Designation: D 350 – 96

An American National Standard

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

This standard is issued under the fixed designation D 350; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

*This standard has been approved for use by agencies of the Department of Defense.*

## 1. Scope

1.1 These test methods cover 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 | Sections |
|---|---|
| Brittleness Temperature | 18 to 21 |
| Compatibility of Sleeving with Magnet Wire Insulation | 45 to 59 |
| Conditioning | 6 |
| Dielectric Breakdown Voltage | 12 to 17 |
| Dielectric Breakdown Voltage After Short-Time Aging | 29 to 33 |
| Dimensions | 7 to 11 |
| Effect of Push-Back After Heat Aging | 73 to 78 |
| Flammability | 22 to 28 |
| Hydrolytic Stability | 66 to 72 |
| Oil Resistance | 34 to 37 |
| Selection of Test Material | 5 |
| Solvent Resistance | 60 to 65 |
| Thermal Endurance | 38 to 44 |

1.3 The values stated in inch-pound units, except for° C, are to be regarded as the standard. The values in parentheses are provided for information only.

1.4 This is a fire-test-response standard. See Sections 22 through 28, which are the procedures for flammability tests.

1.5 These test methods can be used to measure and describe the properties of materials, products, or assemblies in response to heat and flame under controlled laboratory conditions, but should not be used to describe or appraise the fire hazard or fire risk of materials, products, or assemblies under actual fire conditions. However, results of this test may be used as elements of a fire risk assessment which take into account all of the factors which are pertinent to an assessment of the fire hazard of a particular end use.

1.6 *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 45.2 and 63.1.1.

## 2. Referenced Documents

2.1 *ASTM Standards:*

D 149 Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials at Commercial Power Frequencies[2]

D 374 Test Methods for Thickness of Solid Electrical Insulation[2]

D 471 Test Method for Rubber Property—Effect of Liquids[3]

D 618 Practice for Conditioning Plastics and Electrical Insulating Materials for Testing[4]

D 746 Test Method for Brittleness Temperature of Plastics and Elastomers by Impact[4]

D 876 Test Methods for Nonrigid Vinyl Chloride Polymer Tubing Used for Electrical Insulation[2]

D 2307 Test Method for Relative Thermal Endurance of Film-Insulated Round Magnet Wire[2]

D 3487 Specification for Mineral Insulating Oil Used in Electrical Apparatus[5]

D 3636 Practice for Sampling and Judging Quality of Solid Electrical Insulating Materials[6]

D 5423 Specification for Forced-Convection Laboratory Ovens for Evaluation of Electrical Insulation[6]

E 145 Specification for Gravity-Convection and Forced-Ventilation Ovens[7]

2.2 *IEEE Standard:*

IEEE 101 Guide for the Statistical Analysis of Thermal Life Test Data[8]

## 3. Terminology

3.1 *Descriptions of Terms Specific to This Standard:*

3.1.1 *flammability*—a measure of the rate of travel of a flame down a specimen when ignited and held in a vertical position.

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

Current edition approved March 10, 1996. Published May 1996. Last previous edition D 350 – 91.

[2] *Annual Book of ASTM Standards*, Vol 10.01.
[3] *Annual Book of ASTM Standards*, Vol 09.01.
[4] *Annual Book of ASTM Standards*, Vol 08.01.
[5] *Annual Book of ASTM Standards*, Vol 10.03.
[6] *Annual Book of ASTM Standards*, Vol 10.02.
[7] *Annual Book of ASTM Standards*, Vol 14.02.
[8] Available from the Institute of Electrical and Electronics Engineers, Inc., 345 E. 47th St., New York, NY, 10017.

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

3.1.3 *wall thickness*—one half the difference between the outside diameter of the sleeving mounted on a loosely fitting gage rod and the diameter of the gage 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 D 5423.

## 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 D 3636. 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.

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 D 618.

**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) |

**DIMENSIONS**

## 7. Apparatus

7.1 *Gage Rods*—Standard gage 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 gage rod for the size sleeving under test into the specimen for a distance of 5 in. (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 gage rod fits loosely, insert the maximum gage rod into the specimen. If the maximum gage 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 gage rods.

9.2 *Wall Thickness*—Insert in the specimen the largest standard gage 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 D 374 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 D 374 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 gage 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.

## 11. Precision and Bias

11.1 *Precision*—The overall estimates of the precision

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) |

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.[9]

11.2 *Bias*—Since there is no accepted reference material suitable for determining the bias for the procedure for measuring wall thickness, bias has not been determined.

## 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 may be of considerable value in comparing different materials or different lots, in controlling manufacturing processes or, when coupled with experience, for a limited degree of design work. 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 D 149.

### 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, it may be convenient to use either stranded conductors or a bundle of wires of smaller size, instead of 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 D 149 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 D 149 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 D 149 apply a voltage starting at zero and increasing at a constant rate of 0.5 kV/s until breakdown. Calculate the average breakdown voltage of the ten specimens.

NOTE 1—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.[9]

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.

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 |

[9] Supporting data are on file at ASTM Headquarters. Request RR: D-9-1024.

## 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. The temperature as determined may vary for different sleeving sizes for materials of the same composition due to differences in cross-sectional dimensions and in specimen configuration.

### 19. Procedure

19.1 Determine the brittleness temperature in accordance with Test Method D 746, 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.

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 D 876. 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 D 746),

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 statement of precision has been made and no activity is planned to develop such a statement.

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

22.1 Determine the flammability in accordance with Test Methods D 876. The results of this test give an indication of the tendency of the material to burn in case of fire.

## FLAMMABILITY—METHOD B

### 23. Significance and Use

23.1 This test gives an indication of the relative rate at which materials that will burn will propagate a flame.

### 24. Apparatus

24.1 *Bunsen burner*.

24.2 *Stopwatch*.

### 25. Test Specimens

25.1 Cut at least three specimens from the material selected in accordance with Section 5.

### 26. Procedure

26.1 Mark a gage length of 1 in. (25 mm) on each test specimen approximately 0.5 in. (13 mm) from one end of the specimen. Using a method that will not distort the test area, close the other end to prevent passage of air through the specimen during the test.

26.2 Insert the open end of the sleeving into the side of the burner flame with the lower side of the sleeving about 0.5 in. (13 mm) above the top of the burner. Rotate the specimen in the flame to ignite it uniformly. Remove the sleeving from the flame and hold vertically in the air with the burning end uppermost.

26.3 Start the timer when the leading edge of the flame reaches the upper gage mark and observe the time in seconds for the leading edge of the flame to travel down the specimen to the lower gage mark.

### 27. Report

27.1 Report the following information:

27.1.1 Identification of the sleeving, and

27.1.2 For each specimen, the time in seconds required to burn 1 in. (25.4 mm).

### 28. Precision and Bias

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

## DIELECTRIC BREAKDOWN VOLTAGE AFTER SHORT-TIME AGING

### 29. Significance and Use

29.1 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 38 to 44).

### 30. Test Specimens

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

### 31. Procedure

31.1 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.

## 32. Report

32.1 Report the following information:

32.1.1 Identification of the sleeving,

32.1.2 Temperature of conditioning, and

32.1.3 Average, minimum, and maximum voltage breakdown values.

## 33. Precision and Bias

33.1 *Precision*—This test method has been in use for many years, but no statement of precision has been made and no activity is planned to develop such a statement.

# OIL RESISTANCE

## 34. Test Specimens

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

## 35. Procedure

35.1 Immerse the specimens for 24 h in ASTM Oil No. 2 as described in Test Method D 471, 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 D 3487 has been found suitable as a substitute for ASTM Oil No. 2.

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

## 36. Report

36.1 Report the following information:

36.1.1 Identification of the sleeving,

36.1.2 Evidence of deterioration of the sleeving,

36.1.3 Percentage of increase in wall thickness, and

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

## 37. Precision and Bias

37.1 *Precision*—This test method has been in use for many years, but no statement of precision has been made and no activity is planned to develop such a statement.

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

# THERMAL ENDURANCE

## 38. Summary of Test Method

38.1 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.

## 39. Significance and Use

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

39.2 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.

39.3 Thermal endurance is based on the evaluation of 7.0 kV grade, size 12 sleeving, even though it is recognized that laboratory results may 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.

## 40. Apparatus and Materials

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

## 41. Test Specimens

41.1 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.

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

## 42. Procedure

42.1 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.

42.2 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.

42.3 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.

42.4 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.

42.5 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.

42.6 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 should be reasonably spaced evenly along the 1/K scale of temperatures.

42.7 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.

## 43. Calculation and Report

43.1 Record the time corresponding to a breakdown voltage of 3500 V as determined from the plot of 42.7 for each test temperature.

43.2 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.[10] Determine the temperature from the above plot corresponding to an endurance of 20 000 h.

43.3 Report the following information:

43.3.1 Identification of the sleeving,

43.3.2 Average breakdown voltage of the unaged specimens,

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

43.3.4 Time in hours, to reach an endpoint of 3500 V for each aging temperature, as determined from the plot of 42.7, and

43.3.5 Temperature corresponding to 20 000 h thermal endurance as obtained from the plot of 43.2.

NOTE 5—Calculation of the regression line can be made using the methods shown in Appendix X1 and Appendix X2 of Test Method D 2307.

## 44. Precision and Bias

44.1 *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.

44.2 *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

## 45. Scope

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

45.2 **Caution:** These procedures include the hazardous operation of the use of glass test tubes in a heated oven.

## PROCEDURE A—LOW PRESSURE METHOD

## 46. Summary of Test Method

46.1 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.

## 47. Significance and Use

47.1 It has been established that sleeving exposed to elevated temperatures may deleteriously affect wire insulation when confined therewith. This test determines the extent of this effect.

47.2 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.

## 48. Apparatus and Materials

48.1 *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).

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

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

## 49. Test Specimens

49.1 The wire specimens shall be a pair of copper wires 6 in. (150 mm) long, twisted in accordance with Test Method D 2307 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.

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

## 50. Procedure

50.1 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.

50.2 Place four tubes containing wire pairs and sleeving, and four tubes containing wire pair controls in an oven at a

[10] Keuffel and Esser No. 46 8282 and No. 46 8242 commercially available graph paper has been found satisfactory for this plot.

temperature 25°C (17°F) higher than the nominal temperature index of the sleeving.

50.3 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 D 149 and a rate of rise of voltage of 0.5 kV/s. No attempt should be made to remove sleeving adhered to the wire pairs until after the breakdown voltage has been measured.

50.4 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 6—Wire pairs in contact with sleeving ordinarily should not show breakdown voltage values higher than the control pairs. When this occurs, it indicates that randomization of the specimens may not have been obtained.

## 51. Report

51.1 Report the following information:

51.1.1 Identification of the sleeving,

51.1.2 Type of insulation on the wire,

51.1.3 Test temperature,

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

51.1.5 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 51.1.4 using a visual best-fit technique, and

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

## 52. Precision and Bias

52.1 *Precision*—This test method has been in use for many years, but no statement of precision has been made and no activity is planned to develop such a statement.

52.2 *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

## 53. Summary of Test Method

53.1 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.

## 54. Significance and Use

54.1 Evaluation of possible interaction between various components of an insulation system provides design data usually not available intuitively. Interpretation of the data obtained must be made with care; 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 may be instances in which such acceleration will produce changes not found in service.

## 55. Apparatus and Materials

55.1 *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).[11]

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

55.3 *Oven*, meeting the requirements of Specification D 5423 or of Type II, Grade B, of Specification E 145.

## 56. Test Specimens

56.1 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 D 2307. 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.

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

NOTE 7—Care must be exercised in handling of test specimens to avoid contamination. The use of nylon or polyethylene gloves is suggested to prevent deposition of oils and salts on the exposed areas of the wire pairs and sleeving specimens.

## 57. Procedure

57.1 Place two randomly-selected twisted wire pairs and one length of sleeving in each bottle. It is not necessary that there be intimate contact between twisted pairs and the sleeving. Insert the bottles containing wires and sleeving into an oven at the test temperature to remove moisture. After 2 h remove and immediately seal the bottles.

57.2 Place eight bottles containing wire pairs and sleeving and eight bottles containing wire pairs only in an oven at a temperature 25°C (77°F) higher than the nominal temperature index of the sleeving.

57.3 After 72 h, cool the bottles, carefully remove the twisted pairs and measure the breakdown voltage using the short-time method of Test Method D 149, increasing the voltage from zero at a rate of 0.5 kV/s. Calculate the average breakdown voltage for the wire specimens. Care should be taken that twisted pairs adhered to sleeving shall not be disturbed until after the voltage breakdown test has been completed.

57.4 If the average breakdown voltage of the control pairs after the 72-h period is less than 50 % of the value for the

[11] Containers similar to the 200-mL pressure bottles provided with glass stoppers and wire clamps, as supplied by T. C. Wheaton Co., Millville, NJ (No. 5800), or by Arthur H. Thomas Co., Philadelphia, PA (No. 2282), have been found satisfactory.

unaged pairs, it is likely that the test temperature was too high for that type of wire insulation, and the test must be repeated at a lower temperature.

NOTE 8—Wire pairs in contact with sleeving ordinarily should not show breakdown voltage values higher than the control pairs. When this occurs, it indicates that randomization of the specimens has not been obtained.

## 58. Report

58.1 Report the following information:

58.1.1 Identification of the sleeving,

58.1.2 Type of insulation on the wire,

58.1.3 Test temperature,

58.1.4 Percentage retention of breakdown voltage for the twisted pairs with sleeving based on the value for the wire pair controls, both determined after 72 h aging, and

58.1.5 Evidence of softening or liquefaction of the sleeving coating or presence of condensate on the bottle walls during the test.

## 59. Precision and Bias

59.1 *Precision*—This test method has been in use for many years, but no statement of precision has been made and no activity is planned to develop such a statement.

59.2 *Bias*—This test method has no bias because the value for compatibility with magnet wire insulation in a sealed tube is determined solely in terms of this test method.

# SOLVENT RESISTANCE

## 60. Significance and Use

60.1 Sleeving may be exposed to a variety of solvents during cleaning or repair of electrical equipment. This procedure serves to evaluate the possible degrading effects of exposure to these materials.

## 61. Apparatus and Materials

61.1 *Test Tubes*, glass, stoppered, about 0.63 in. (16 mm) in outside diameter and 5.9 in. (150 mm) long.

61.2 *Swelling Oil*, Type 3, Test Method D 471.

61.3 *Xylene*, reagent grade

61.4 *Trichloroethane*, 1,1,1-isomer, reagent grade.

61.5 *Paraffin oil*, USP grade.

## 62. Test Specimens

62.1 Prepare three specimens about 2 in. (50 mm) long for each solvent to be evaluated.

## 63. Procedure

63.1 Immerse the specimens in a test tube containing solvent and stopper, and maintain at 23 ± 2°C (73.4 ± 3.6°F) for the period prescribed in the material specification.

63.1.1 **Caution:** The solvents used in this procedure may be hazardous to personnel performing this test because of their toxicity and fire hazard. Adequate precautions shall be taken to protect the operator against contact with the solvents or breathing the vapors by suitable protective clothing and adequate ventilation. Avoid proximity to open flames or electrical contacts in the immediate area.

63.2 At the end of the specified test period, remove the specimens and immediately examine for visible effects of the solvent, such as flaking, shredding or peeling of the coating.

63.3 Determine the amount of swelling, if any, by measurement of the wall thickness of the sleeving, as described in 9.2.

63.4 Allow the specimens to recover in free air under the test conditions specified in Section 6, and repeat the examination described in 63.2 and 63.3.

## 64. Report

64.1 Report the following information:

64.1.1 Identification of the sleeving,

64.1.2 Identification of the immersion liquid,

64.1.3 Period of immersion, h,

64.1.4 Visible effects of immersion, and

64.1.5 Swelling, expressed as a percentage change in wall thickness based on the original dimension, both immediately after removal and after recovery.

## 65. Precision and Bias

65.1 *Precision*—This test method has been in use for many years, but no statement of precision has been made and no activity is planned to develop such a statement.

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

# HYDROLYTIC STABILITY

## 66. Scope

66.1 This procedure evaluates the permanent effects of prolonged exposure to moisture at elevated temperatures by means of a visual and electrical test. It is limited to sizes of sleeving that can be conveniently conditioned in test tubes (about size 0 maximum). It is possible to evaluate larger sizes if chambers capable of maintaining the prescribed exposure conditions are available.

## 67. Significance and Use

67.1 Exposure of sleeving to moisture at elevated temperature and under conditions of confinement may result in chemical deterioration. This is usually evidenced by irreversible physical deterioration of the polymer coating which causes permanent damage, distinct from a reversible type of effect usually the result of less rigorous exposure. This procedure serves to evaluate these permanent effects, if any.

## 68. Apparatus

68.1 *Test tubes*, borosilicate type, glass stoppered, 25-mm outside diameter by 200 mm long. Stopper must provide a means by which a wire can be suspended from its center.

## 69. Test Specimens

69.1 Prepare three lengths of sleeving, each 5 in. (125 mm), from the material selected in accordance with Section 5.

## 70. Procedure

70.1 Into each specimen insert a clean, bare copper wire of such size as to provide a loose fit and of such length as to permit suspension of the specimen within about 2 in. (50 mm) from the bottom of the test tube. The stopper shall be treated, if necessary, to provide a water-vapor tight seal, as for example by wax-coating.

70.2 Add distilled water to the test tube to a depth of about 1 in. (25 mm). Bring the tube and water to 70 ± 2°C (158± 3.6°F). Insert the specimen in the tube and suspend it by means of the wire attached to the stopper so as to prevent contact of the specimen with the water. Stopper the assembly and place it in an oven at 70°C (158°F).

70.3 After a period of 336 h, remove the assembly and allow it to cool to room temperature. Remove the specimen and allow it to hang freely at the conditions noted in 6.1 for 24 h.

70.4 Examine each specimen visually for a change in color and in surface characteristics, such as softening, flow, or an increase in tack.

## 71. Report

71.1 Report the following information:

71.1.1 Identification of the sleeving, and

71.1.2 Visual observations made for reversion, tackiness, flow, discoloration, and the like.

## 72. Precision and Bias

72.1 *Precision*—This test method has been in use for many years, but no statement of precision has been made and no activity is planned to develop such a statement.

72.2 *Bias*—This test method has no bias because the value for hydrolic stability is determined solely in terms of this test method.

# EFFECT OF PUSH-BACK AFTER HEAT AGING

## 73. Scope

73.1 While possibly applicable to other types of sleeving of an elastomeric nature, this test method applies principally to silicone elastomer sleeving.

## 74. Significance and Use

74.1 Silicone elastomer sleeving is used principally for its ability to respond to marked mechanical distortion after prolonged exposure to elevated temperatures, without suffering permanent damage. This test serves to evaluate this property. It also provides a convenient means of determining continuity of quality with respect to processing and compounding.

## 75. Test Specimens

75.1 Prepare three specimens of sleeving 4 in. (100 mm) in length for sizes up to AWG 0, and 5 in. (125 mm) in length for sizes AWG 0 and larger.

## 76. Procedure

76.1 Place specimens in an oven at 250 ± 3°C for a period of 168 h. Remove specimens and allow to cool in the conditions described in 6.1 for a period of 0.5 h.

76.2 Insert into the specimen a straight copper wire of the same size as the nominal size of the sleeving to be tested. Gently and slowly push the ends of the sleeving toward each other along the wire until the length of the specimen has been reduced 20 %.

76.3 Examine the specimen while in the pushed-back state for evidence of cracks in the coating. Allow the sleeving to relax and conduct dielectric breakdown voltage tests on the pushed-back area using the procedure described in 14.2.

## 77. Report

77.1 Report the following information:

77.1.1 Identification of the sleeving,

77.1.2 Visual evidence of cracks in the pushed-back area, and

77.1.3 Average dielectric breakdown voltage of the sleeving.

## 78. Precision and Bias

78.1 *Precision*—This test method has been in use for many years, but no statement of precision has been made and no activity is planned to develop such a statement.

78.2 *Bias*—This test method has no bias because the value for push-back after heat aging is determined solely in terms of this test method.

## 79. Keywords

79.1 a-c breakdown voltage; bending effects; brittleness temperature; coated textile sleeving; compatibility (magnet wire); flame resistance; flexible tubes; fluid resistance; heat aging; high humidity; hydrolytic stability; oil resistance; push-back; temperature index; thermal endurance; woven textile tubes