Standard Test Methods for Nonrigid Vinyl Chloride Polymer Tubing Used for Electrical Insulation[1]

This standard is issued under the fixed designation D876; 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 general-purpose (Grade A), low-temperature (Grade B), and high-temperature (Grade C)[2] nonrigid vinyl chloride polymer tubing, or its copolymers with other materials, for use as electrical insulation. For the purpose of these test methods nonrigid tubing shall be tubing having an initial elongation in excess of 100 % at break.

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

1.2 The values stated in inch-pound units are 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.

1.3 The procedures appear in the following sections:

Procedure	Section	ASTM Reference Standard
Brittleness Temperature	43 – 45	D746
Corrosion Tests	74 – 85	D1000
Dielectric Breakdown Voltage at High Humidity	65 – 73	E104
Dielectric Breakdown Voltage	58 – 64	D149
Dimensional Tests	8 – 14	D374
Effect of Elevated Temperatures	25 – 36	D412
Flammability Test	15 – 21	
Oil Resistance Test	35 – 42	D471
Penetration Test	46 – 51	
Sampling	6	
Strain Relief Test	68 – 73	
Tension Test	22 – 24	D412
Test Conditions	7	
Volume Resistivity	52 – 57	D257

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* For specific hazard statements, see Section 5.

1.5 *For fire test caveats, see Section 15.*

2. Referenced Documents

2.1 *ASTM Standards:*[3]

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

D374 Test Methods for Thickness of Solid Electrical Insulation (Withdrawn 2013)[4]

D412 Test Methods for Vulcanized Rubber and Thermoplastic Elastomers—Tension

D471 Test Method for Rubber Property—Effect of Liquids

D746 Test Method for Brittleness Temperature of Plastics and Elastomers by Impact

D1000 Test Methods for Pressure-Sensitive Adhesive-Coated Tapes Used for Electrical and Electronic Applications

D1711 Terminology Relating to Electrical Insulation

D5032 Practice for Maintaining Constant Relative Humidity by Means of Aqueous Glycerin Solutions

E104 Practice for Maintaining Constant Relative Humidity by Means of Aqueous Solutions

E176 Terminology of Fire Standards

2.2 *IEC Standards:*

60684–2 Flexible insulating sleeving, Part 2, Methods of test[5]

3. Terminology

3.1 *Definitions:*

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

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[2] Test methods applicable to Grade B will be specified at a later date.

[3] 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.

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

[5] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

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

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.

3.2 *Definitions of Terms Specific to This Standard:*

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

3.2.2 *corrosive effect, n*—under the prescribed conditions, the percentage change in electrical resistance of a fine copper wire in contact with the tubing.

3.2.3 *resistance to penetration, n*—that property of tubing indicated by its resistance to high local pressures, as determined by the temperature at which a steel ball punctures the tubing under the conditions of loading and temperature rise specified in these test methods.

3.2.4 *wall thickness, n*—an average value determined as one half of the difference between the inside and outside diameters of the tubing measured by the test method prescribed herein.

4. Significance and Use

4.1 These test methods include most of the test methods that are considered important to characterize nonrigid vinyl chloride polymer tubing. While they were developed initially for this type of extruded tubing, their use is not limited to this type of tubing.

4.2 Variations in these test methods or alternate contemporary methods are acceptable for use 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 test 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 Process Control (SPC) conditions, using equipment and methods other than those specified herein. An example would be the use of laser micrometers or optical comparators to measure dimensions.

5. Hazards

5.1 *Lethal voltages are a potential hazard during the performance of this test. It is essential that the test apparatus, and all associated equipment electrically connected to it, be properly designed and installed for safe operation. Solidly ground all electrically conductive parts which it is possible for a person to contact during the test. Provide means for use at the completion of any test to ground any parts which were at high voltage during the test or have the potential for acquiring an induced charge during the test or retaining a charge even after disconnection of the voltage source. Thoroughly instruct all operators as to the correct procedures for performing tests safely. When making high voltage tests, particularly in compressed gas or in oil, it is possible for the energy released at breakdown to be sufficient to result in fire, explosion, or rupture of the test chamber. Design test equipment, test chambers, and test specimens so as to minimize the possibility of such occurrences, and to eliminate the possibility of personal injury. If the potential for fire exists, have fire suppression equipment available.*

6. Sampling

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

6.2 Cut the number of specimens required for the purpose of tests from the pieces selected in accordance with 6.1, taking care to select material that is free from obvious defects.

7. Test Conditions

7.1 Unless otherwise specified in these test methods, conduct tests at atmospheric pressure and at a temperature of 23 ± 2 °C (73 ± 4 °F). Room temperature, as stated in these test methods, shall be within this temperature range.

DIMENSIONAL TESTS

8. Significance and Use

8.1 The inside diameter and wall thickness are of importance as a measure of dimensional uniformity. They also provide important data for design purposes, and are used in the calculation of certain physical and electrical properties of the tubing.

9. Apparatus

9.1 *Tapered-Steel Gages*—Use chromium-plated gages suitable for covering the range of tubing sizes shown in Table 1. The gages shall have a uniform taper of 0.010 in./1 in. (0.010 mm/mm) of length, and shall be graduated with circular lathe-cut rings every 0.5 in. (13 mm) of length. The graduations shall then represent a uniform increase in diameter of 0.005 in./0.5 in. (0.010 mm/mm) of length.

9.2 *Micrometers*—Use machinist's type micrometers suitable for covering the range of tubing sizes shown in Table 1.

9.3 *Steel Scale*—A steel scale graduated in 0.01 in. (0.25 mm).

10. Test Specimens

10.1 Cut a 1-in. (25-mm) specimen free of kinks from the sample. Perform this operation perpendicular to the longitudinal axis of the tubing specimen, giving a specimen 1 in. in length having cleanly cut square ends.

11. Procedure for Measuring Inside Diameter

11.1 Select a gage that will fit part way into the tubular specimen. Slip the specimen, without forcing (Note 3), over the gage until there is no visible air space between the end of the specimen and the gage anywhere on the circumference. Consider this point on the gage the inside diameter of the specimen.

NOTE 3—When the tubing specimen tends to stick, it is acceptable to dip the gage in water to facilitate slipping the specimen over the gage. However, when water is used as a lubricant on the gage, exercise sufficient caution to ensure that the specimen is not forced on the gage, thereby stretching the specimen.

TABLE 1 Tubing Sizes

Size	Inside Diameter, in.[A]		
	Max	Min	Nominal
2 in.	2.070	2.000	....
1¾ in.	1.812	1.750	....
1½ in.	1.550	1.500	....
1¼ in.	1.290	1.250	....
1 in.	1.036	1.000	....
⅞ in.	0.911	0.875	....
¾ in.	0.786	0.750	....
⅝ in.	0.655	0.625	....
½ in.	0.524	0.500	....
7⁄16 in.	0.462	0.438	....
⅜ in.	0.399	0.375	....
5⁄16 in.	0.334	0.3125	....
No. 0	0.347	0.325	0.330
No. 1	0.311	0.289	0.294
No. 2	0.278	0.258	0.263
No. 3	0.249	0.229	0.234
No. 4	0.224	0.204	0.208
No. 5	0.198	0.182	0.186
No. 6	0.178	0.162	0.166
No. 7	0.158	0.144	0.148
No. 8	0.141	0.129	0.133
No. 9	0.124	0.114	0.118
No. 10	0.112	0.102	0.106
No. 11	0.101	0.091	0.095
No. 12	0.089	0.081	0.085
No. 14	0.072	0.064	0.066
No. 16	0.061	0.051	0.053
No. 18	0.049	0.040	0.042
No. 20	0.039	0.032	0.034

[A] NOTE—One inch equals 25.4 mm.

11.2 Determine the diameter at the point of contact between the specimen and gage by referring to the nearest visible graduation. With the steel scale, measure any distance between the edge of the specimen and the nearest graduation. Each 0.1 in. (2.5 mm) on the length of the gage represents an increase of 0.001 in. (0.025 mm) in diameter. Since the diameter at the nearest graduation is known, obtain the inside diameter of the specimen by interpolation and report to the nearest 0.001 in.

12. Procedure for Measuring Outside Diameter

12.1 With the specimen located on the tapered gage as described in 11.1, make three outside diameter measurements approximately 120° apart and adjacent to the edge of each specimen. Make the measurements in accordance with Test Methods D374 using Apparatus B, and observing the following additional details:

12.1.1 Support the micrometer to allow both hands to be free for manipulation.

12.1.2 Measure the outside diameter adjacent to, but not on or over the cut edge, and

12.1.3 Rotate the tubular specimen, which is on the tapered mandrel, so that the rotation is an oscillating motion with the outside surface of the tube just touching the fixed anvil of the micrometer. Slowly move the micrometer spindle onto the surface of the tube until the first definite increase in the resistance to rotation of the specimen is encountered. The micrometer reading at this time is the outside diameter of the specimen.

13. Report

13.1 Report the following information:

13.1.1 Inside diameter of the specimen to the nearest 0.001 in. (0.025 mm),

13.1.2 All readings on outside diameter of the specimen to the nearest 0.001 in.,

13.1.3 Average outside diameter, and

13.1.4 Average wall thickness.

14. Precision and Bias

14.1 The precision of this test method has not been determined due to inadequate voluntary participation and funding needed to conduct the round-robin testing. A statement of bias is unavailable in view of the lack of a standard reference material for this property.

FLAMMABILITY TEST

15. Scope

15.1 This is a fire-test-response standard. The test procedure described measures the resistance of the tubing to ignition or the spread of flame after ignition when tested under the specified conditions.

15.2 *This standard is used to measure and describe the response of materials, products, or assemblies to heat and flame under controlled conditions, but does not by itself incorporate all factors required for fire hazard or fire risk assessment of the materials, products, or assemblies under actual fire conditions.*

15.3 *Fire testing is inherently hazardous. Adequate safeguards for personnel and property shall be employed in conducting these tests.*

16. Significance and Use

16.1 This is an acceptable test for use to compare tubing made from different compounds provided that specimens with the same dimensions are used, but it is not necessarily a measure of the flammability of the compound.

17. Apparatus

17.1 *Sheet Metal Enclosure*—A three-walled sheet metal enclosure 12 in. (300 mm) wide by 14 in. (360 mm) deep by 29 in. (740 mm) high, open at the top. It shall be equipped with two parallel horizontal metal rods 16 in. (410 mm) apart, so situated that a wire stretched perpendicularly across each rod shall be at a 70° angle with the horizontal. The lower rod shall be approximately 2 in. (50 mm) from the rear wall.

17.2 *Bare Steel Wire*—A length of bare steel wire, approximately 0.029 in. (0.74 mm) in diameter, shall be used for supporting the specimens during the test.

17.3 *Burner*—A burner with a ⅜-in. (9.5-mm) nominal bore and suitable for the gas supplied. The tube of the burner shall be approximately 3½ in. (90 mm) long above the primary inlet. It shall be mounted upon a positioning mechanism similar to that shown in Fig. 1. As shown in the figure, a pivoted positioner which forms an extension of the center line of the burner barrel is attached to the barrel of the burner so as to locate the exact point of impingement of the inner cone on the test specimen. The base of the burner shall be tilted 25° from the horizontal during the period that the flame is applied to the specimen, and the flame shall impinge upon the specimen at an angle of 45°. The system shall contain a gas regulating valve as well as a shutoff valve.

17.4 *Gas Supply*—Public utility or propane gas are acceptable for use. For referee purposes, commercial grade propane gas having a nominal heating value of 2521 Btu/ft^3 and a specific gravity of 0.508 at 60 °F shall be used at a line pressure of 11 in. (279 mm) water column.

NOTE 4—If no regular delivery lines are available for propane gas, the use of small tanks is an acceptable alternate.

17.5 *Timepiece*—A timepiece measuring seconds shall be provided to measure the duration of flame application and specimen burning time.

17.6 *Flame Indicators*—Strips of gummed paper shall be provided to be used in determining the length of specimen burned.

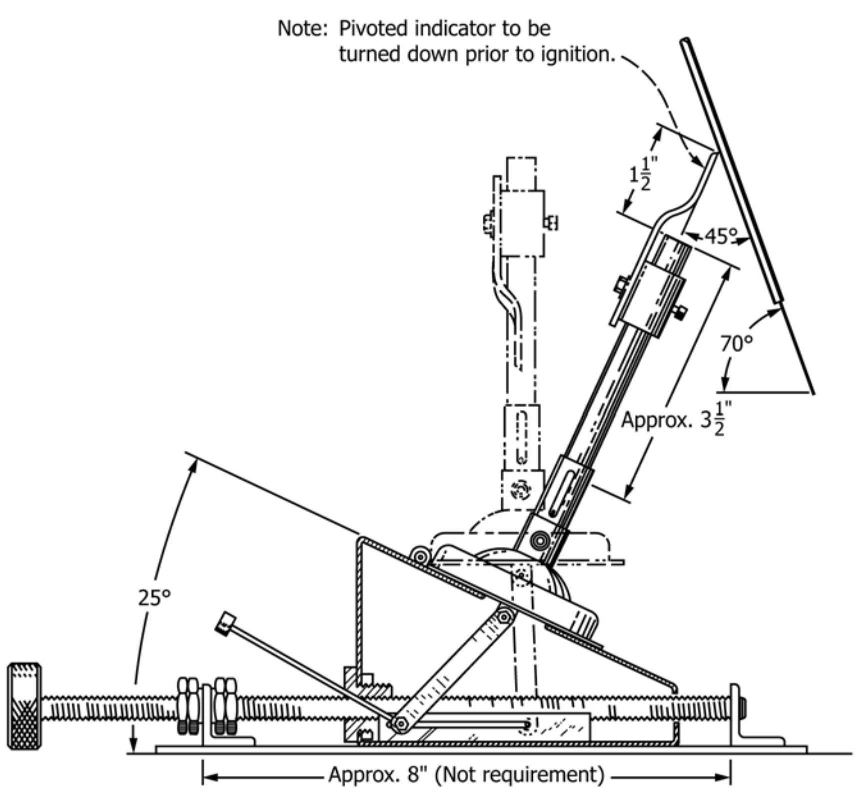
18. Test Specimens

18.1 Cut five test specimens approximately 22 in. (560 mm) in length from the sample.

19. Procedure

19.1 Conduct the test with the enclosure situated in a hood or cabinet free from drafts. Draw the specimen onto the wire. Attach the specimen and the wire at one end to the middle of the upper horizontal bar by kinking the tubing and clamping so as to provide a closed end to the specimen, thus preventing any chimney effects during the test. Pass the lower end of the wire protruding from the open end of the tubing over the middle of the lower horizontal bar, and hold it taut against the bar by a weight of at least 1 lb (500 g), attached to the free end of the wire. In the case of tubing having a cross section deviating from circular, position the edge having the smallest radius of curvature nearest the flame. Attach the paper indicator to the specimen so that the lower edge is 10 in. (250 mm) above the point of flame application.

19.2 With the burner in a vertical position adjust the height of the flame to 5 in. (130 mm) with the inner cone at 1½ in. (40 mm). The distance between the end of the burner and the edge of the test specimen shall be 1½ in. measured along the axis of the burner. After preliminary positioning of the burner and before lighting the burner preparatory to application of the



Metric Equivalents

in.	1½	3½	8
mm	38.1	88.9	203.2

FIG. 1 Positioning Mechanism for Burner

flame to the tubing, pivot the positioner away from the flame area. The burner shall be in an upright position when ignited and shall be dropped into testing position at the instant that the timer is started. Apply the flame to the specimen for 15 s and then extinguish it by turning off the gas supply from outside the test cabinet.

19.3 Determine the duration of burning of the specimen from the time of extinction of the gas flame. Determine the length of specimen burned either by direct measurement or by subtracting the length of the unburned portion from 10 in. (25.4 cm).

20. Report

20.1 Report the following information:

20.1.1 Inside diameter and average wall thickness of the sample, in inches, from which the specimens were taken (Sections 11 and 12),

20.1.2 Maximum and minimum durations of burning, in seconds, for the five specimens; and the average duration of burning based on the remaining three tests, after the exclusion of one maximum and one minimum value, and

20.1.3 Maximum and minimum burned lengths, in inches, for the five specimens, and the average burned length based on the remaining three tests, after the exclusion of one maximum and one minimum value.

20.2 The results are the average duration of burning and the average burned length based on the remaining three tests after exclusion of one maximum and one minimum value.

21. Precision and Bias

21.1 The precision of this test method has not been determined due to inadequate voluntary participation and funding needed to conduct the round-robin testing. This test method has no bias because the results are expressed purely in terms of this test method.

TENSION TEST

22. Procedure

22.1 Determine the tensile strength and ultimate elongation in accordance with Test Methods D412, with the following exceptions:

22.1.1 For sizes No. 20 to 0, inclusive, prepare six test specimens by cutting lengths from the sample and subjecting them to the tension test in tubing form.

22.1.2 For sizes 5⁄16 in. to 2 in. (7.9 to 50 mm), inclusive, in inside diameter prepare six test specimens taken from the sample in the form as represented by Die B of Test Methods D412. Do this by cutting one wall along a longitudinal axis, flattening the piece, and applying Die B parallel to this axis.

22.1.3 Measure the inside and outside diameters in accordance with Sections 9 – 13.

22.1.4 In determining the tensile strength use the average area of the specimens selected.

22.1.5 Mark two parallel gage lines for use in determining elongation on the tubing, perpendicular to the longitudinal axis, one on each side of the center and 1 in. (25 mm) therefrom.

22.1.6 Make the distance between grips of the testing machine 4 in. (100 mm).

22.1.7 Use a uniform rate of travel of the power actuated grip of 12 in. (305 mm)/min.

22.1.8 Discard results on specimens that break outside of the gage marks and retest.

23. Report

23.1 Report the following information:

23.1.1 Size of tubing from which the specimens were taken,

23.1.2 All observed and recorded data on which the calculations are based,

23.1.3 Average tensile strength determined on the best five out of six specimens, and

23.1.4 Average ultimate elongation determined on the best five out of six specimens.

24. Precision and Bias

24.1 The precision of this test method has not been determined due to inadequate voluntary participation and funding needed to conduct the round-robin testing. A statement of bias is unavailable in view of the lack of a standard reference material for this property.

EFFECT OF ELEVATED TEMPERATURES

25. Scope

25.1 The effect of elevated temperature is indicated by the changes in ultimate elongation and weight caused by exposure of the tubing to elevated temperatures for a specified time under controlled conditions of air circulation.

26. Significance and Use

26.1 Loss of elongation or weight as caused by exposure of the tubing to elevated temperatures is indicative of factors such as volatile constituents or chemical changes in the tubing. The temperature used is higher than that recommended for continuous service and the exposure period of Procedure B is relatively short so that the test is suitable for use as an acceptance test for quality control. Longer exposure times and other temperatures are necessary for research purposes.

26.2 Both methods shall be conducted to obtain full data on the effect of elevated temperatures. It is recommended that Procedure A be correlated with the Strain Relief Test (Sections 71 to 75), since percentage change in ultimate elongation indicates the effect of elevated temperatures on a specimen only if it originally has a minimum of internal strains. Specimens with initially high internal strains will, in general, show less change in ultimate elongation than those with a minimum of strains. Use procedure A only for qualification or for comparative evaluation of various materials, not as an inspection test for quality control purposes.

Procedure A—Using Tension Test

27. Apparatus

27.1 *Oven*—The oven shall conform to the following requirements:

27.1.1 The design shall be such that heated air passes through the specimen chamber and is exhausted without being recirculated.

27.1.2 Provision shall be made for suspending specimens, preferably vertically, without bending and without touching each other or the sides of the chamber. The specimen chamber shall be so designed, or the oven so compartmented, that air passing over any specimen shall not come in contact with other specimens in the oven.

27.1.3 The temperature at any point along the length of the specimens shall vary not more than ±1 °C from the specified temperature.

27.1.4 The heating medium shall be air at atmospheric pressure, and the source of heat shall be external to the specimen chamber or chambers.

27.1.5 The air flow shall be lengthwise along the specimens and shall be at the rate of 100 ± 10 in. (2500 ± 250 mm)/min.

27.1.6 *Tension Testing Machine*—The tension testing machine shall be the same as prescribed in Test Methods D412.

28. Test Specimens

28.1 Cut six specimens from the sample (Section 5), and prepare in a manner similar to that described in 22.1.1 and 22.1.2, according to the various sizes of tubing.

29. Procedure

29.1 Suspend three specimens in the oven described in 27.1. Keep tubing specimens open throughout their entire lengths. Maintain the specimens at the temperatures listed below for a period of 400 h:

Grade A, Grade B	100 ± 1 °C (212 ± 2 °F)
Grade C	130 ± 2 °C (266 ± 4 °F)

At the end of the specified time, remove the specimens, and keep them at room temperature for a period of 16 h but not longer than 20 h. After the rest period, place gage lines, 2 in. (50 mm) apart, on each specimen. Place each specimen in the tension testing machine and determine the ultimate elongation as described in Section 22.

29.2 Place gage lines 2 in. (50 mm) apart on each of the remaining three untreated specimens. Place each specimen in the tension testing machine and determine the ultimate elongation.

NOTE 5—The results for elongation obtained in Section 21 are an acceptable choice for use as the unaged values.

29.3 Compare the ultimate elongation values from the aged specimens to the values from the unaged specimens. If these ultimate elongation values are not within 10 % of the highest value obtained in the unaged specimens, test three additional specimens. Use the average of all tests run as the final value of ultimate elongation for aged specimens.

30. Report

30.1 Report the following information:

30.1.1 The sample size from which specimens were taken,

30.1.2 Average ultimate elongation of specimens before aging,

30.1.3 Average ultimate elongation of specimens after aging, and

30.1.4 Average percentage change in ultimate elongation.

31. Precision and Bias

31.1 The precision of this test method has not been determined due to inadequate voluntary participation and funding needed to conduct the round-robin testing. A statement of bias is unavailable in view of the lack of a standard reference material for this property.

Procedure B—Using Weight Loss on Heating

32. Apparatus

32.1 *Chemical Balance.*

32.2 *Oven*—The oven shall conform to the requirements prescribed in 27.1.

32.3 *Desiccator.*

33. Test Specimens

33.1 Cut test specimens 6 in. (152 mm) in length from full-section tubing.

34. Procedure

34.1 Place three specimens in a desiccator and condition them at room temperature over calcium chloride for 24 h. At the end of this period immediately weigh the specimens. Suspend them vertically in the oven described in 27.1, without touching each other or the sides of the oven. Keep the tubing specimens open throughout their entire lengths. Maintain the specimens at the temperatures listed below for 72 h:

Grade A, Grade B	100 ± 1 °C (212 ± 2 °F)
Grade C	130 ± 2 °C (266 ± 4 °F)

At the end of the specified time, remove the specimens, and keep them at room temperature over calcium chloride for 1 h. Upon removal from the desiccator immediately weigh the specimens.

35. Report

35.1 Report the following information:

35.1.1 The sample size from which specimens were taken, and

35.1.2 The loss of weight calculated as a percentage of the original weight.

36. Precision and Bias

36.1 The precision of this test method has not been determined due to inadequate voluntary participation and funding needed to conduct the round-robin testing. This test method has no bias because the results are expressed purely in terms of this test method.

OIL RESISTANCE TEST

37. Significance and Use

37.1 The tubing covered in these test methods is often used in places where it comes into contact with lubricating oils. While the tubing is in service, it is possible that there will be accidental oil spill on the surface or that there will be deposits due to oil splashes resulting from lubricated moving parts. As a consequence it is important to ascertain the effect of lubricating oil in contact with flexible vinyl tubing.

37.2 Correlate the oil resistance test with the Strain Relief Test (Sections 68 – 73) since percentage change in ultimate elongation indicates the oil resistance of a specimen only if it originally has a minimum of internal strains. Specimens with initially high internal strains will, in general, show less change in ultimate elongation than those with a minimum of strains.

38. Apparatus

38.1 The apparatus shall be the same as that described in Section 27.

39. Test Specimens

39.1 Cut three specimens from the sample (Section 5) in a manner similar to that described in 22.1.1 and 22.1.2 according to the various sizes of tubing.

40. Procedure

40.1 Totally immerse the test specimens in IRM 903 high-swelling oil as described in Test Method D471, at temperatures listed below for a period of 4 h:

Grade A, Grade B	70 ± 1 °C (158± 2 °F)
Grade C	105 ± 1 °C (221 ± 2 °F)

At the end of this time, remove the specimens from the oil, blot to remove excess oil, allow them to cool at room temperature for 30 min, bathe in mineral spirits at room temperature to remove the remaining film of oil from the surface, and wipe them dry. Place gage marks 2 in. (50 mm) apart on each specimen and determine the ultimate elongation of each.

NOTE 6—This procedure formerly used ASTM No. 3 immersion oil as described in Test Method D471 – 79 (Reapproved 1991). ASTM Oil No. 3 was discontinued in 1990 and IRM 903 was specified as a replacement for ASTM Oil No. 3. Test Method D471 – 1995 incorporated this change. Test Method D471 – 1995 described the properties of IRM 903.

40.2 Compare the ultimate elongation values from the oil-immersed specimens with the corresponding values from the specimens tested in Section 22. If the ultimate elongation values from oil-immersed specimens are not within 10 % of the highest value obtained for the specimens of Section 22, immerse three additional specimens in oil and test them. The final value of ultimate elongation for specimens immersed in oil shall be the average of all tests run.

41. Report

41.1 Report the following information:

41.1.1 Sample size from which the specimens were taken,

41.1.2 Average ultimate elongation of the specimens before aging,

41.1.3 Average ultimate elongation of the specimens after aging, and

41.1.4 Average percentage change in ultimate elongation, and

41.1.5 Type of oil used if other than IRM 903.

42. Precision and Bias

42.1 The precision of this test method has not been determined due to inadequate voluntary participation and funding needed to conduct the round-robin testing. This test method has no bias because the results are expressed purely in terms of this test method.

BRITTLENESS TEMPERATURE

43. Significance and Use

43.1 This test establishes a quality level when the tubing is tested by the procedure specified. Results cannot be correlated with those obtained by a mandrel bending or other simple flexure tests. The brittleness temperature of different sizes of tubing made from the same compound will vary due to differences in cross-sectional dimensions and to testing the product in full section or as die-cut specimens. This test has been found to produce lower brittleness temperatures with specimens cut from tubing smaller than ⅝ in. (15.9 mm) in inside diameter than from the balance of the size range. Differences in brittleness temperature of less than 3 °C (5 °F) have no significance. For a more detailed explanation of results, see Test Method D746.

44. Procedure

44.1 Determine the brittleness temperature in accordance with Test Method D746 except as follows:

44.1.1 Use only motor-driven or gravity-type apparatus. Equipment of the types permitted cannot be guaranteed to meet the specified operational limits from a design basis; therefore, calibrate all equipment before initial use. In gravity-type apparatus, use a minimum weight for the falling element of 12.0 lb (5.45 kg) and use a distance of fall of 8.85 ± 0.10 in. (225 ± 3 mm).

44.1.2 For tubing sizes No. 20 to 7, inclusive, cut test specimens in full 1½ in. (40 mm) in length from the sample.

44.1.3 For tubing sizes No. 6 to 2 in. in inside diameter, inclusive, cut test specimens ¼ in. (6.4 mm) in width and 1½ in. (40 mm) in length from the sample. Do this by cutting a ¼ in. (6.4-mm) strip along a longitudinal axis of the sample. Strike specimens on the convex side from a section of tubing as free from curvature as available.

44.1.4 Clamp the specimens firmly between substantially parallel surfaces.

45. Precision and Bias

45.1 The precision of this test method has not been determined due to inadequate voluntary participation and funding needed to conduct the round-robin testing. This test method has no bias because the results are expressed purely in terms of this test method.

PENETRATION TEST

46. Significance and Use

46.1 Vinyl chloride polymer tubing sometimes is used in contact with irregular surfaces or relatively sharp contours under tension. It is possible that this will produce small areas of high pressure, which are potential sources of electrical failure at elevated temperatures. This test gives a measure of the resistance of tubing to penetration under such conditions. Differences in penetration temperature of less than 3 °C have no significance.

47. Apparatus

47.1 *Penetration Tester*—A penetration tester as shown in Fig. 2 is recommended. The component parts of the penetration tester are:

47.1.1 *Load-Bearing System,* comprised of a 1⁄16-in. (1.6-mm) diameter magnetized steel rod, recessed at one end to accommodate a 1⁄16-in. diameter steel ball bearing against test specimens mounted on a 4 by 1¼ by ⅛ in. (102 by 32 by 3.2 mm) stainless steel plate,

47.1.2 *Weight System,* capable of exerting a force of 1000 g on the magnetized steel rod, including a counterbalance with a rider capable of being adjusted to neutralize the pressure of the ball bearing against the steel plate at no load,

47.1.3 *Light C-Clamp,* containing the steel rod, counterbalance, and weight, mounted on a bearing capable of giving the unit the necessary freedom of rotation, and

47.1.4 *Electrical Circuit,* with a 110-V ac supply and containing a 110-V glow lamp.

47.2 *Oven*—An oven capable of holding the penetration tester and raising the temperature of the steel plate at a rate of 1 °C/2 min (2 °F/2 min).

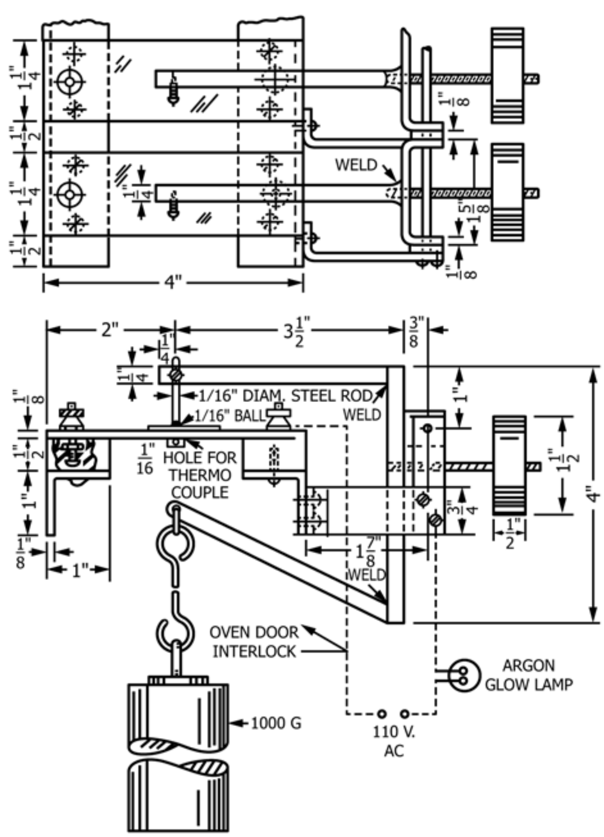
47.3 *Temperature-Measuring Device*—A device for measuring the temperature of the steel plate immediately below the point of contact of the ball bearing. A thermocouple is suggested for this application.

48. Test Specimens

48.1 Cut five 1-in. (25-mm) specimens from the sample and prepare for test by slitting the tubing open on one side along a longitudinal axis.

49. Procedure

49.1 With no load on the rod, insert each specimen between the steel ball and the steel plate, with the outside surface of the tubing facing the plate. Connect the electric circuit in such a way that when the steel ball comes into contact with the plate (when the specimen fails), the lamp outside the oven lights. Apply the compression load of 1000 g to the specimen in the oven at room temperature (Note 6). Raise the temperature of the steel plate at a uniform rate of 1 °C/2 min (2 °F/2 min) until failure of specimen is indicated by illumination of the glow lamp outside the oven.



							Metric Equivalents							
in.	1⁄16	⅛	¼	⅜	½	¾	1	1¼	1½	1⅝	1⅞	2	3½	4
mm	1.6	3.2	6.3	9.5	12.7	19.1	25.4	31.8	38.1	41.3	47.6	50.8	88.9	101.6

FIG. 2 Penetration Tester for Determining Resistance to Penetration at Elevated Temperatures

49.2 In order to facilitate testing, it is acceptable to use an initial starting temperature of 40°C (104°F) instead of room temperature. For convenience, the construction of five penetration testers in order to test simultaneously the required number of specimens, is an acceptable approach.

50. Report

50.1 Report the following information:

50.1.1 Average wall thickness of the specimens,

50.1.2 Maximum and minimum temperatures at which the specimens failed, and

50.1.3 Average temperature of failure of the five specimens.

50.2 The result is the average temperature of failure of the five specimens.

51. Precision and Bias

51.1 The precision of this test method has not been determined due to inadequate voluntary participation and funding needed to conduct the round-robin testing. This test method has no bias because the results are expressed purely in terms of this test method.

VOLUME RESISTIVITY

52. Significance and Use

52.1 The volume resistivity test on tubing is a nondestructive test that is useful in determining product uniformity, effects of moisture absorption, and changes in composition. The test is also suitable for specification acceptance tests, for factory control, or in connection with referee tests.

53. Apparatus

53.1 The resistance-measuring apparatus shall be in accordance with Test Methods D257.

54. Test Specimens

54.1 Cut three specimens at least 600 mm long from the sample of tubing.

54.2 Mount specimens about 300 mm long on a metal rod so that the tubing fits snugly on the rod without expansion or inclusion of voids between the rod and the tubing.

54.3 Apply a foil electrode centrally and snugly around the outside of the tubing for a distance of 150 mm along its length. Apply a short length of foil (guard electrode) at each end of the foil electrode and spaced therefrom a distance of not more than twice the wall thickness of the specimen.

55. Procedure

55.1 **Warning**—See Section 5.

55.2 Determine the volume resistivity of the specimens in accordance with Test Methods D257, using an electrification time of 60 s and a dc potential of 500 V.

56. Report

56.1 Report the following information:

56.1.1 Identification of the tubing,

56.1.2 Inside and outside diameter of the specimens, and

56.1.3 Individual and average values of volume resistivity of the three specimens in ohm centimetres.

56.2 The result is the average volume resistivity.

57. Precision and Bias

57.1 The precision of this test method has not been determined due to inadequate voluntary participation and funding needed to conduct the round-robin testing. A statement of bias is unavailable in view of the lack of a standard reference material for this property.

DIELECTRIC BREAKDOWN VOLTAGE

58. Significance and Use

58.1 The dielectric breakdown 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 expected in service, but has the potential to 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. The comparison of dielectric breakdowns of the same tubing before and after humidity conditioning gives an indication of the quality of the tubing as a moisture resistant dielectric. For a more complete discussion, refer to Test Method D149.

59. Dielectric Breakdown Voltage

59.1 Determine the dielectric breakdown voltage in accordance with Test Method D149, except as modified in Sections 60 – 62.

60. Apparatus

60.1 *For Tubing Sizes No. 20 to ½ in., Inclusive, in Inside Diameter*—Use straight metal rods as inner electrodes. Select the nearest AWG size of rod that will fit tightly without stretching the tubing as it is being slipped onto the rod. Use strips of metal foil as the outer electrodes 1 in. (25 mm) in width and not more than 0.0005 in. (0.013 mm) in thickness.

60.2 *For Tubing Sizes 9⁄16 to 2 in., Inclusive, in Inside Diameter*—The test electrodes shall consist of opposing cylindrical rods ¼ in. (6.4 mm) in diameter with edges rounded to a radius of 1⁄32 in. (0.8 mm). The upper movable electrode shall weigh 0.1 ± 0.006 lb.

61. Test Specimens and Conditioning

61.1 Cut ten pieces each approximately 1 ft (300 mm) long from the sample. The specimens for dry dielectric breakdown voltage test shall consist of one half of each of the pieces and the remainder of each piece shall be reserved for dielectric breakdown at high humidity. Condition dry dielectric breakdown voltage specimens for 96 h at 23 ± 1 °C (73 ± 2 °F) in a desiccator over dry calcium chloride.

62. Procedure

62.1 *For Tubing Sizes No. 20 to ½ in., Inclusive, in Inside Diameter*—From each sample cut a 6-in. (152-mm) specimen and place it on the inner electrode. Leave part of the inner electrode exposed to make electrical connection. Tightly wrap the outer electrode, consisting of a strip of metal foil, around the middle of the specimen. Wind the first turn of the foil tightly against the tubing. Wind two more turns of the foil over the first turn. Allow a free end of ½ in. (13 mm) to make an electrical connection.

62.2 *For Tubing Sizes 9⁄16 to 2 in., Inclusive, in Inside Diameter*—Cut the specimen on one side along a longitudinal axis, flatten, and place it between the ¼-in. (6.4-mm) electrodes. Use a specimen of sufficient area around the electrodes to prevent flashover.

62.3 (**Warning**—See Section 5.) Conduct the test in transformer oil, free from foreign matter, and determine the dielectric breakdown voltage by the short-time test. Increase the voltage between the electrodes at the rate of 0.5 kV/s, using motor-driven regulating equipment.

62.4 Obtain one breakdown voltage on each specimen tested.

63. Report

63.1 Report the following information:

63.1.1 Sample size from which the specimen was taken,

63.1.2 Total volts at each puncture, and

63.1.3 Average voltage breakdown for all ten punctures.

63.2 The result is the average voltage breakdown.

64. Precision and Bias

64.1 The precision of this test method has not been determined due to inadequate voluntary participation and funding needed to conduct the round-robin testing. A statement of bias is unavailable in view of the lack of a standard reference material for this property.

DIELECTRIC BREAKDOWN VOLTAGE AT HIGH HUMIDITY

65. Procedure

65.1 (**Warning**—See Section 5.)

65.2 Determine the dielectric breakdown voltage at high humidity in accordance with Sections 59 – 63, except that the tubing specimens shall be conditioned for 96 h at 23 ± 1 °C (73 ± 2 °F) and 96.5 ± 1 % relative humidity (see Practice D5032). Cause the breakdowns to occur in the conditioning chamber or immediately upon removal therefrom.

66. Report

66.1 Report the information specified in Section 63, and also the following:

66.1.1 Average percent retention of dielectric breakdown voltage value at high humidity (obtained by dividing the average dielectric breakdown voltage value at high humidity by the average dielectric breakdown voltage value dry and multiplying by 100).

67. Precision and Bias

67.1 The precision of this test method has not been determined due to inadequate voluntary participation and funding needed to conduct the round-robin testing. This test method has no bias because the results are expressed purely in terms of this test method.

STRAIN RELIEF TEST

68. Significance and Use

68.1 This test method is intended to provide a measure of internal stress retained in plastic tubing after extrusion; the results of this method give an indication of the degree of potential shrinkage when tubing is in close proximity to a joint being soldered or when an assembly is exposed to heat in the process of manufacture.

69. Apparatus

69.1 *Glass Tank*—A covered stainless steel or heat-resistant glass tank at least 12 in. (310 mm) long by 5 in. (130 mm) wide and 5 in. deep.

69.2 *Screening*—A basket of light-weight stainless steel wire screening at least 11 in. (280 mm) long, approximately 1 in. (25 mm) deep, and of a width slightly less than the width of the tank. It shall be compartmented with screening in a lengthwise direction to hold tubing specimens straight while immersed. A wire-screen cover shall be provided to keep specimens in their respective compartments and to ensure complete immersion.

69.3 *Heat Source,* controlled.

69.4 *Thermometer,* graduated in increments of not more than 1 °C per division.

69.5 *Scale,* graduated to 0.01 in. (0.2 mm).

70. Test Specimens

70.1 Cut three straight lengths of tubing 10 ± 0.01 in. (250 ± 0.25 mm) long and with square ends.

71. Procedure

71.1 Fill the tank with glycerin to a level about 1 in. (25 mm) below the top with the basket immersed and bring the temperature of the glycerin up to a steady state of 150 ± 1 °C (302 ± 2 °F). Raise the basket to the surface of the glycerin and place the tubing specimens in the basket as rapidly as possible. Place no more than one specimen in any one compartment. Cover the basket and lower 1 in. below the surface of the glycerin for at least 15 min. Maintain the glycerin at 150 ± 1 °C (302 ± 2 °F) during the entire test period. Remove the basket from the glycerin and allow the specimens to cool to room temperature. Remove the specimens from the basket and measure and record the length of each. Calculate the percentage change for each specimen.

72. Report

72.1 Report the following information:

72.1.1 Size of tubing from which specimen was taken, 72.1.2 Length of tubing, in inches or millimetres, after completion of test,

72.1.3 Percentage change in length (shrinkage) calculated for each 10-in. (250-mm) length, and

72.1.4 Average shrinkage.

72.2 The result is the average shrinkage.

73. Precision and Bias

73.1 The precision of this test method has not been determined due to inadequate voluntary participation and funding needed to conduct the round-robin testing. This test method has no bias because the results are expressed purely in terms of this test method.

CORROSION TESTS

Procedure A—Corrosive Effect on Copper

74. Significance and Use

74.1 Tubing of this type is often used in contact with copper conductors. This test simulates these conditions and accelerates the effects by increased temperature and humidity. Electrical resistance of the copper is measured both before and during exposure to these accelerated conditions, and excessive deterioration is often indicative of troubles that would be encountered in actual service conditions.

75. Apparatus

75.1 *Copper Wire* of same size as the nominal inside diameter of tubing specimen.

75.2 *Copper Wire,* clean, bare, 0.006-in. (0.152-mm) (AWG No. 34).

75.2.1 Clean and prepare copper wires by drawing through fine emery paper or crocus cloth to remove any surface scale, and then wipe clean with a lint-free rag saturated with analytical-grade toluene. Allow wires to dry by hanging in a clean area, and store by hanging until ready for use. At no time after cleaning shall they be touched by the bare hand.

75.3 *Copper Wire,* clean, bare, 0.040-in. (1.012-mm) (AWG No. 18).

75.3.1 Clean and prepare the copper wire as described in 75.2.1.

75.4 *Copper Wire*, clean, bare, 0.081 in. (2.053 mm) (AWG No. 12).

75.4.1 Clean and prepare the copper wire as described in 75.2.1.

75.5 *Test Tube,* 38 by 290 mm with cork stoppers to fit.

75.6 *Wax,* microcrystalline (not paraffin).

75.7 *Oil Bath,* capable of maintaining temperature of 70 ± 0.4 °C (158 ± 0.7 °F).

75.8 *Distilled Water,* freshly boiled and cooled.

75.9 *Kelvin Bridge,* capable of measuring resistance from 0.0001 to 11 Ω in at least five ranges, readable to 10 μΩ on the lowest range.

75.10 *Cork Stoppers,* research or select grade, prepared for insertion of wires in accordance with 77.1, thereafter boiled in distilled water for 4 h, or long enough to remove materials corrosive to copper, dried, and then immersed in molten microcrystalline wax until bubbling ceases.

75.11 *Gloves,* lint-free, clean.

76. Test Specimens and Conditioning

76.1 Cut test specimens 6 in. (152 mm) in length and not greater than 0.315 in. (7.95 mm) in inside diameter. Select specimens from the larger sample in a manner that will avoid contact with the bare hands or with other possible sources of contamination.

NOTE 7—It is advisable to confine tests to tubing sizes from AWG Nos. 0 through 6 due to spatial considerations for the larger sizes and to mechanical problems in maintaining the bifilar wire contact on the smaller sizes. It is considered that this test is not size-dependent and that this range is not too restrictive for evaluation purposes.

76.2 No conditioning prior to the test is necessary.

77. Procedure

77.1 Insert a 10-in. (250-mm) length of the proper size wire into the 6-in. (152 mm) length of tubing, positioning the tubing at one end of the wire. Insert the other end of the wire into a snug hole drilled into (but not through) the smaller end of the cork stopper. Insert two lengths of 0.081-in. (2.053-mm) (AWG No. 12) wire through the cork as support leads (see Fig. 3). Hook the ends of each wire lead to facilitate securing the lead in the cork and to provide a lug for anchoring the 0.006-in. (0.152-mm) wire. Also insert two lengths of 0.040-in. (1.012-mm) (AWG No. 18) wire through the cork as bridge leads, attaching to the support leads as shown in Fig. 3. Attach a short

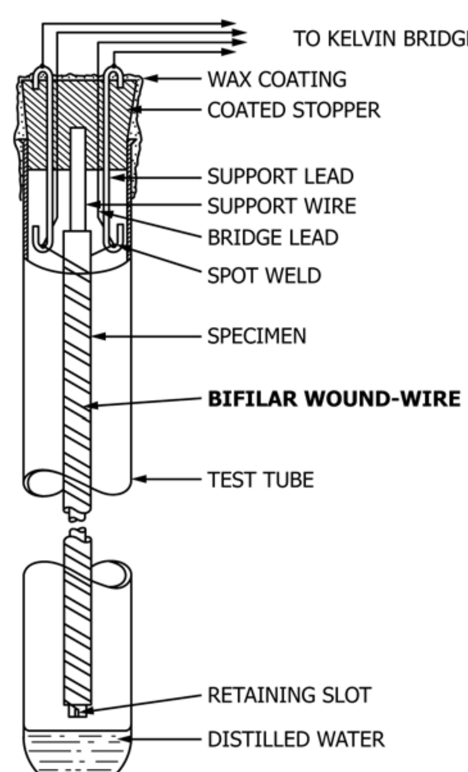


FIG. 3 Test Specimen Assembly for Corrosive Effect

length of 0.040-in. (1.012-mm) (AWG No. 18) wire twisted tightly around the lower end of the tubing to form a hook that will serve as an anchor for the 0.006-in. wire and hold the tubing from rotating. Alternatively for the larger diameter tubing specimens, a shallow slit can be sawn into the bottom of the support wire to serve as a slot for the 0.006-in. wire.

77.2 Holding the both ends of the cleaned 0.006-in. (0.152-mm) wire in one gloved hand, and the cork stoppered end of the tubing assembly in the other, loop the center of the 0.006-in. wire over the hook (or through the slot) at the bottom of the tubing specimen. While maintaining a given spacing between the free ends of the 0.006-in. wire, rotate the tubing specimen assembly slowly while guiding the wire around the tubing in a bifilar winding configuration, keeping the turns as evenly-spaced as possible to the top of the specimen. Do not release the tension on the bifilar winding until the free ends have been secured to the 0.081-in. (2.053-mm) (AWG No. 12) leads.

77.3 Wrap one free end of the bifilar-wound wire several times around one of the 0.081-in. (2.053-mm) (AWG No. 12) leads; wrap the other free end around the other lead. Spot-weld the wires to the leads, including at this point the 0.040-in. (1.012-mm) (AWG No. 18) leads into the bridge.

NOTE 8—It is possible, alternatively, to secure the wires to the leads by scoring the latter at the inside of the bend using a jeweler's saw and inserting the bifilar wire and bridge leads and then crimping back the lead support to form a snug force-fit contact.

77.4 Spot-weld 0.040-in. (1.012-mm) (AWG No. 18) wires of adequate length to the leads to serve as connections to the Kelvin bridge.

NOTE 9—If the test assembly has been properly constructed, the total resistance will not be greater than about 0.4 Ω.

77.5 Place about ¾ in. (20 mm) of distilled water in the bottom of the test tube and carefully insert the tubing specimen assembly into the test tube, securing the cork stopper. Support the test tube vertically in an oil bath at 70 ± 0.4 °C (158 ± 0.7 °F) and allow to come to thermal equilibrium. Making certain that the stopper is secure, coat the exposed surfaces of the stopper with melted wax sufficiently to cover all holes, making certain that the wax extends down the sides of the stopper, into the space between the stopper and the lip of the test tube, and down the sides of the tube to a distance of about ½ in. (12.7 mm). Sufficient wax must be used to ensure a vapor-tight seal during the test period.

77.6 Measure the resistance of the bifilar-wound wire daily (exclusive of week-ends and holidays) until an exposure of 720 h has been completed. Make measurements under conditions which avoid any changes in electrical resistance resulting from a temperature rise of the specimen wire (the bifilar-wound wire) due to resistance heating. Prolonged application of too high a voltage can result in elevated levels of energy input.

78. Report

78.1 Report the following information:

78.1.1 A description of the tubing tested,

78.1.2 A table showing the resistance readings throughout the 720 h,

78.1.3 A graph showing the change in resistance versus time,

78.1.4 Percentage change in resistance at the 700-h point computed from the curve of 78.1.3 and based on the average resistance of the wire calculated from the first three daily measurements, and

78.1.5 Visual evidence of discoloration of the bifilar wire, water, or specimen, and any exudation on the wire or specimen, and any material deposited in the water (for information only).

79. Precision and Bias

79.1 The precision of this test method has not been determined due to inadequate voluntary participation and funding needed to conduct the round-robin testing. This test method has no bias because the results are expressed purely in terms of this test method.

Procedure B—High-Humidity Insulation Resistance

80. Significance and Use

80.1 It is possible that electrolytic corrosion, from applied direct (and rarely alternating) voltage will cause open circuit failures, especially in very small wires. Failure takes place by chemical attack and ionic migration, which can be correlated in some degree with the insulation resistance of the associated electrical insulation. At high humidity the insulation resistance of many materials will decrease markedly with the time of exposure.

81. Apparatus

81.1 Use the electrode assembly and the ancillary measuring apparatus described in Test Methods D1000.

82. Test Specimens

82.1 For tubing of inside diameter 0.3 in. (7.6 mm) or less, slit the tubing along one element of its length to provide pieces about 6 in. (150 mm) long and of the width of the slit tubing. For tubing of inside diameter greater than 0.3 in., slit the tubing as described above and cut 1 in. (25 mm) wide strips about 6 in. long.

83. Procedure

83.1 Follow the procedure specified in Test Methods D1000, except mount the slit tubing specimens flat on the electrodes in such manner that both sides of the slit tubing shall be in contact with the electrodes. It is not essential that the entire 6-in. (150-mm) length of tubing be flattened.

84. Report

84.1 Report the median value of resistance in megohms of at least five measurements, calculated to a 1-in. (25-mm) width. Assume the resistance to be inversely proportional to the width for the purposes of this test. Report the maximum and minimum values of resistance.

84.2 The result is the median value of resistance.

85. Precision and Bias

85.1 A significant source of error in this test is due to the allowable variation in relative humidity of ±2 %. This has been found, in the case of some vinyl materials, to cause a six- to ten-fold change in resistance.

85.2 This test method has no bias because the results are expressed purely in terms of this test method.

86. Keywords

86.1 brittleness temperature; corrosion; dielectric breakdown voltage; dimensions; electrical insulation; flammability; oil resistance; penetration; poly(vinyl chloride); PVC; temperature tests; tension properties/tests; tubing; vinyl chloride polymer; volume resistivity

SUMMARY OF CHANGES

Committee D09 has identified the location of selected changes to these test methods since the last issue, D876 – 09, that may impact the use of these test methods. (Approved Nov. 1, 2013)

(*1*) Eliminated non mandatory language.
(*2*) Note 4 reworded; Note 7 in Section 49 deleted and Section 49.2 added.