INTERNATIONAL

Designation: D350 – 21

Standard Test Methods for Flexible Treated Sleeving Used for Electrical Insulation[1]

This standard is issued under the fixed designation D350; 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 procedures for testing electrical insulating sleeving comprising a flexible tubular product made from a woven textile fibre base, such as cotton, rayon, nylon, or glass, thereafter impregnated, or coated, or impregnated and coated, with a suitable dielectric material.

1.2 The procedures appear in the following sections:

Procedures	Section(s)
Selection of Test Material	5
Conditioning	6
Dimensions	7 to 11
Dielectric Breakdown Voltage	12 to 17
Brittleness Temperature	18 to 21
Flammability (See Test Methods D8355)	22 to 23
Dielectric Breakdown Voltage After Short-Time Aging	24 to 28
Oil Resistance	29 to 32
Thermal Endurance	33 to 39
Compatibility of Sleeving with Magnet Wire Insulation	40 to 54
Solvent Resistance	55 to 60
Hydrolytic Stability	61 to 67
Effect of Push-Back After Heat Aging	68 to 73

1.3 The values stated in inch-pound units, except for °C, are to be regarded as the standard. The values in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.4 This is a fire-test-response standard. See Test Methods D8355, which contains procedures for flammability tests.

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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.* For specific hazard statements, see 40.2 and 58.1.1.

NOTE 1—This standard resembles IEC 60684-2, Specification for Flexible Insulating Sleeving—Part 2 Methods of Test, in a number of ways, but is not consistently similar throughout. The data obtained using either standard are not necessarily technically equivalent.

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:*[2]

D149 Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials at Commercial Power Frequencies
D374 Test Methods for Thickness of Solid Electrical Insulation (Metric) D0374_D0374M
D471 Test Method for Rubber Property—Effect of Liquids
D746 Test Method for Brittleness Temperature of Plastics and Elastomers by Impact
D876 Test Methods for Nonrigid Vinyl Chloride Polymer Tubing Used for Electrical Insulation
D1711 Terminology Relating to Electrical Insulation
D2307 Test Method for Thermal Endurance of Film-Insulated Round Magnet Wire
D3487 Specification for Mineral Insulating Oil Used in Electrical Apparatus
D3636 Practice for Sampling and Judging Quality of Solid Electrical Insulating Materials
D5423 Specification for Forced-Convection Laboratory Ovens for Evaluation of Electrical Insulation
D6054 Practice for Conditioning Electrical Insulating Materials for Testing (Withdrawn 2012)[3]
D8355 Test Methods for Flammability of Electrical Insulating Materials Used for Sleeving or Tubing
E145 Specification for Gravity-Convection and Forced-Ventilation Ovens
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] 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.

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

2.2 *IEEE Standard:*[4]
IEEE 101 Guide for the Statistical Analysis of Thermal Life Test Data
2.3 *IEC Standard:*[5]
IEC 60684-2 Specification for Flexible Insulating Sleeving—Part 2 Methods of Test
2.4 *ISO Standard:*[6]
ISO 13943 Fire Safety—Vocabulary

3. Terminology

3.1 *Definitions:*

3.1.1 Use Terminology E176 and ISO 13943 for definitions of terms used in this test method and associated with fire issues. Where differences exist in definitions, those contained in Terminology E176 shall be used. Use Terminology D1711 for definitions of terms used in this test method and associated with electrical insulation materials.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *size, n*—a numerical designation which indicates that the inside diameter of the sleeving lies within the limits prescribed in Table 1.

3.2.2 *wall thickness, n*—one half the difference between the outside diameter of the sleeving mounted on a loosely fitting gauge rod and the diameter of the gauge rod when measured in accordance with 9.2.

4. Apparatus and Materials

4.1 Ovens used in these test methods shall meet the requirements of Specification D5423.

5. Selection of Test Material

5.1 In the case of sleeving on spools or in coils, not less than three turns of the product shall be removed before the selection of material from which test specimens are to be prepared.

5.2 In the case of sleeving offered in cut lengths, test specimens shall not be prepared from material closer than 1 in. (25 mm) from each end.

5.3 Specimens for test shall not show obvious defects unless the purpose of the test is to determine the effect of such defects.

5.4 Specimens shall be prepared from samples selected in accordance with Practice D3636. The sampling plan and acceptance quality level shall be as agreed upon between the user and the producer.

6. Conditioning

6.1 Unless otherwise specified, a standard laboratory atmosphere of 50 ± 5 % relative humidity and 23 ± 2 °C (73.4 ± 3.6 °F) shall be used in conducting all tests and for conditioning specimens for a period of at least 18 h prior to testing.

TABLE 1 ASTM Standard Sizes for Flexible Sleeving

Size	Inside Diameter, in. (mm)	
	Max	Min
1 in.	1.036 (26.3)	1.000 (25.4)
7/8 in.	0.911 (23.1)	0.875 (22.2)
3/4 in.	0.786 (20.0)	0.750 (19.1)
5/8 in.	0.655 (16.6)	0.625 (15.9)
1/2 in.	0.524 (13.3)	0.500 (12.7)
7/16 in.	0.462 (11.7)	0.438 (11.1)
3/8 in.	0.399 (10.1)	0.375 (9.5)
No. 0	0.347 (8.8)	0.325 (8.3)
No. 1	0.311 (7.9)	0.289 (7.3)
No. 2	0.278 (7.1)	0.258 (6.6)
No. 3	0.249 (6.3)	0.229 (5.8)
No. 4	0.224 (5.7)	0.204 (5.2)
No. 5	0.198 (5.0)	0.182 (4.6)
No. 6	0.178 (4.5)	0.162 (4.1)
No. 7	0.158 (4.0)	0.144 (3.7)
No. 8	0.141 (3.6)	0.129 (3.3)
No. 9	0.124 (3.1)	0.114 (2.9)
No. 10	0.112 (2.8)	0.102 (2.6)
No. 11	0.101 (2.6)	0.091 (2.31)
No. 12	0.091 (2.31)	0.081 (2.06)
No. 13	0.082 (2.08)	0.072 (1.83)
No. 14	0.074 (1.88)	0.064 (1.63)
No. 15	0.067 (1.70)	0.057 (1.45)
No. 16	0.061 (1.55)	0.051 (1.30)
No. 17	0.054 (1.37)	0.045 (1.14)
No. 18	0.049 (1.24)	0.040 (1.02)
No. 20	0.039 (0.99)	0.032 (0.81)
No. 22	0.032 (0.81)	0.025 (0.64)
No. 24	0.027 (0.69)	0.020 (0.51)

6.2 In the case of dielectric breakdown voltage tests after humidity conditioning, specimens shall be conditioned for 96 h in an atmosphere of 93 ± 3 % relative humidity and 23 ± 2 °C (73.4 ± 3.6 °F) before testing. If a conditioning cabinet is used, specimens shall be tested for dielectric breakdown voltage within 1 min after removal from the cabinet.

6.3 For details regarding conditioning, refer to Practice D6054.

DIMENSIONS

7. Apparatus

7.1 *Gauge Rods*—Standard gauge rods shall be made of steel and shall have smooth surfaces and rounded edges. One rod is required for each of the maximum and minimum diameters shown in Table 1 for each size. Each rod shall be within ±0.005 in. (±6.012 mm) of the values shown in Table 1.

8. Test Specimens

8.1 Five test specimens of at least 7 in. (180 mm) in length shall be cut from material obtained in accordance with Section 5.

9. Procedure

9.1 *Inside Diameter*—Pass the minimum gauge rod for the size sleeving under test into the specimen for a distance of 5 in.

[4] Available from Institute of Electrical and Electronics Engineers, Inc. (IEEE), 445 Hoes Ln., Piscataway, NJ 08854-4141, http://www.ieee.org.
[5] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.
[6] Available from International Organization for Standardization (ISO), ISO Central Secretariat, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, https://www.iso.org.

(127 mm) without expanding the wall of the sleeving. If the rod has a snug fit, then consider the specimen as having an inside diameter equal to the diameter of the rod. If the minimum gauge rod fits loosely, insert the maximum gauge rod into the specimen. If the maximum gauge rod passes freely into the specimen for a distance of 5 in. with a snug fit, or if it expands the wall of the specimen, then consider the sleeving to be of that size which falls within the limits of the maximum and minimum inside diameters as represented by the gauge rods.

9.2 *Wall Thickness*—Insert in the specimen the largest standard gauge rod that will pass freely into the sleeving. Apply a micrometer over the specimen and make thickness measurements as specified in Method C of Test Methods D374 except that the force on the pressor foot shall be 3 oz (85 g). Obtain the average of five thickness readings taking the micrometer readings at approximately 90° intervals about the circumference of the specimen and spaced lineally approximately 0.25 in. (6 mm). Methods A and B of Test Methods D374 can be used as alternative methods where agreed upon between the manufacturer and purchaser. Compute wall thickness as half the distance between the outside diameter of the mounted sleeving and the diameter of the gauge rod.

10. Report

10.1 Report the following information:

10.1.1 Identification of the sleeving,

10.1.2 Method of measurement if other than Method C,

10.1.3 Size of sleeving, and

10.1.4 Wall thickness.

TABLE 2 Estimated Precision of Wall Thickness Measurement

Sleeving Type	Nominal Value, in. (mm)		$(Sr)_j$, in. (mm)		$(SR)_j$, in. (mm)	
Acrylic	0.0213	(0.54)	0.0007	(0.018)	0.0017	(0.043)
PVC	0.0237	(0.60)	0.0007	(0.018)	0.0021	(0.053)
Silicone Rubber	0.0331	(0.84)	0.0012	(0.030)	0.0019	(0.048)

11. Precision and Bias

11.1 *Precision*—The overall estimates of the precision within laboratories $(Sr)_j$ and the precision between laboratories $(SR)_j$ for the determination of wall thickness are given in Table 2 for three selected materials. These estimates are based on a round robin of the three materials with six laboratories participating.[7]

11.2 *Bias*—This test method has no bias because the value for wall thickness is determined solely in terms of this test method itself.

DIELECTRIC BREAKDOWN VOLTAGE

12. Significance and Use

12.1 The dielectric breakdown voltage of the sleeving is of importance as a measure of its ability to withstand electrical stress without failure. This value does not correspond to the dielectric breakdown voltage expected in service, but is of 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 breakdown voltage of the same sleeving before and after environmental conditioning (moisture, heat, and the like) gives a measure of its ability to resist these effects. For a more detailed discussion, refer to Test Method D149.

13. Apparatus

13.1 *Inner Electrode*—A straight suitable metallic conductor which fits snugly into the sleeving, without stretching the wall, in such a manner that one end of the wire is exposed and can be used to support the specimen.

13.1.1 For specimens having an inside diameter greater than about size 8, the use of stranded conductors or of a bundle of wires of smaller size, is recommended, instead of using a solid conductor.

13.2 *Outer Electrode*—Strips of soft metal foil 1-in. (25 mm) wide and not more than 0.001 in. (0.03 mm) in thickness.

14. Procedure A—Straight Specimens

14.1 *Test Specimens*—Ten specimens 7 in. (180 mm) long shall be prepared for each conditioning test (see Section 6) from material selected in accordance with Section 5.

14.2 *Procedure:*

14.2.1 After conditioning in accordance with 6.1, determine the dielectric breakdown voltage in accordance with Test Method D149 except as specified in 14.2.2 and 14.2.3.

14.2.2 Mount a sleeving specimen on the inner electrode. Wrap the outer electrode tightly on the outside of the sleeving at a distance of not less than 1 in. (25 mm) from the ends of the specimens. Snugly wrap the foil over the sleeving. Wind two more turns of foil over the first turn, leaving a free end of about 0.5 in. (13 mm) to which an electrical contact can be made.

14.2.3 Determine the breakdown voltage, in accordance with Test Method D149 by the short time method, increasing the voltage from zero at a rate of 0.5 kV/s. Calculate the average breakdown voltage for the ten tests.

15. Procedure B—90° Bent Specimens

15.1 *Test Specimens*—Ten specimens 4 in. (100 mm) long shall be prepared for each conditioning test (see Section 6) from material selected in accordance with Section 5.

15.2 *Procedure:*

15.2.1 Mount a sleeving specimen on the inner electrode.

15.2.2 Bend the specimen through an angle of 90 ± 2° over a smooth mandrel having a diameter of ten times the nominal inside diameter of the specimen. Arrange the bend so that it is centrally located on the specimen.

15.2.3 Condition the samples as specified in 6.1.

15.2.4 Determine the dielectric breakdown voltage of the bent specimen using the following procedure:

15.2.4.1 Carefully wrap a strip of metal foil as in 14.2.2 snugly over the specimens at the bend. In accordance with Test Method D149 apply a voltage starting at zero and increasing at

[7] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D09-1024. Contact ASTM Customer Service at service@astm.org.

a constant rate of 0.5 kV/s until breakdown. Calculate the average breakdown voltage of the ten specimens.

15.2.4.2 Apply the foil electrode after exposure to conditioning.

16. Report

16.1 Report the following information:

16.1.1 Identification of the sleeving,

16.1.2 Conditioning before test,

16.1.3 Voltage breakdown for each puncture,

16.1.4 Average, minimum, and maximum voltage breakdown,

16.1.5 Procedure used (Method A or B), and

16.1.6 Temperature and relative humidity of test, if different from 6.1.

17. Precision and Bias

17.1 *Precision*—The overall estimates of the precision within laboratories $(Sr)_j$ and the precision between laboratories $(SR)_j$ for the determination of Dielectric Breakdown Voltage by Procedure A are given in Table 3 for three selected materials. These estimates are based on a round robin of the three materials with six laboratories participating.[7]

17.2 *Bias*—This test method has no bias because the value for dielectric breakdown voltage is determined solely in terms of this test method.

BRITTLENESS TEMPERATURE

18. Significance and Use

18.1 This test method serves to measure the brittleness temperature of the sleeving. It is useful for comparative and quality control purposes.

18.2 Results of this test have not been found to correlate with those obtained by bending or flexing around mandrels at low temperatures. Brittleness temperatures determined for sleeving materials by this test are affected by differences in cross-sectional dimensions and in specimen configuration, even if the materials have the same composition.

19. Procedure

19.1 Determine the brittleness temperature in accordance with Test Method D746, except as specified in 19.1.1 – 19.1.4.

19.1.1 For sleeving sizes 20 through 8, cut specimens in full section and 1.5 in. (38 mm) long.

TABLE 3 Estimated Precision of Dielectric Breakdown Voltage Measurement

Sleeving Type	Nominal Value, volts	$(Sr)_j$, volts	$(SR)_j$, volts
	Conditioned 18 h/23 °C/50 % RH		
Acrylic	8480	802	1126
PVC	10980	983	1528
Silicone Rubber	10770	904	1616
	Conditioned 96 h/23 °C/93 % RH		
Acrylic	2048	197	828
PVC	8100	1003	2137
Silicone Rubber	8540	1367	2550

19.1.2 For sleeving sizes 7 through 1 in. inside diameter, cut specimens 0.25 in. (6.4 mm) wide and 1.5 in. (38 mm) long with the longer dimension parallel to the axis of the sleeving. Take care to avoid cutting the specimens from the edges of sleeving that has been flattened during manufacture or storage.

19.1.3 Use only motor-driven or gravity-fall apparatus, such as described in Test Methods D876. Mount specimens so that the striking edge of the apparatus contacts the film and not the braid.

19.1.4 Failure of a specimen is indicated by cracking of the film completely through to the braid, as determined by visual examination.

20. Report

20.1 Report the following information:

20.1.1 Identification of the sleeving,

20.1.2 Brittleness temperature to the nearest °C,

20.1.3 Method of calculation (see Test Method D746),

20.1.4 Type of apparatus used, and

20.1.5 Number of specimens tested.

21. Precision and Bias

21.1 *Precision*—This test method has been in use for many years, but no information has been presented to ASTM upon which to base a statement of precision. No activity has been planned to develop such information.

21.2 *Bias*—This test method has no bias because the value for brittleness temperature is determined solely in terms of this test method.

FLAMMABILITY—METHOD A

22. *Procedure*—Determine the flammability in accordance with test method A in Test Methods D8355.

FLAMMABILITY—METHOD B

23. *Procedure*—Determine the flammability in accordance with test method B in Test Methods D8355.

DIELECTRIC BREAKDOWN VOLTAGE AFTER SHORT-TIME AGING

24. Significance and Use

24.1 This test method serves to indicate the resistance of sleeving to the effects of short-time exposure to elevated temperatures. While this test method provides a means of determining continuity of quality and is useful as a lot acceptance test, it is not intended to provide information regarding the thermal endurance of the sleeving (see Sections 33 to 39).

25. Test Specimens

25.1 Prepare five 90° bent test specimens as described in 15.2.1 and 15.2.2.

26. Procedure

26.1 Condition the test specimens in an oven for a period of 96 h at a temperature 50 °C (90 °F) higher than the nominal temperature index of the sleeving. Remove the specimens and allow to cool to room temperature. Apply the outer electrode and determine the dielectric breakdown voltage in accordance with 14.2.

27. Report

27.1 Report the following information:

27.1.1 Identification of the sleeving,

27.1.2 Temperature of conditioning, and

27.1.3 Average, minimum, and maximum voltage breakdown values.

28. Precision and Bias

28.1 *Precision*—This test method has been in use for many years, but no information has been presented to ASTM upon which to base a statement of precision. No activity has been planned to develop such information.

28.2 *Bias*—This test method has no bias because the value for dielectric breakdown voltage after short-time aging is determined solely in terms of this test method.

OIL RESISTANCE

29. Test Specimens

29.1 Cut three specimens, each 3 in. (76 mm) long, from material selected in accordance with Section 5.

30. Procedure

30.1 Immerse the specimens for 24 h in ASTM Oil No. 2 as described in Test Method D471, the oil being maintained at a temperature of 105 ± 2 °C (221 ± 3.6 °F). At the end of this period, remove the specimens from the oil, wipe off excess oil with a clean cloth, and examine the specimens for deterioration as evidenced by blistering, splitting, flaking off of the film, and other visual defects.

NOTE 2—Oil meeting Specification D3487 has been found suitable as a substitute for ASTM Oil No. 2.

30.2 Determine the degree of swelling by measurements of wall thickness as specified in 9.2.

31. Report

31.1 Report the following information:

31.1.1 Identification of the sleeving,

31.1.2 Evidence of deterioration of the sleeving,

31.1.3 Percentage of increase in wall thickness, and

31.1.4 Type of oil used (if other than ASTM No. 2).

32. Precision and Bias

32.1 *Precision*—This test method has been in use for many years, but no information has been presented to ASTM upon which to base a statement of precision. No activity has been planned to develop such information.

32.2 *Bias*—This test method has no bias because the value for oil resistance is determined solely in terms of this test method.

THERMAL ENDURANCE

33. Summary of Test Method

33.1 This test method describes preparation of specimens, aging of specimens at elevated temperatures, and periodic testing of breakdown voltage. The data obtained are used to plot a regression line on logarithmic-time versus reciprocal-absolute-temperature coordinates from which the thermal endurance in terms of a temperature index is derived.

34. Significance and Use

34.1 This test method is useful in determining the relative thermal endurance of sleeving initially capable of being bent 90° without splitting.

34.2 The criterion of failure by this test method is reduction of breakdown voltage of the sleeving below a value of 3500 V. It is believed that this embodies several modes of failure, such as cracking by embrittlement, volatilization, porosity, and crazing, which are not independently determinable.

34.3 Thermal endurance is based on the evaluation of 7.0 kV grade, size 12 sleeving, even though it is recognized that laboratory results do not necessarily agree with those obtained using other voltage grades and sizes. Future work will attempt to determine the effects of grade and size differences, if any.

35. Apparatus and Materials

35.1 *Soft Copper Wire,* AWG Size No. 12, bare.

36. Test Specimens

36.1 Obtain specimens 4 in. (100 mm) in length from size 12 sleeving having an average voltage breakdown value of between 7 and 9 kV. This size and voltage range is defined as the qualifying style.

NOTE 3—Experience has indicated that the initial breakdown voltage, which is a function of coating thickness, can be a factor affecting thermal life. A limited range of initial breakdown voltage has been set to minimize this as a possible variable.

36.2 Specimens shall be randomized with respect to position in the sample, with care being exercised to prevent damage to the sleeving during this process.

37. Procedure

37.1 Place the sleeving on a 5-in. (130 mm) straight length of copper wire, which fits snugly into the sleeving without stretching the wall, in such a manner that one end of the wire is exposed and can be used to support the specimen in the oven.

37.2 Bend the specimen through an angle of 90 ± 2° over a smooth mandrel having a diameter of 0.85 ± 0.04 in. (21.6 ± 1.0 mm), which is ten times the nominal inside diameter of the sleeving. Make the bend so that it is centrally located on the sleeving specimen.

37.3 Prepare at least ten sets of five specimens for each test temperature. Prepare an additional ten specimens for testing the initial breakdown voltage.

NOTE 4—Although not used to evaluate the end point, the initial value of breakdown voltage is useful in determining the shape of the plot of dielectric breakdown voltage versus time of aging.

37.4 Condition all specimens for 48 h at 23 ± 2 °C (73.4 ± 3.6 °F) and a relative humidity of 50 ± 2 % (Standard Laboratory Conditions). Subject all specimens for about 5 s to a proof voltage of 75 % of the average breakdown voltage obtained on unaged specimens prepared for initial breakdown voltage testing. Specimens failing this test are to be discarded. The foil shall be removed from the specimens before they are to be aged.

37.5 Determine the dielectric breakdown of both aged and unaged specimens by the following procedure: Apply the outer electrode over the specimen at the bend and then determine the breakdown voltage as described in 14.2.2 and 14.2.3.

37.6 Choose three or more different aging temperatures. Selection of temperatures requires an estimate of the temperature rating of the sleeving under evaluation, since extrapolation to a classification temperature from the lowest aging temperature selected must not exceed 25 °C (77 °F). Additionally, the highest aging temperature shall be selected to result in thermal endurance of not less than 100 h, preferably just over 100 h. In the case of an odd number of aging temperatures, the median shall be located midway, ±5 °C, between the highest and lowest aging temperatures chosen. In all cases they shall be reasonably spaced evenly along the 1/K scale of temperatures.

37.7 During aging remove sets periodically from the oven and cool at least 2 h at Standard Laboratory Conditions. Determine the average breakdown voltage for each set of five specimens and plot this average against time in hours, using semilogarithmic coordinates, and with the logarithm of time as the abscissa and breakdown voltage as the ordinate. Estimate time intervals between testing of sets from the appearance of the plot, with as many tests as practical being grouped in the region of the estimated occurrence of the end point.

38. Calculation and Report

38.1 Record the time corresponding to a breakdown voltage of 3500 V as determined from the plot of 37.7 for each test temperature.

38.2 Plot these recorded times as the ordinate with test temperatures as the abscissa on graph paper arranged to show the logarithm of time against the reciprocal of the absolute temperature in kelvins. Determine the temperature from the above plot corresponding to an endurance of 20 000 h.

38.3 Report the following information:

38.3.1 Identification of the sleeving,

38.3.2 Average breakdown voltage of the unaged specimens,

38.3.3 Average breakdown voltage for each aged set of specimens, together with time and temperature of aging,

38.3.4 Time in hours, to reach an endpoint of 3500 V for each aging temperature, as determined from the plot of 37.7, and

38.3.5 Temperature corresponding to 20 000 h thermal endurance as obtained from the plot of 38.2.

38.3.6 The methods shown in Appendix X1 and Appendix X2 of Test Method D2307 are recommended for use in calculating the regression line.

39. Precision and Bias

39.1 *Precision*—The precision of this test method is determinable in terms of the confidence interval for the mean logarithm of the life at a selected temperature using the procedure described in IEEE Guide 101.

39.2 *Bias*—This test method has no bias because the value for thermal endurance is determined solely in terms of this test method.

COMPATIBILITY OF SLEEVING WITH MAGNET WIRE INSULATION

40. Scope

40.1 These test methods evaluate the degrading effects, if any, of sleeving on magnet wire insulation.

40.2 (**Warning—**These procedures include the hazardous operation of the use of glass test tubes in a heated oven.)

40.3 *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.*

PROCEDURE A—LOW PRESSURE METHOD

41. Summary of Test Method

41.1 Specimens are aged in the presence of a selected insulated wire at several elevated temperatures under confined but not hermetically sealed conditions, and the breakdown voltage of the wire insulation is determined after increments of 168 h aging. Data obtained are used to plot voltage versus time curves showing the deterioration of wire insulation, aged both alone and in the presence of sleeving.

42. Significance and Use

42.1 It has been established that it is possible that sleeving exposed to elevated temperatures will deleteriously affect wire insulation when confined therewith. This test determines the extent of this effect.

42.2 The criterion of failure by this test method is the reduction in breakdown voltage of the insulated wire aged in a confined system with sleeving to a value below 70 % of that obtained on control specimens aged similarly but separately. Values below 70 % are taken to indicate a condition of incompatibility.

43. Apparatus and Materials

43.1 *Test Tubes,* borosilicate, 38 by 200 mm, washed with detergent, rinsed with triple-distilled water to remove residue, and dried at 180 °C (356 °F).

43.2 *Aluminum Foil,* 0.001 in. (0.025 mm) thick.

43.3 *Copper Wire,* AWG Size No. 18, heavy enameled, round.

44. Test Specimens

44.1 The wire specimens shall be a pair of copper wires 6 in. (150 mm) long, twisted in accordance with Test Method D2307 with eight twists using 3-lb (1.4 kg) tension per wire. Flare the ends of the pairs to prevent flash-over during the breakdown voltage test and to avoid unnecessary handling of the pairs after aging. Each pair shall be proof tested for about 5 s at a voltage equal to 75 % of the average breakdown voltage previously determined on ten pairs. Twisted pairs failing this test are to be discarded.

44.2 Sleeving specimens shall be AWG Size No. 8 ± 2 cut to 6-in. (150 mm) lengths.

45. Procedure

45.1 Place five wire pairs selected at random in each of eight test tubes. Place one specimen of sleeving each in four of the tubes. It is not necessary that there be intimate contact of wire pairs and sleeving. Insert the tubes containing the wire pairs and sleeving in an oven at the selected test temperature for 2 h to remove moisture. Remove tubes and immediately apply three layers of aluminum foil over the open end of the tube and secure with copper wire applied around the neck of the tube.

45.2 Place four tubes containing wire pairs and sleeving, and four tubes containing wire pair controls in an oven at a temperature 25 °C (17 °F) higher than the nominal temperature index of the sleeving.

45.3 At the end of each 168-h period remove and cool one tube containing wire pairs and sleeving and one tube containing wire pair controls, carefully remove the wire pairs and sleeving and measure the dielectric breakdown voltage on each set of wire pairs using the short-time test of Test Method D149 and a rate of rise of voltage of 0.5 kV/s. Make no attempt to remove sleeving adhered to the wire pairs until after the breakdown voltage has been measured.

45.4 If the breakdown voltage of the control wire pairs falls to a value below 50 % of the unaged value within a 4-week period, then the test temperature used is considered too high for that type of magnet wire insulation, and a lower temperature must be selected.

NOTE 5—Wire pairs in contact with sleeving ordinarily will not show breakdown voltage values higher than the control pairs. When this occurs, it suggests that randomization of the specimens has not been obtained.

46. Report

46.1 Report the following information:

46.1.1 Identification of the sleeving,

46.1.2 Type of insulation on the wire,

46.1.3 Test temperature,

46.1.4 Plot of average breakdown voltage as a function of hours aging for both the wire pairs with sleeving and the wire pair controls,

46.1.5 Percentage retention of breakdown voltage for the wire pairs with sleeving based on the value for the wire pair controls, both determined at the end of 672 h aging as obtained from the plot of 46.1.4 using a visual best-fit technique, and

46.1.6 Evidence of softening or liquefaction of the sleeving coating, or the presence of condensate on the tube walls at any time during the test.

47. Precision and Bias

47.1 *Precision*—This test method has been in use for many years, but no information has been presented to ASTM upon which to base a statement of precision. No activity has been planned to develop such information.

47.2 *Bias*—This test method has no bias because the value for compatibility with magnet wire insulation at low pressure is determined solely in terms of this test method.

PROCEDURE B—SEALED TUBE METHOD

48. Summary of Test Method

48.1 Wire is aged with the sleeving in a sealed and initially anhydrous environment at elevated temperatures. The dielectric breakdown voltage of the wire insulation is determined after 72 h. Employment of a sealed system having a specified loading and a judicious choice of accelerated aging temperatures makes it possible to obtain indicative data after as little as 72 h of aging.

49. Significance and Use

49.1 Evaluation of possible interaction between various components of an insulation system provides design data usually not available intuitively. Care is needed for interpretation of the data obtained; while in many cases acceleration of the test conditions will provide interactions representative of those which occur over longer periods of time under normal service, there are likely to be instances in which such acceleration will produce changes not found in service.

50. Apparatus and Materials

50.1 *Glass Containers,* sealable, equipped with gaskets of silicone rubber, copper, or lead, and cleaned by washing with detergent, rinsed until clean with triple-distilled water, and dried at 180 °C (356 °F).

50.2 *Copper Wire,* round, insulated, AWG Size No. 18, heavy enameled.

50.3 *Oven,* meeting the requirements of Specification D5423 or of Type II, Grade B, of Specification E145.

51. Test Specimens

51.1 The wire specimens shall be a pair of insulated copper wires about 6 in. (150 mm) long and twisted in accordance with the procedure described in Test Method D2307. Flare the ends of the twisted pairs in order to accommodate the voltage breakdown apparatus and to obviate the necessity of disturbing the wire insulation after aging. Each twisted pair shall be proof tested for about 5 s at a voltage equal to 75 % of the average breakdown voltage previously determined on ten pairs. Twisted pairs failing this test are to be discarded.

51.2 Sleeving specimens shall be of AWG Size No. 8 ± 2, cut to lengths of 6 in. (150 mm).

NOTE 6—Care must be exercised in handling of test specimens to avoid