with 23.1 and 23.2, except do not apply metal foil.

75.3 For specimens tested over mandrels, apply a 6-in. (150-mm) long silver-paint electrode around the center section of the specimen. At least 1 in. (25 mm) of tubing should extend beyond the silver paint at each end of the specimen.

75.4 For specimens tested as sheets, apply a silver-paint measuring electrode at least 2 in. (50 mm) in diameter to the center of the specimen. Guarded or unequal electrode systems may be used.

76. Procedure

76.1 Determine the volume resistivity in accordance with Test Methods D 257.

76.2 Make the measurement at 500 V dc after an electrification time of 1 min.

77. Report

77.1 Report the following information:

77.1.1 Identification of tubing,

77.1.2 Form of specimens tested (that is, mandrel or flat),

77.1.3 Thickness of the specimens,

77.1.4 Size and type of electrode system used,

77.1.5 Test conditions at time of measurement (temperature, relative humidity, and conditioning time),

77.1.6 Method of measurement (See Appendix of Test Methods D 257), and

77.1.7 Calculated values of volume resistivity in ohm-centimetres.

78. Precision and Bias

78.1 The discussion of precision in Test Methods D 257 is applicable. Operators familiar with testing heat-shrinkable tubing using this test method estimate that results will not differ significantly from results obtained on other materials commonly tested with Test Methods D 257. There is no information on bias.

WATER ABSORPTION

79. Procedure

79.1 Determine the water absorption of tubing in accordance with Test Method D 570. Unless otherwise stated in the tubing specification, immerse the specimens for 24 h in distilled water maintained at a temperature of 23 ± 2°C (73 ± 4°F).

80. Precision and Bias

80.1 The precision and bias of Test Method D 570 is applicable.

SECANT MODULUS

81. Test Specimens

81.1 Cut five lengths, each 12 in. (300 mm) long, from the tubing sample in the expanded form unless otherwise specified in the tubing specification.

81.2 For tubing of inside diameter not greater than 0.25 in. (6.4 mm), test specimens in the tubing form. For tubing with an inside diameter greater than 0.25 in., test the specimens in strip form.

82. Procedure

82.1 Determine the secant modulus in accordance with Test Methods D 882, using Method A and calculating at 2 % strain, except that the conditioning shall be in accordance with 7.1.

83. Report

83.1 Report the following information:

83.1.1 Identification of tubing,

83.1.2 Form of specimens tested,

83.1.3 Cross-sectional area of each specimen,

83.1.4 Average tensile strength in pounds-force per square inch (kilopascals) at 2 % strain, and

83.1.5 Secant modulus at 2 % strain.

84. Precision and Bias

84.1 The average overall estimate of the precision within laboratories, $(S_r)j$, is 1800 psi (12 411 kPa) and the average overall estimate of the precision between laboratories, $(S_r)j$, is 2600 psi (17 927 kPa) based on a round robin of two materials and six laboratories. These estimates of precision apply to the average result for five specimens of a material having a 2 % secant modulus within the range from 20 000 to 23 000 psi (137 900 to 158 585 kPa).[12] A statement of bias is unavailable in view of the lack of a standard reference material for this property.

STRESS MODULUS

85. Test Specimens

85.1 Prepare the test specimens in accordance with Sections 44 and 45.

86. Procedure

86.1 Determine the stress modulus in accordance with Test Methods D 412, using an elongation of 100 % or other specified elongation.

87. Report

87.1 Report the following information:

87.1.1 Identification of the tubing,

87.1.2 Form of specimens tested,

87.1.3 Cross-sectional area of each specimen,

87.1.4 Average tensile stress in pounds-force per square inch (megapascals) at 100 % or other specified strain, and

87.1.5 Stress modulus in pounds-force per square inch (megapascals) at 100 % or other specified strain.

88. Precision and Bias

88.1 The overall estimates of the precision within laboratories, (S_r) j, and the precision between laboratories, $(S_r)j$, are given in Table 6 for four selected materials. These estimates are based on a round robin of five specimens, each run in six laboratories.[11] No bias statement can be made due to the lack of a standard reference material.

CORROSION TESTING

89. Summary of Test Methods

89.1 Three tests have found use among purchasers and sellers, depending on compound. Procedure A is a noncontact-type test

using a copper mirror at elevated temperature. Procedure B is contact corrosion with heat. Procedure C is a cyclical-corrosion test using humidity and copper dust. The sample preparation procedure is common to all three procedures, and the materials are to be selected for the applicable method. These test procedures have specific applications with respect to the type of composition for tubing material and to the environmental conditions. Tubing specifications shall indicate which procedure, or procedures, shall be applicable.

90. Significance and Use

90.1 Severe corrosion of copper conductor may cause wires to become physically weaker due to pitting (etching), or may affect significantly the current-carrying capacity of such wire. Since corrosion may be the result of chemical interaction between the copper and the tubing composition, the latter may be altered so that its electrical properties are reduced, thereby inducing leakage of current, or even circuit failures. Undesirable volatile or surface by-products may result, having adverse effects on adjacent components of the system.

90.2 Corrosion is frequently dependent upon environmental conditions. Certain tubing compositions may have no effect upon metallic copper in dry heat, but may etch it in humid heat, or vice versa. The oxidation of certain tubing materials may be accelerated in contact with copper if the compounds are stabilized inadequately. In addition, corrosion reactions sometimes are functions of time.

90.3 It is important in many applications to know and understand the corrosive effects of materials in different environments encountered in practice. The three procedures given involve the concepts of temperature, humidity, contact, and noncontact. They are all relatively short-term tests, and can be used relatively easily for purposes of quality control. Experience has shown that no one corrosion test provides all the information concerning the corrosive nature of materials, but these three tests used in conjunction with one another can give extremely good guidance for practical application of materials. Like other corrosion tests, these procedures are subjective in the determination of end points, but experience has been shown to reduce variability in the interpretation of results.

91. Specimen Preparation

91.1 Condition the tubing for 4 h at 23 ± 1°C (73 ± 2°F) and at a relative humidity of 50 ± 2 % prior to testing, unless specified otherwise. Heat shrink the tubing at the time and the temperature specified in the applicable specification.

92. Apparatus

92.1 *Test Tubes*, ½ by 12-in. (13 by 300-mm).

92.2 *Copper-Glass Mirrors*, [13] about 0.25 in. (6 mm) wide and 1 in. (25 mm) long. Store them in a properly conditioned desiccator.

92.2.1 The mirror shall be vacuum deposited copper with a thickness equal to 10 ± 5 % transmission of normal incident light of 5000 A. Do not use these mirrors if an oxide film is present or the copper is visibly damaged.

92.3 *Fine-Copper Wires*.

92.4 *Thermometer or Thermocouple*, 0 to 100°C.

92.5 *Cork*.

92.6 *Aluminum Foil*.

92.7 *Clean Bare-Copper Conductors*.

92.8 *Powdered Copper (Electrolytic)*— Store the powdered copper in a desiccator.

92.9 *Desiccator*.

93. Procedures

93.1 *Procedure A— Copper-Mirror Corrosion:*

93.1.1 *Important Parameters in Copper-Mirror Corrosion*—This test is designed to detect corrosive materials that may be driven off a tubing material at elevated temperatures and condense and corrode a nearby copper mirror that is at or near room temperature. This procedure lends itself to a short-time test; usually a period of 16 h is sufficient to distinguish corrosive from noncorrosive materials.

93.1.2 For tubing having a recovered diameter less than 0.40 in. (10.2 mm), place a number of cut pieces of tubing having a surface area (outside) of approximately 0.25 $in.^2$(150 mm^2) in the bottom of two clean, dry 0.5 by 12-in. (13 by 300-mm) test tubes. For tubing having a recovered diameter of 0.40 in. and greater, use a 0.25 by 1-in. (6 by 25-mm) strip cut longitudinally. Use a third test tube as a control. Suspend a copper-glass mirror about 0.25 in. wide by 1 in. long, along with a thermometer, 6 to 7 in. (150 to 180 mm) above the bottom of the test tube by means of fine copper wires attached to a cork. Seal the test tube with the cork wrapped in aluminum foil.

93.1.3 Immerse the lower 2 in. (50 mm) of the test tubes in an oil bath at the temperature and for the time specified in the applicable specification sheet. Keep the temperature of that portion of the test tube containing the mirror at a temperature below 60°C (140°F).

[13] Mirrors available from the Evaporated Metal Films Corp., 701 Spencer Road, Ithica, New York 14850, have been found satisfactory for this method.

93.1.4 After cooling, examine the mirror by placing it in a white background in good light. Any removal of copper from the mirror will be a sign of corrosion. Disregard any removal of copper from the mirror on the bottom 0.08 in. (2 mm) of the mirror, since drippings may cause this condition. Do not consider discoloration of the copper film or reduction of its thickness as corrosion. Consider the removal of copper so as to be transparent as the corrosion estimate area of copper removal.

NOTE 67—Corrosion may take the form of a meniscus, higher on the edges and lower in the middle of the mirror. In this case, a sample is considered noncorrosive if the total removal of copper from the mirror does not exceed 8 %.

93.2 *Procedure B—Corrosion in Contact with Copper and Copper Stability*:

93.2.1 *Important Parameters in Copper Contact Corrosion*—The test is designed to observe the corrosive effect on copper in contact with the tubing at an elevated temperature. The test can be designed to be a relatively short-time test dependent on the conditions of time and temperature chosen. The stability of the material properties of the tubing when exposed to elevated temperature while in direct contact with bare copper (copper stability) may also be evaluated in this test.

93.2.2 Slide three 6-in. (150-mm) lengths of recovered tubing over straight, clean bare-copper conductors. For tubing of 0.25 in. (6 mm) in inside diameter or smaller, use a single conductor. For tubing larger than 0.25 in. in inside diameter, use several conductors, each AWG 18 (1.02 mm) or smaller. Condition the assembled specimens 24 h at 23 ± 1°C (73 ± 2°F) and 90 to 95 % relative humidity prior to the oven exposure.

93.2.3 Heat the specimens in an air-circulating oven for the time and at the temperature specified in the applicable specification. Remove the specimens from the oven, cool, and condition for 4 h at 23 ± 1°C and a relative humidity of 50 ± 2 %. Slit the tubing open and examine the copper for pitting and blackening. Consider the tubing noncorrosive only if the copper is not pitted or blackened. If the copper is darkened due to air oxidation, this is not cause for rejection. When a copper stability test is being performed, carefully remove the copper conductor from the tubing specimens and perform tensile strength and ultimate elongation on the exposed tubing specimens in accordance with Section 45.

93.3 *Procedure C—Copper Dust Humidity Test*:

93.3.1 *Important Parameters in Copper Dust Humidity Test*—This test is designed to observe the corrosive effect on copper dust of the tubing material when exposed to conditions of humidity and heat. This test supplements the two previous test methods and is a good corrosion test where ingredients in the composition may be fugitive in a humid environment. The temperature-cycling times are chosen to enable the test to be carried out by laboratories that only work an 8-h day shift.

93.3.2 Dust 1.5 in. (38 mm) of each 3-in. (80-mm) length of tubing with powdered copper (electrolytic) by dipping the test specimens into the powder and clamping the tubing at one end. For sizes 1 in. (25 mm) and larger after unrestricted shrinkage, use a 0.5-in. (13-mm) wide strip cut longitudinally.

93.3.3 Place the test specimens on the shelf of a vented desiccator containing water in the lower portion. Then temperature cycle the desiccator containing the samples for a total period of 48 h as follows:

93.3.3.1 Place the desiccator in the oven at 99°C for 16 h. Cool it to room temperature for 1 h.

93.3.3.2 Replace it in the oven for 7 h. Cool it to room temperature for 1 h.

93.3.3.3 Replace it in the oven for 15 h. Cool it to room temperature for 1 h.

93.3.3.4 Replace it in the oven for 7 h. Cool it to room temperature for 1 h.

93.3.4 Condition the test specimens for 4 h at 23 ± 1°C (73 ± 2°F) and at a relative humidity of 50 ± 2 %. Slit the tubing open and examine the copper for evidence of corrosion. Corrosion shall be any evidence of extensive green or brown discoloration of the powdered copper.

94. Report

94.1 Report the following information:

94.1.1 *Procedure A*—Statement that the tubing is corrosive or noncorrosive as defined by the test procedure.

94.1.2 *Procedure B*:

94.1.2.1 Description of copper conductor following removal from the tubing specimen indicating the presence or absence of pitting or blackening.

94.1.2.2 Individual and mean values for tensile strength of tubing if performed.

94.1.2.3 Individual and mean values for ultimate elongation of tubing if performed.

94.1.3 *Procedure C*—Statement that the tubing is corrosive or noncorrosive as defined by the test procedure.

95. Precision and Bias

95.1 The overall estimates of the precision within laboratories, $(S_r)j$, and the precision between laboratories, $(S_R)j$, are given in Table 9 for four materials. These estimates are based on a round robin of five specimens, each run in five laboratories.[12] This test method has no bias because the results are expressed purely in terms of this test method.

THERMAL ENDURANCE

96. Procedure

96.1 Determine the thermal endurance profile and the temperature index in accordance with IEC 216. The property to be evaluated and the end point shall be defined in the tubing specification.

TABLE 9 Estimated Precision for Copper Stability Property Measurements for Four Tubings

Property	Units	Tubing Type	Nominal Value	$(S_r)j$	$(S_R)j$
Tensile strength	psi (MPa)	Polyolefin, flexible whole tube specimen	2250 (15.5)	88 (0.61)	182 (1.26)
		Polyolefin, flexible die cut specimen	2060 (14.2)	84 (0.58)	143 (0.99)
		PVC	3130 (21.6)	110 (0.76)	110 (0.76)
		Polychloroprene	1380 (9.5)	90 (0.62)	122 (0.84)
Ultimate elongation	%	Polyolefin, flexible whole tube specimen	325	15	28
		Polyolefin, flexible die cut specimen	370	23	30
		PVC	185	27	43
		Polychloroprene	260	25	44

NOTE ~~7~~8—Further useful information regarding thermal endurance testing may be found in IEEE 98-Thermal Evaluation and Establishment of Temperature Indices of Solid Electrical Insulation Materials.[14]

97. Precision and Bias

97.1 The precision of this test method has not been determined. This test method has no bias because the results are expressed purely in terms of this test method.

ADHESIVE PEEL STRENGTH

98. Significance and Use

98.1 Heat-shrinkable tubing is sometimes used as a component in an assembly. Quite often in these assemblies, adhesives are used to provide bonding for mechanical joining or for environmental sealing. As part of the evaluation of the suitability of an adhesive for its intended use, an adhesive peel strength test is usually used. Selection of an adhesive which is compatible with the chosen components of the assembly, particularly the heat-shrinkable tubing, is critical in obtaining the desired performance of the assembly. Adhesive peel strength is a measurement procedure which is very sensitive to many factors such as temperature, the thickness of the adhesive, the speed of testing, and the condition of the surfaces of the components of the specimen.

99. Apparatus

99.1 *Tensile Test Machine*—A machine that will provide a uniform rate of jaw separation of 2 in. (50 mm) per minute unless otherwise specified. It shall also be equipped with a chart recorder to provide a continuous record of the force required to peel the specimen.

99.2 *Oven,* forced-convection type, capable of maintaining temperature to within ±5°C (±9°F).

99.3 *Heat Gun*—A forced hot air gun capable of providing heated air at 288 to 343°C (550 to 650°F), equipped with a suitable size reflector to direct and concentrate the heat on the specimens being assembled.

100. Procedure

100.1 **Warning—Flammable Solvent** (see 5.2).

100.2 *Heat-Shrinkable Tubing to Heat-Shrinkable Tubing*:

100.2.1 Heat recover a 6-in. (150-mm) length of the specified heat-shrinkable tubing on a glass-laminated plastic or a metal tube 1 in. (25 mm) in diameter. Apply heat with a heat gun operating at 288 to 343°C (550 to 650°F). Cool the recovered tubing to room temperature. After cooling, lightly abrade the outside of the recovered tubing and the insides of three 1½-in. (39-mm) lengths of the specified 1½-in. diameter expanded tubing with No. 320 emery cloth.

100.2.2 Wipe with a clean cloth or paper towel wet with methyl ethyl ketone or other compatible solvent and allow to dry 20 to 30 min. If the adhesive to be evaluated is supplied in tape form, spiral wrap the tape, with a 50 % overlap to produce a double thickness of adhesive, over the recovered tubing. If the adhesive is a liquid or paste, spread the adhesive over the entire bonding area of the recovered tubing on the tube following the manufacturer's instructions for the application of the adhesive. Place a strip of ¾ in. wide (19 mm) masking tape lengthwise over the adhesive tape to hold it in place and to provide unbonded ends to insert into a tensile tester. (Fig. 2)

100.2.3 Place three 1½-in. (39-mm) lengths of the tubings, abraded on the inside, over the adhesive, as shown in Fig. 2, and recover as described above. Continue heating for 30 s after the tubing has recovered. To ensure uniform heating, place the assembly in an oven for 10 min at the appropriate shrink temperature for the tubing being used. Cure the adhesive in accordance with the manufacturer's instructions, if the heat shrinking operation is not adequate to do so. Cool to room temperature, and cut along one edge of the masking tape to remove the bonded assembly from the mandrel (Fig. 3). Cut a specimen 1 in. wide (25 mm) (Fig. 4) from the center of each double thickness.

100.2.4 Insert the unbonded ends of each specimen into the jaws of a tensile tester. Operate the machine at a jaw separation speed of 2 in. (50 mm) per minute. Make readings of peel strength at every ½ in. (13 mm) of jaw separation after 1 in. (25 mm) initial separation. The average of four readings shall define peel strength.

[14] Available from the Institute of Electrical and Electronic Engineers, 345 E. 47th St., New York, NY 10017.

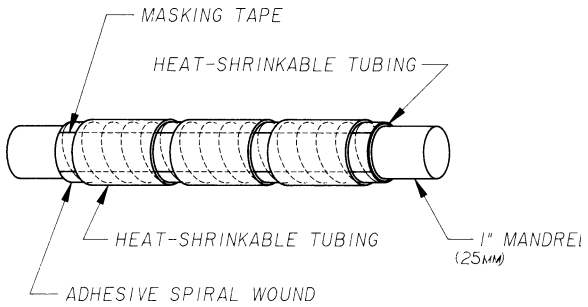

FIG. 2 Mandrel Assembly

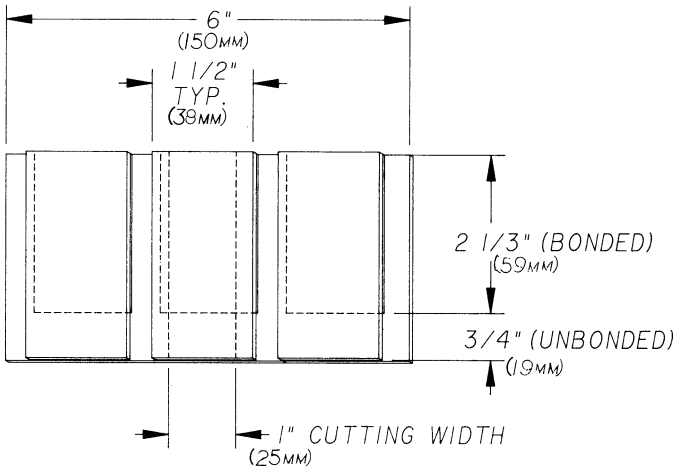

FIG. 3 Slab Specimen

100.3 *Heat-Shrinkable Tubing to Aluminum and Steel*:

100.3.1 Abrade an 8-in. (203-mm) length of 1-in. (25-mm) diameter aluminum pipe or steel pipe (specific material is by choice of the user), with No. 320 emery cloth and wipe with a clean cloth or paper towel wet with methyl ethyl ketone or other compatible solvent. If the adhesive to be evaluated is supplied in tape form, spiral wrap the tape on the mandrel, with a 50 % overlap to produce a double thickness of adhesive. If the adhesive is a liquid or paste, spread the adhesive over the entire bonding area of the metal tube following the manufacturer's instructions for application of the adhesive. Place a strip of ¾ in. wide (19 mm) masking tape lengthwise over the adhesive to hold it in place and to provide unbonded ends to insert into a tensile tester. (Fig. 5)

100.3.2 Abrade, clean, recover, and oven-heat three 1½-in. (39-mm) lengths of 1½-in. diameter heat-shrinkable tubing as described in 100.2.3. After cooling to room temperature, cut tubing into 1 in. (25 mm) wide sections (Fig. 5). Cut each specimen along the edge of the masking tape to free unbonded ends of the tubing.

100.3.3 Place the specimen in a tensile testing machine, with the specimen around the positioning mandrel and the free end of the specimen inserted into the tensile testing machine jaw (Fig. 6). Construct the holding fixture so that the yoke is free to rotate during testing. Test with a jaw-separation speed of 2 in. (50 mm) per min. Take readings of peel strength at every ½ in. (13 mm) of jaw separation after 1-in. (25-mm) initial separation. The average of four readings shall define peel strength.

101. Calculation

101.1 Determine the force to peel the specimen in terms of units of force per unit width of specimen, that is, pounds force per 1 in. or Newtons per 25 mm.

102. Report

102.1 Report the following information:

102.1.1 Description of heat-shrinkable tubing being evaluated.

102.1.2 Description of adhesive used,

102.1.3 Metal substrate, if any,

102.1.4 Cure time and temperature of adhesive, if any,

102.1.5 Averaged peel force for each specimen tested,

102.1.6 Width of each specimen, and

102.1.7 Test result for each specimen and mean for all tests.

103. Precision and Bias

103.1 This test method has been in use for many years, but no statement of precision has been made, and no activity is planned

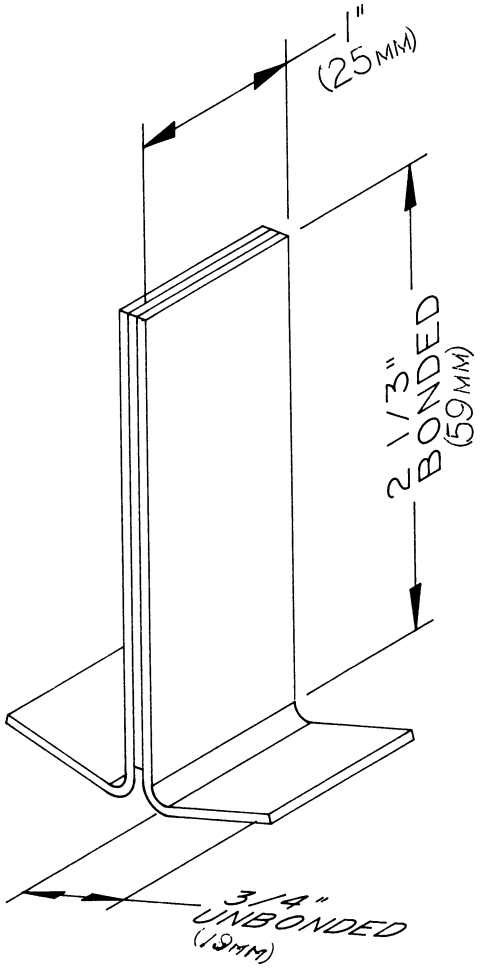

FIG. 4 Peel Strength Specimen

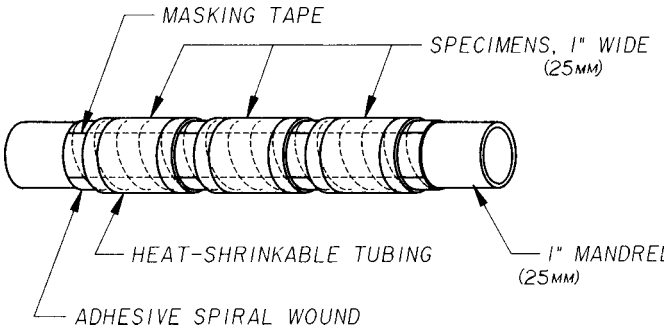

FIG. 5 Peel Specimen Preparation

to develop such a statement. This test method has no bias because the results are expressed purely in terms of this test method.

MELTING POINT

104. Significance and Use

104.1 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.

104.2 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.

104.3 For the purposes of this standard, the terms *melting point* and *melting peak temperature* are used interchangeably.

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

105. Test Specimen

105.1 For specification purposes, conduct the test using a 10 ± 2-mg specimen cut from recovered tubing.

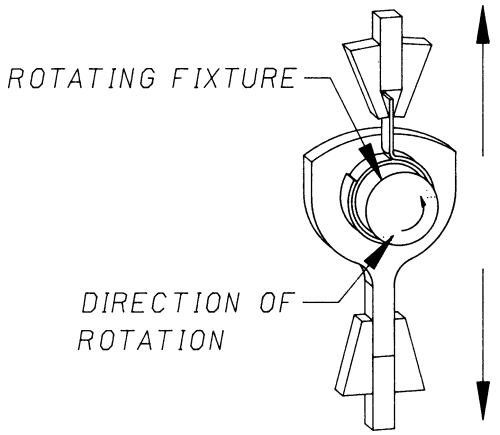

FIG. 6 Peel Specimen in Tensile Tester

106. Procedure

106.1 Use differential scanning calorimetry (DSC) as desribed in Test method D 3418 for this determination; only a single determination is necessary.

106.2 Use a heating rate of 10 ± 1°C (18 ± 1.8°F).

106.3 Report the melting peak temperature of the peak with the largest height as the melting point if a single value is required.

106.4 If a melting peak temperature is difficult to discern from the curves, that is, if the peak is rounded rather than pointed, draw straight lines tangent to the sides of the peak. The temperature corresponding to the point where the lines intersect beyond the peak is the melting peak temperature.

107. Report

107.1 Report the following information:

107.1.1 Indentification of the tubing.

107.1.2 Melting point.

108. Precision and Bias

108.1 The precision and bias information in this section is taken from Test Method D 3418.

108.2 This test method does not yet contain a numerical precision and bias statement, and it shall not be used as a referee test method in case of dispute.

108.3 The precision and bias of this test method are under investigation. Refer to Test Method D 3418 for additional information.

FUNGUS RESISTANCE

109. Significance and Use

109.1 The synthetic polymer portion of these tubings is usually fungus resistant in that it does not serve as a carbon source for the growth of fungi. It is generally the other components, such as plasticizers, stabilizers, and colorants, that are responsible for fungus attack on heat-shrinkable tubings. This test method serves to evaluate the effects of fungus exposure on the tubing by means of determining the tensile strength, ultimate elongation, and dielectric strength of specimens exposed to a suspension of fungus spores in the presence of a complete medium, that is, with a carbon source, under favorable growth conditions. For a more complete discussion, refer to ISO 846.

NOTE 89—This test method is similar to ISO 846, Method B.

110. Test Specimen

110.1 Prepare five specimens for tensile strength and ultimate elongation in accordance with Section 44.

110.2 Prepare five specimens for dielectric strength in accordance with Section 22. Recover specimens which have a recovered diameter of 1 in. (25.4 mm) or less without mandrels using the procedure of 11.1.3. Recover large-size specimens in accordance with the procedure in 23.2.

111. Procedure

111.1 Conduct fungus testing in accordance with ISO 846, Method B for an incubation time of 56 days.

111.2 Determine the tensile strength and ultimate elongation of the five specimens in accordance with Sections 44-47.

111.3 For specimens being tested for dielectric strength as tubes, insert metal mandrels, choosing a mandrel diameter that will snugly fit the specimen. Determine the dielectric strength on the five specimens in accordance with Section 23.

112. Report

112.1 Report the following information on tensile strength and ultimate elongation:
112.1.1 Identification of the tubing,
112.1.2 Rate of jaw separation used,
112.1.3 Average values for tensile strength in pounds-force per square inch (megapascals), and
112.1.4 Average values for ultimate elongation in percent.
112.2 Report the following information on dielectric strength:
112.2.1 Identification of the tubing,
112.2.2 Dielectric strength in volts per mil or kilovolts per millimetre for each specimen, and
112.2.3 Average dielectric strength for the five specimens.

113. Precision and Bias

113.1 The precision of this test method has not been determined by the committee. Operators familiar with this test method estimate that the coefficient of variation of the tensile strength results after fungus exposure within a single laboratory by a single operator is approximately 6 %; the coefficient of variation of the ultimate elongation results after fungus exposure within a single laboratory by a single operator is approximately 5 %; and the coefficient of variation of the dielectric strength results after fungus exposure within a single laboratory by a single operator is approximately 8 %. This test method has no bias because the values for tensile strength, ultimate elongation, and dielectric strength are defined solely in terms of the test methods themselves.

114. Keywords

114.1 adhesive peel strength; brittleness temperature; color; color stability; copper corrosion; dielectric breakdown voltage; dielectric strength; flame resistance; fluid resistance; fungus resistance; heat resistance; heat shock; heat shrinkable tubing; inside diameter; length; low temperature; melting point; restricted shrinkage; secant modulus; specific gravity; storage life; stress modulus; temperature index; tensile strength; test methods; thermal endurance; thermal endurance graph; tubing; heat-shrinkable; ultimate elongation; volume resistivity; wall concentricity; wall thickness; water absorption