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

INTERNATIONAL

Designation: D876 – 21

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	37 – 39	D746
Corrosion Tests	68 – 79	D1000
Dielectric Breakdown Voltage at High Humidity	59 – 67	E104
Dielectric Breakdown Voltage	52 – 58	D149
Dimensional Tests	8 – 14	D374
Effect of Elevated Temperatures	19 – 30	D412
Flammability Test		D8355, Test Method A
Oil Resistance Test	29 – 36	D471
Penetration Test	40 – 45	
Sampling	6	
Strain Relief Test	62 – 67	
Tension Test	16 – 18	D412
Test Conditions	7	
Volume Resistivity	46 – 51	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, health, and environmental 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 Test Methods D8355.*

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

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 (Metric) D0374_D0374M
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
D8355 Test Methods for Flammability of Electrical Insulating Materials Used for Sleeving or Tubing
E104 Practice for Maintaining Constant Relative Humidity by Means of Aqueous Solutions
E176 Terminology of Fire Standards

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

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[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.

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

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2.2 *IEC Standards:*[4]

60684–2 Flexible insulating sleeving, Part 2, Methods of test

3. Terminology

3.1 *Definitions:*

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

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

3.2 *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.

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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 Gauges*—Use chromium-plated gauges suitable for covering the range of tubing sizes shown in Table 1. The gauges 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 gauge that will fit part way into the tubular specimen. Slip the specimen, without forcing (Note 3), over the

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

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.

gauge until there is no visible air space between the end of the specimen and the gauge anywhere on the circumference. Consider this point on the gauge the inside diameter of the specimen.

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

11.2 Determine the diameter at the point of contact between the specimen and gauge 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 gauge 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 gauge 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.

15. Flammability Test

15.1 Conduct flammability tests in accordance with method A from Test Methods D8355.

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TENSION TEST

16. Procedure

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

16.1.1 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.

16.1.2 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.

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

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

16.1.5 Mark two parallel gauge 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.

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

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

16.1.8 Discard results on specimens that break outside of the gauge marks and retest.

17. Report

17.1 Report the following information:

17.1.1 Size of tubing from which the specimens were taken,

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

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

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

18. Precision and Bias

18.1 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

19. Scope

19.1 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.

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20. Significance and Use

20.1 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.

20.2 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 65 to 69), 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

21. Apparatus

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

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

21.1.2 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.

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

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

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

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

22. Test Specimens

22.1 Cut six specimens from the sample (Section 5), and prepare in a manner similar to that described in 16.1.1 and 16.1.2, according to the various sizes of tubing.

23. Procedure

23.1 Suspend three specimens in the oven described in 21.1. 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 gauge 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 16.

23.2 Place gauge 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 4—The results for elongation obtained in Test Method A of Test Methods D8355 are an acceptable choice for use as the unaged values.

23.3 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.

24. Report

24.1 Report the following information:

24.1.1 The sample size from which specimens were taken,

24.1.2 Average ultimate elongation of specimens before aging,

24.1.3 Average ultimate elongation of specimens after aging, and

24.1.4 Average percentage change in ultimate elongation.

25. Precision and Bias

25.1 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

26. Apparatus

26.1 *Chemical Balance.*

26.2 *Oven*—The oven shall conform to the requirements prescribed in 21.1.

26.3 *Desiccator.*

27. Test Specimens

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

28. Procedure

28.1 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 21.1, 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.

29. Report

29.1 Report the following information:

29.1.1 The sample size from which specimens were taken, and

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

30. Precision and Bias

30.1 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

31. Significance and Use

31.1 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.

31.2 Correlate the oil resistance test with the Strain Relief Test (Sections 62 – 67) 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.

32. Apparatus

32.1 The apparatus shall be the same as that described in Section 21.

33. Test Specimens

33.1 Cut three specimens from the sample (Section 5) in a manner similar to that described in 16.1.1 and 16.1.2 according to the various sizes of tubing.

34. Procedure

34.1 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 gauge marks 2 in. (50 mm) apart on each specimen and determine the ultimate elongation of each.

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NOTE 5—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.

34.2 Compare the ultimate elongation values from the oil-immersed specimens with the corresponding values from the specimens tested in Section 16. If the ultimate elongation values from oil-immersed specimens are not within 10 % of the highest value obtained for the specimens of Section 16, 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.

35. Report

35.1 Report the following information:

35.1.1 Sample size from which the specimens were taken,

35.1.2 Average ultimate elongation of the specimens before aging,

35.1.3 Average ultimate elongation of the specimens after aging, and

35.1.4 Average percentage change in ultimate elongation, and

35.1.5 Type of oil used if other than IRM 903.

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.

BRITTLENESS TEMPERATURE

37. Significance and Use

37.1 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.

38. Procedure

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

38.1.1 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).

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

38.1.3 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.

38.1.4 Clamp the specimens firmly between substantially parallel surfaces.

39. Precision and Bias

39.1 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

40. Significance and Use

40.1 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.

41. Apparatus

41.1 *Penetration Tester*—A penetration tester as shown in Fig. 1 is recommended. The component parts of the penetration tester are:

41.1.1 *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,

41.1.2 *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,

41.1.3 *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

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

41.2 *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).

41.3 *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.

42. Test Specimens

42.1 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.

43. Procedure

43.1 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 5). 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.

43.2 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.

44. Report

44.1 Report the following information:

44.1.1 Average wall thickness of the specimens,

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

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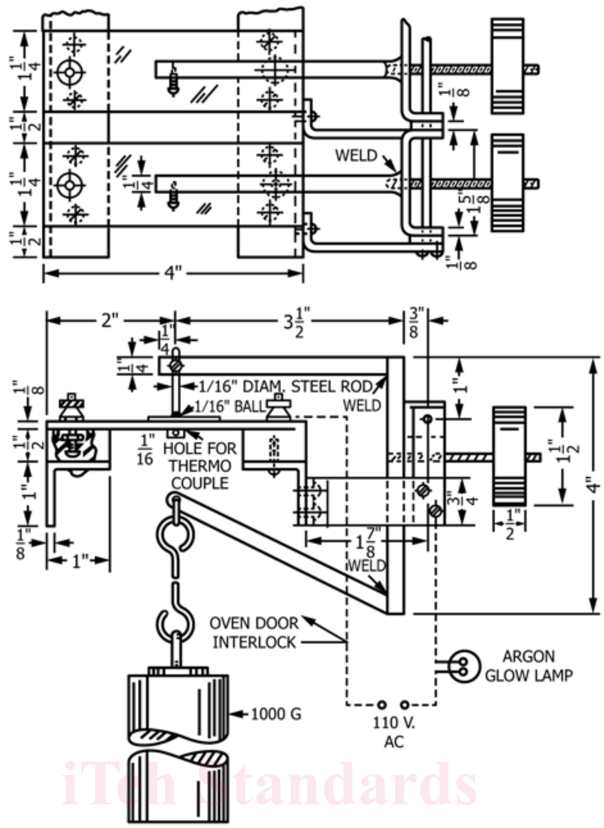

Metric Equivalents

in.	1⁄16	1⁄8	1⁄4	3⁄8	1⁄2	3⁄4	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. 1 Penetration Tester for Determining Resistance to Penetration at Elevated Temperatures

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44.1.3 Average temperature of failure of the five specimens.

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

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.

VOLUME RESISTIVITY

46. Significance and Use

46.1 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.

47. Apparatus

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

48. Test Specimens

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

48.2 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.

48.3 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.

49. Procedure

49.1 **Warning**—See Section 5.

49.2 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.

50. Report

50.1 Report the following information:

50.1.1 Identification of the tubing,

50.1.2 Inside and outside diameter of the specimens, and