



Standard Test Methods for Testing Solvent Containing Varnishes Used for Electrical Insulation¹

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1. Scope

1.1 These test methods cover tests for solvent containing varnishes primarily intended to provide electrical, mechanical, and chemical protection for electrical equipment. These test methods include tests for control and performance as follows:

	Procedure	Section
Build		37-41
Dielectric Strength		42-47
Drainage		25-31
Flash Point		17-19
Nonvolatile Matter		20-24
Oil Resistance		53-55
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Specific Gravity		9-12
Temperature Index		48-49
Time of Drying		32-36
Varnish Compatibility		50-52
Viscosity		13-16

1.2 Where the entire test method is included in this standard, the precision and bias are not known unless given in the stated method.

1.3 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

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

2. Referenced Documents

2.1 ASTM Standards:

- D 56 Test Method for Flash Point by Tag Closed Tester²
- D 93 Test Methods for Flash Point by Pensky-Martens Closed Tester²
- D 149 Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials at Commercial Power Frequencies³
- D 202 Test Methods for Sampling and Testing Untreated

Paper Used for Electrical Insulation³

- D 287 Test Method for API Gravity of Crude Petroleum and Petroleum Products (Hydrometer Method)²
- D 295 Test Methods for Varnished Cotton Fabrics Used for Electrical Insulation³
- D 374 Test Methods for Thickness of Solid Electrical Insulation³
- D 580 Specification for Greige Woven Glass Tapes and Webbing⁴
- D 611 Test Methods for Aniline Point and Mixed Aniline Point of Petroleum Products and Hydrocarbon Solvents²
- D 1475 Test Method for Density of Paint, Varnish, Lacquer, and Related Products⁵
- D 1638 Method of Testing Urethane Foam Isocyanate Raw Materials⁶
- D 1932 Test Method for Thermal Endurance of Flexible Electrical Insulating Varnishes³
- D 2436 Specification for Forced-Convection Laboratory Ovens for Electrical Insulation³
- D 2518 Specification for Woven Glass Fabrics for Electrical Insulation⁷
- D 2519 Test Method for Bond Strength of Electrical Insulating Varnishes by the Helical Coil Test⁷
- D 3145 Test Method for Thermal Endurance of Electrical Insulating Varnishes by the Helical Coil Method⁷
- D 3251 Test Method for Thermal-Aging Characteristics of Electrical Insulating Varnishes Applied Over Film-Insulated Magnet Wire⁷
- D 3278 Test Method for Flash Point of Liquids by Small Scale Closed-Cup Apparatus⁵
- D 3487 Specification for Mineral Insulating Oil Used in Electrical Apparatus⁸
- D 5032 Practice for Maintaining Constant Relative Humidity by Means of Aqueous Glycerin Solutions⁷
- E 104 Practice for Maintaining Constant Relative Humidity by Means of Aqueous Solutions⁹

3. Terminology

3.1 Definitions:

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² *Annual Book of ASTM Standards*, Vol 05.01.

³ *Annual Book of ASTM Standards*, Vol 10.01.

⁴ *Annual Book of ASTM Standards*, Vol 07.01.

⁵ *Annual Book of ASTM Standards*, Vol 06.01.

⁶ Discontinued. See 1991 *Annual Book of ASTM Standards*, Vol 08.02.

⁷ *Annual Book of ASTM Standards*, Vol 10.02.

⁸ *Annual Book of ASTM Standards*, Vol 10.03.

⁹ *Annual Book of ASTM Standards*, Vol 11.03.

3.1.1 *dielectric strength*—the voltage gradient at which dielectric failure of the insulating material occurs under specific conditions of test.

3.1.2 *drainage*—of an insulating varnish, a measure of the variation in thickness from top to bottom of a varnish film obtained on the surface of a vertically dip coated panel after a specified time and temperature.

3.1.3 *flash point*—the lowest temperature of the specimen, corrected to a pressure of 760 mm Hg (101.3 kPa), at which application of an ignition source causes any vapor from the specimen to ignite under specified conditions of test.

3.1.4 *nonvolatile matter*—in insulating varnish, that portion of a varnish which is not volatilized when exposed to specified conditions; the value obtained is not necessarily equal to the calculated solids incorporated during compounding.

3.1.4.1 *Discussion*—For example, the theoretical chemical solids are often assumed to be the solid phase materials incorporated in the varnish at the time of compounding. Many of these solid phase intermediate materials will lose volatile fractions due to the specified conditions of the nonvolatile matter procedure. An example is phenolic resin.

3.1.5 *oil resistance*—of insulating varnish, a measure of the retention of properties after exposure to a specified oil under specified conditions of test.

3.1.6 *time of drying*—of insulating varnish, the time required for a film of varnish to dry to a tackfree state under specified conditions.

3.1.7 *varnish, air-drying, n*—a liquid resin system that forms a dry, tack free coating, without the application of heat, either through evaporation of solvent or by reaction with atmospheric oxygen.

3.1.8 *varnish, baking, n*—a liquid resin system that forms a dry, tack free coating when exposed to elevated temperatures.

3.2 Definitions of Terms Specific to This Standard:

3.2.1 *build, n*—of an insulating varnish on copper, the average thickness of varnish film on one side of a copper panel that has received a single coat of the varnish applied and measured under specified conditions.

3.2.2 *build, n*—of an insulating varnish on glass cloth, the average overall thickness of strips of glass cloth that have received two dips of the varnish applied and measured under specified conditions.

4. Significance and Use

4.1 *Control*—The following tests are useful for control purposes during the manufacture and use of varnishes, and for determining the uniformity of batches:

- 4.1.1 Specific gravity,
- 4.1.2 Viscosity,
- 4.1.3 Flash point, and
- 4.1.4 Nonvolatile matter by weight.

4.2 *Performance*—The following tests are useful for determining the performance of varnishes during application and use:

- 4.2.1 Drainage,
- 4.2.2 Time of drying,
- 4.2.3 Build,
- 4.2.4 Dielectric strength,
- 4.2.5 Thermal endurance,

- 4.2.6 Varnish compatibility,
- 4.2.7 Salt water proofness, and
- 4.2.8 Oil resistance.

5. Hazards

5.1 **Precaution:** Do not use varnish at temperatures above the flash point when inadequate ventilation, and the possibility of flames or sparks exist. Store varnish in sealed containers. The precautions shall also apply to the handling of the reagents and solvents called for herein.

6. Sampling

6.1 For all tests the sample shall be taken from a representative lot of the varnish under study. To avoid skin formation and escape of solvents, protect the sample by keeping it at room temperature in a nearly filled, tightly sealed container.

7. Preparation of Test Specimens

7.1 *Selection of Substrate*—The selection of the substrate is determined in part by application and in part by thermal class. Two types of substrates may be used: copper strip or glass cloth. Copper strip is generally not used for applications over 180°C (356°F) due to oxidation.

7.2 Copper Base:

7.2.1 For tests that are to be performed upon the varnish as a film on a copper base, copper strips 38 mm (1½ in.) in width, 200 mm (8 in.) in length, and 0.127 ± 0.08 mm (0.005 ± 0.0003 in.) in thickness shall be used, unless otherwise specified. Measure the thickness of these strips to the nearest 0.002 mm (0.0001 in.). Clean the strips with a suitable solvent (Note 1), then polish thoroughly with No. 000 steel wool. Wipe the strips free of any fingerprints or metal particles with the solvent and a lint-free cloth. If the strips are not to be used immediately, they should be kept stored in a noncorrosive varnish solvent.

NOTE 1—Xylene and denatured alcohol (1:1) have been found to be suitable cleaning solvents. V.M.&P. naphtha is a suitable solvent in which to store the strips.

7.2.2 Prepare all varnish films for tests at $23 \pm 1^\circ\text{C}$ ($73.5 \pm 2^\circ\text{F}$) and $50 \pm 5\%$ relative humidity. The air of the room shall be relatively free of dust by some satisfactory method of filtering.

7.2.3 After the strips have been wiped clean and dry, prepare the test specimens by dipping them into a tank of the varnish that has been adjusted to a proper consistency and allowed to stand covered until free of bubbles (not to exceed 1 h). Trial testing may be required to establish the proper consistency. Proper consistency has been reached when the strips are dipped in the varnish at a temperature of $23 \pm 1^\circ\text{C}$ ($73.5 \pm 2^\circ\text{F}$) and are withdrawn slowly and uniformly at the rate of 100 mm (4 in.)/min., the average thickness of the film remaining on each side of a strip when dry shall be 0.025 ± 0.005 mm (0.0010 ± 0.0002 in.).

7.2.4 Calculate the average thickness by averaging at least six measurements taken along the length of the strip and over 3 mm (⅜ in.) from either edge. Thickness measurements shall be made in accordance with Test Methods D 374.

7.2.5 It is recognized that the thickness of the film cannot be measured with the precision stated, but a close control of the

thickness of the varnish film is desired. With the method specified, the actual average thickness should be within ± 0.005 mm (± 0.0002 in.) of the measured thickness.

7.2.6 With air dry varnishes, except where time of drying is the property being measured, following each dip, suspend the specimens vertically in a dipping position and dry in dust-free air for such times and at such temperatures as the user and the supplier agree are suitable. If necessary, readjust the consistency of the varnish and dip the specimen in the reverse direction to the first and air dry.

7.2.7 With baking varnishes, allow the specimens to drain at a temperature of $23 \pm 1^\circ\text{C}$ ($73.5 \pm 2^\circ\text{F}$) then bake for such times and at such temperatures as the user and the supplier agree are suitable. If necessary, readjust the consistency of the varnish and dip the specimen in the reverse direction to the first and bake.

7.3 Glass Cloth Base:

7.3.1 For tests that are to be performed on the varnish as a combination with glass cloth, use a glass strip instead of a copper strip. Prepare the strip from specimens 38 mm (1.5 in.) wide by approximately 250 mm (10 in.) long from heat-cleaned woven glass fabric (Note 2). The length shall be in the direction of the warp threads. The fabric shall be Style No. 116 as listed in Table 1 of Specification D 2518. The volatile content of the heat-cleaned fabric shall not exceed 0.1 % as determined in accordance with the organic content test of Specification D 580 (Note 3). The strip form specimens shall be kept in a Standard Laboratory Atmosphere (see 7.2.2).

7.3.2 Condition the heat-cleaned glass strips 1 h at 105°C (221°F) and cool in a Standard Laboratory Atmosphere before coating.

NOTE 2—The strip form specimens may be stamped out of the woven glass fabric by means of die and clicker. This technique causes the ends of the fibers to bind together and prevents the unraveling of the yarn.

NOTE 3—Commercially heat-cleaned fiberglass fabric meeting this volatile content is available.

7.3.3 *Dipping and Curing*—Condition the varnish to be tested for a minimum of 4 h at Standard Laboratory Temperature before coating the strips. Immerse specimens in the varnish until bubbling stops. Withdraw at 100 mm (4 in.)/min. and drain in a dipping and draining chamber in the same position as dipped for 30 min., or as agreed between the user and supplier. In order to facilitate dipping and curing and to obtain smoother specimens, the fiberglass strips may be secured at the ends to rectangular wire frames about 240 by 70 mm (9.5 by 2.75 in.). Bake specimens for the time and at the temperature specified by the manufacturer for the first coat. Apply the next coat by reverse dipping, except, withdraw specimens as soon as immersed and drain as for the previous coat. Bake the second coat in accordance with the manufacturer's recommended schedule for a final coat.

7.3.4 *Measuring Specimen Thickness*—Measure specimen thickness using a dead-weight dial-type micrometer in accordance with Test Methods D 374, Method C, except that the weight on the specimen shall be limited to 567 ± 7 g (20 ± 0.25 oz.) and the anvil surface upon which the specimen rests shall be 51 mm (2 in.) in diameter. Allow the presser foot to remain on the specimens about 2 s before taking a reading.

Where thickness measurements along a line or in an area are nonuniform, repeat the measurements, taking care to avoid film abnormalities.

8. Conditioning

8.1 Condition the specimens as described in the individual test procedures.

SPECIFIC GRAVITY

9. Terminology

9.1 *Definitions of a Term Specific to This Standard:*

9.1.1 *specific gravity*—the ratio of the weight of a unit volume of sample as compared with the weight of the same unit volume of distilled water at $23 \pm 1^\circ\text{C}$ ($73.5 \pm 2^\circ\text{F}$).

10. Significance and Use

10.1 Specific gravity indicates the relative weight per unit volume of a varnish. It is a useful test for control purposes.

11. Procedure

11.1 Determine the specific gravity of the varnish by using a wide-mouth pycnometer (25-mL minimum capacity) at $23 \pm 1^\circ\text{C}$ ($73.5 \pm 2^\circ\text{F}$). Refer to Test Method D 1475. Determine the specific gravity by dividing the weight of an equal volume of distilled water at the same temperature.

11.2 A hydrometer is another method for determining this property, in accordance with Test Method D 287 or Method D 1638.

12. Report

12.1 Report the following information:

12.1.1 Identification of the varnish used, and

12.1.2 The specific gravity at $23 \pm 1^\circ\text{C}$ ($73.5 \pm 2^\circ\text{F}$), reported to the third decimal place.

VISCOSITY

13. Significance and Use

13.1 The viscosity measurement may be used to indicate the flowing characteristics of a varnish.

13.2 Viscosity is also useful for control purposes during the manufacture and use of a varnish.

14. Apparatus

14.1 *Brookfield Viscometer* (Note 4)—The viscometers shall be kept calibrated over the range of viscosity of the varnishes to be tested by means of oils verified as to absolute viscosity at $23 \pm 1^\circ\text{C}$ ($73.5 \pm 2^\circ\text{F}$) by the National Institute of Standards and Technology. A calibration curve showing the relation between viscosity in absolute units and the instrument readings shall be used.

NOTE 4—If the Brookfield viscometer is used without the guard, it must be restandardized in a suitable container.

15. Procedure

15.1 Determine the viscosity in accordance with Method D 1638.

15.2 Adjust the temperature of the varnish to $23 \pm 1^\circ\text{C}$ ($73.5 \pm 2^\circ\text{F}$) and follow Method D 1638. Take precautions to avoid evaporation or formation of skin on the surface of the varnish. State results in terms of absolute viscosity, in centipoises.

15.3 Test two specimens and report the mean value, provided the average deviation of a single observation from the mean is not greater than 2 %. Otherwise, check the instrument and method used and make additional tests until the average deviation from the mean does not exceed 2 %.

16. Report

16.1 Report the following information:

- 16.1.1 Identification of the varnish used,
- 16.1.2 Temperature of test,
- 16.1.3 Model of Brookfield viscometer,
- 16.1.4 Speed of rotation,
- 16.1.5 Spindle number, and
- 16.1.6 Viscosity in centipoises.

FLASH POINT

17. Significance and Use

17.1 Flash point approximates the lower temperature limit of flammability, or the temperature at which the concentration of the vapors of a liquid in air equals the lower flammability limits. It is used in regulations for storage, transportation, handling, and use of a liquid by U.S. regulatory agencies, and state and local ordinances or codes.

18. Procedure

18.1 Determine flash point in accordance with one of the following methods, depending on viscosity, type of material, and anticipated flash point:

- 18.1.1 Test Method D 56,
- 18.1.2 Test Methods D 93, or
- 18.1.3 Test Method D 3278.

19. Report

19.1 Report the following information:

- 19.1.1 Identification of the varnish used, and
- 19.1.2 Flash point and method used. The flash point shall be reported as the average value in degrees Celsius or degrees Fahrenheit, corrected to standard barometric pressure.

NONVOLATILE MATTER

20. Significance and Use

20.1 The percent of nonvolatile matter is indicative of the amount of film-forming material available in the varnish.

20.2 The percent of nonvolatile matter is useful for control purposes during the manufacture and use of the varnish and in determining the uniformity of batches.

21. Apparatus

- 21.1 *Analytical Balance*, capable of weighing to ± 0.1 mg.
- 21.2 *Forced-Convection Oven*, see Specification D 2436 for a representative oven.
- 21.3 *Weighing Dishes*, aluminum, approximately 51 mm (2 in.) in diameter, and 16 mm ($\frac{5}{8}$ in.) high on the sides.

21.4 *Desiccator*.

22. Procedure

22.1 Preheat weighing dishes 15 min at 150°C (302°F) to remove moisture.

22.2 Place the dishes in a desiccator and cool to room temperature.

22.3 Weigh the dishes to ± 0.1 mg and return to the desiccator.

22.4 Pour a 1.5 to 1.6 g sample of varnish into a predried, preweighed aluminum dish.

22.5 Within 10 sec., reweigh the aluminum dish with the varnish to ± 0.1 mg and determine the weight of the varnish transferred.

22.6 Prepare a minimum of two specimens.

22.7 The specimen must completely cover the bottom surface of the weighing dish (More viscous specimens may require warming).

22.8 Within 30 min after preparation, place the dish and its contents in a $135 \pm 2^\circ\text{C}$ ($275 \pm 5^\circ\text{F}$) forced-convection oven for 3 h (± 5 min). Other temperatures may be used when agreed upon between user and supplier.

22.9 Cool the dish containing the specimen to room temperature in a desiccator and reweigh to ± 0.1 mg.

22.10 Determine the residue weight by subtracting the weight of the aluminum dish from the total weight.

23. Calculation

23.1 Calculate the nonvolatile matter as the ratio of the residue weight to the weight of the original specimen, expressed as a percentage.

24. Report

24.1 Report the following information:

- 24.1.1 Identification of the varnish used,
- 24.1.2 Number of specimens tested and individual values,
- 24.1.3 Average percentage of nonvolatile matter of all specimens, and
- 24.1.4 Time and temperature for drying specimen.

DRAINAGE

25. Significance and Use

25.1 The drainage test is used for an indication of the amount of varnish retained on the surface, and to some extent, in the interior of a dipped structure.

26. Procedure (Using Copper Strip)

26.1 Allow the varnish to stand long enough to be free of air bubbles. Immerse a strip of sheet copper or brass 38 mm (1.5 in.) in width, 200 mm (8 in.) in length, and 0.127 ± 0.008 mm (0.005 ± 0.0003 in.) in thickness in the varnish at $23 \pm 1^\circ\text{C}$ ($73.5 \pm 2^\circ\text{F}$). Immerse up to a line previously drawn across the strip 25 mm (1 in.) from the top.

26.2 Withdraw the strip at the rate of 100 mm (4 in.)/min, and allow to drain thoroughly at room temperature while suspended vertically. Dry as described in 7.2.6 and 7.2.7.

26.3 Measure thickness at points 25 and 150 mm (1 and 6 in.) respectively, from the line to which the specimen was immersed.

27. Calculation

27.1 Calculate the variation in film thickness caused by draining as the ratio of the difference between the thickness at the upper point 25 mm (1 in.) and at the lower point 100 mm (6 in.), to the thickness of the upper point expressed as a percentage, as follows:

$$\text{Drainage, \%} = (\text{lower measurement} - \text{upper measurement} / \text{upper measurement}) \times 100. \quad (1)$$

28. Report

28.1 Report the following information:

28.1.1 Thickness of each film at the two points specified in Section 26.

29. Procedure (Using Glass Cloth)

29.1 Prepare five specimens in accordance with 7.3 with the varnish viscosity adjusted to obtain a build of 0.18 ± 0.013 mm (0.007 ± 0.0005 in.). Apply three coats of the varnish to the specimen all in the same direction and for each dip immerse 25 mm (1.0 in.) from the top of the specimen (or frame if used). Condition specimens for 15 min at the Standard Laboratory Atmosphere after the final bake and measure the thickness as described with the presser foot carefully centered on lines 25 ± 1.0 mm ($1 \pm 1/32$ in.) and 150 ± 1.0 mm ($6 \pm 1/32$ in.), respectively below the dipping line. Make three measurements in the center 25 mm (1.0 in.) section of each line to avoid edge beads.

30. Calculation

30.1 Average the three thickness readings of the upper, or 25 mm (1 in.), and the lower, or 150 mm (6 in.), lines respectively for each specimen. Subtract the thickness at the upper line from that at the lower, divide by the thickness at the upper and multiply by 100 to give the percent drainage for the specimen.

31. Report

31.1 Report the following information:

- 31.1.1 Description of thinner, if used,
- 31.1.2 Curing time and temperature for each coat,
- 31.1.3 Average thickness of each specimen at the 25 mm (1 in.) line and at the 150 mm (6 in.) line,
- 31.1.4 Percent drainage of each specimen, and
- 31.1.5 Average percent drainage of the five specimens.

TIME OF DRYING

32. Significance and Use

32.1 Drying time is useful for determining the time required, at specified conditions, to cure to the point when coated objects will have no surface tack at room temperature. It does not measure cure of a varnish or possible softening at an elevated operating temperature.

33. Procedure (Using Copper Strips)

33.1 Dip once the specimens described in 7.2. At the end of the first 10 min, and again at the end of the 10 min period thereafter, take one specimen from the oven and examine. In the case of slow-drying varnishes these periods may be lengthened at the discretion of the operator.

33.2 Where an oven is used, its particular size and ventilation have a considerable effect on the drying time of varnishes. The oven must conform with Specification D 2436.

33.3 Consider the varnish dry (Note 5) when a piece of kraft paper that has been pressed by a weight on the surface of the varnish for 1 min falls free from the panel within 15 s after the panel has been inverted. Apply the paper in the vicinity of the center of the specimen and at right angles to it. For the weight use a cylindrical 0.45 kg (1 lb) weight, 25 mm (1 in.) in diameter. The kraft paper should be 50 mm (2 in.) in width, 75 mm (3 in.) in length, and approximately 0.20 mm (0.0078 in.) in thickness. The paper should also have the following typical requirements when tested in accordance with Test Methods D 202.

Basis Weight, g/m ²	145
Thickness, mm	0.17
Air resistance (s/100 mL/in. ²)	350
Coefficient of dynamic friction	0.4

NOTE 5—The drying time of varnishes may vary with the base on which the varnish is dried. It is not expected that varnishes will dry in the same manner on all materials or on all metals. Some varnishes dry with what is commonly known as “tack”. Therefore, the drying time is reported as the number of hours required to first reach consistency, and the varnish should be reported as drying with a “tack.”

34. Report

34.1 Report the following information:

- 34.1.1 Identification of the varnish used, and
- 34.1.2 Drying time and temperature.

35. Procedure (Using Glass Cloth)

35.1 Drying time of a varnish on glass tape is the time required for the second coat of varnish on a glass fiber tape to be converted to a tackfree state, as determined under specified conditions.

35.2 Prepare at least five specimens in accordance with 7.3, after the varnish build has been adjusted by trial to give a double reverse dip specimen thickness of 0.18 ± 0.013 mm (0.007 ± 0.0005 in.) as measured in 7.2. During drying of the second coat, remove specimens from the oven periodically and after cooling at the Standard Laboratory Atmosphere for 15 min. Check for dryness using the end point specified in 33.3. Adjust intervals to determine the drying time within a ½ h range.

36. Report

36.1 Report the following identification of varnish:

- 36.1.1 Curing time and temperature for the first coat,
- 36.1.2 Drying temperature for the second coat, and
- 36.1.3 Time to dry.

BUILD

37. Significance and Use

37.1 Build is used as an indication of the amount of varnish that will be obtained on a dipped structure. Build will be affected by varnish properties such as viscosity, non-volatile content, weight loss and curing characteristics. This method determines the total effect without attempting to separate these several factors.

38. Procedure (Using Glass Cloth)

38.1 Prepare three specimens using the varnish “as supplied” after the varnish has been conditioned at least 4 h at the Standard Laboratory Atmosphere. Dip, drain and cure the specimens as described in 7.3. Reverse the specimens and apply a second coat.

38.2 After curing the second coat, condition the specimens for 10 h at the Standard Laboratory Atmosphere. Measure the thickness in accordance with 7.3 along imaginary lines 40, 100 and 160 mm (1.5, 4.0 and 6.5 in.) from the dip line at one end of the specimen. Make three measurements along each line in the 25 mm (1.0 in.) center section of the strip to avoid edge beads.

39. Report

39.1 Report the following information:

39.1.1 Curing time and temperature for each coat,

39.1.2 Average of the nine thickness measurements on each specimen, and

39.1.3 Average thickness of three specimens, which is considered the build on glass cloth of the varnish.

40. Procedure (Using Copper Strips)

40.1 Prepare a specimen as described in 7.2 using the varnish “as supplied” after the varnish has been conditioned at least 4 h at the Standard Laboratory Atmosphere. Dip, drain and cure the specimen as described in 7.2.

40.2 Condition the specimen for 1 h at the Standard Laboratory Atmosphere. Measure the total thickness at six points along the panel. Make measurements over 13 mm (½ in.) from either edge, the dip line and the bottom.

40.3 Determine the difference between each measurement and the thickness of the copper strip. One half of this difference is the film thickness on one side of the strip.

41. Report

41.1 Report the following information:

41.1.1 Curing time and temperature, and

41.1.2 Average of the film thickness on one side of the copper strip which is considered the build on copper strips of the varnish.

DIELECTRIC STRENGTH OF DRIED VARNISH FILM

42. Significance and Use

42.1 The dielectric strength of an insulating varnish is an important indication of its ability to withstand electric stress without failure. This value does not correspond to dielectric strength expected in service, but is a numerical value which may be used for purchase by specification as an indication of quality, for comparison of different varnishes, and to a limited degree, for design work when coupled with experience. The comparison of dielectric strengths of a given varnish under various conditions is of considerable significance and provides much more information than is obtained by making the test under only one condition.

43. Apparatus

43.1 *Apparatus for Applying and Measuring Test Voltages*—A description of this apparatus is found in Test

Method D 149. Power supply frequency shall not be greater than 100 Hz, the transformer shall have a rating of not less than 2 kVA, and the short-time test shall have a rate-of-voltage rise of 500 V/s.

43.2 *Electrodes and Assembly*—Electrodes shall consist of opposing cylindrical metal rods 6.1 mm (¼ in.) in diameter with edges rounded to a radius of 0.8 mm (⅓ in.) (see Table 1 of Test Method D 149). Electrode faces shall be parallel and electrodes shall be held exactly opposite one another. The upper movable electrode shall weigh 0.045 ± 0.002 kg (0.100 ± 0.005 lb). Faces of the electrodes shall be kept smooth and polished. To prevent flashover, 3-mm (⅛-in.) thick annular rubber gaskets, having the center hole 9 mm (⅜ in.) in diameter, shall be used to surround the electrodes. The electrode assembly shall be designed to hold gaskets under pressure just sufficient to prevent flashover when voltage is applied. Such an assembly is shown in Fig. X1.1 of Test Methods D 295.

44. Test Specimens

44.1 The selection of the substrate to be used for these tests is based on the functional requirements of the varnish and the application. The following may be used as a guide. In general, the temperature index of the varnish will determine the substrate.

Substrate	Temperature Index				
Copper	105	130	155	180	
Glass Cloth			155	180	200 220

44.2 For tests requiring copper substrate, make the specimens from pieces of cold rolled, hard, smooth sheet copper approximately 200 mm (8 in.) in length, 90 mm (3.5 in.) in width, and 0.13 mm (0.005 in.) in thickness. Clean the specimens thoroughly with xylene:denatured alcohol solvent (1:1) and rub dry with a clean cheesecloth. Place two sheets together and seal them at the edges so that a varnish film will be obtained on one side only of each copper sheet. Allow the varnish to stand until it is free of air bubbles. Trial testing may be required to establish the proper consistency. Proper consistency has been reached when the final thickness of the dry film of varnish on one side of the test specimen shall be not less than 0.043 mm (0.0017 in.) nor more than 0.053 mm (0.0021 in.).

44.3 Reverse dip the assembly, once in each direction, in the varnish to be tested in order to give a more uniform thickness of coating. Withdraw the panels at the rate of 100 mm (4 in.)/min at room temperature $23 \pm 1^\circ\text{C}$ ($73.5 \pm 2^\circ\text{F}$) and 50 % relative humidity.

44.4 Dry the specimens of air-drying varnish in dust-free air after each dip in the same vertical position in which they were dipped at $23 \pm 1^\circ\text{C}$ ($73.5 \pm 2^\circ\text{F}$) and 50 % relative humidity for a period of 24 h. Bake specimens for baking varnishes after each dip in the same vertical position in which they were dipped. Temperature and time of baking should be as specified by the manufacturer. After curing, separate the panels without bending and cut them into halves along the lengthwise center line. Discard the edge strips partially covered by the tape.

45. Conditioning

45.1 Condition two specimens at each of the following conditions:

- 45.1.1 At 96 h at the Standard Laboratory Atmosphere, and
- 45.1.2 At 96 h at the Standard Laboratory Temperature and 96 % relative humidity. This relative humidity can be accurately maintained as described in Practice E 104 or Practice D 5032.

46. Procedure

46.1 Determine the dielectric strength in accordance with Test Method D 149 using the short time test. Increase the voltage from zero to breakdown at a uniform rate of 500 V/s.

46.1.1 Determine the dielectric strength immediately after removal of the specimens from the conditioning chamber, using electrodes as described in 43.2. Make all measurements at a temperature of $23 \pm 1^\circ\text{C}$ ($73.5 \pm 2^\circ\text{F}$).

46.2 *Copper Specimens*—For copper specimens, make five thickness measurements with a dial-type micrometer on each copper panel and at the same points on the coated panels. Use the difference in averages of these two sets of measurements as the thickness of the varnish film on each panel in calculating dielectric strength in volts per mil.

46.3 *Glass Cloth Substrates*:

46.3.1 For tests requiring glass substrates, prepare two specimens in accordance with 35.2 for each test condition. The varnish viscosity shall be adjusted to provide a specimen thickness of 0.180 ± 0.013 mm (0.0070 ± 0.0005 in.). Apply two coats, reversed between dips, and allow the specimens to cool 15 min at the Standard Laboratory Atmosphere after the last bake.

46.3.2 Measure dielectric breakdown at five points approximately 32 mm ($1\frac{1}{4}$ in.) apart on each specimen, preferably in the same atmosphere at which they were conditioned. If this is not possible, measure immediately after removal at the Standard Laboratory Temperature.

46.3.3 Make five thickness measurements on each specimen at points near the breakdowns, but in areas judged to have been undisturbed by the breakdown.

47. Report

- 47.1 For copper specimens, report the following:
 - 47.1.1 Identification of the varnish used,
 - 47.1.2 Conditioning method,
 - 47.1.3 Average copper thickness,
 - 47.1.4 Individual film thicknesses (individual over-all thickness readings minus average copper thickness),
 - 47.1.5 Average film thickness,
 - 47.1.6 Individual breakdown voltages, and
 - 47.1.7 Average dielectric strength in V/mil (or KV/mm).
- 47.2 For glass cloth substrate, report the following:
 - 47.2.1 Identification of the varnish used,
 - 47.2.2 Curing time and temperature for each coat,
 - 47.2.3 Conditioning used,
 - 47.2.4 Average thickness of the two specimens,
 - 47.2.5 Individual breakdown voltages, and
 - 47.2.6 Average dielectric strength in V/mil (or kV/mm).

TEMPERATURE INDEX

48. Procedure

48.1 Determine the temperature index in accordance with at least two of the following tests:

- 48.1.1 Test Method D 3251 (twisted pair), using thermal life of 20 000 h.
- 48.1.2 Test Method D 1932 (curved electrode), using thermal life of 25 000 h.
- 48.1.3 Test Method D 3145 (helical coils), using thermal life of 20 000 h.

48.2 It is recognized that there may be two (or possibly more) temperature indices for electrical insulating varnishes. The requirements of the end use and performance are the determining factor in selecting an appropriate temperature index.

49. Report

- 49.1 Report the following information:
 - 49.1.1 Identification of the varnish used, and
 - 49.1.2 The report as specified under the report section of each method listed in 48.1.

VARNISH COMPATIBILITY

50. Significance and Use

50.1 The varnish compatibility test is required in cases where it is desired to use varnishes from different manufacturers or of different formulations in the same dip tank or system, and the different varnishes are to be added indiscriminately and in all ratios. This test method will aid in determining the relative compatibility of the varnishes under consideration.

51. Procedure

51.1 Designate the new varnish as varnish “A”, and the standard, or varnish in use, as varnish “B”.

51.2 Calculate the ratios of varnish “A” to varnish “B” to obtain blends of 50 mL each of ratios of 9+1, 3+1, 1+3, and 1+9. Prepare the blends in suitable glass containers with adequate stirring.

51.3 After the five mixtures are prepared, examine each for clouding, gelation, precipitation, or separation, as soon as stirring stops.

51.4 Cover and allow to stand for 72 h at Standard Laboratory Conditions and record the appearance and general condition or compatibility.

51.5 Place a 20 ± 1 g specimen of each of the blends in a 50-mm (2-in.) flat-bottom aluminum weighing dish.

51.6 Cure the specimens in an oven in accordance with the manufacturer’s instructions for varnish “A”, or alternatively, using the cure cycle currently in use for varnish “B”. Examine the specimens immediately after removal from the oven and while still hot. Record clarity and general condition of cure.

52. Report

- 52.1 Report the following information:
 - 52.1.1 Identification of the varnishes used,
 - 52.1.2 Condition of the liquids blends, and any evidence of incompatibility,

- 52.1.3 Appearance of the cured specimens, and
- 52.1.4 Condition of the cured specimens, specifically, hardness, tack, flexibility, or other evidence of possible incompatibility in the cured state.

OIL RESISTANCE

53. Significance and Use

53.1 The oil resistance test, when supplemented by practical tests, may be used to indicate the suitability of varnishes applied to equipment in which the varnish is in contact with the insulating oils.

54. Procedure

54.1 Prepare the test specimens from AWG No. 18 bare, annealed copper wire in accordance with Test Method D 2519.

54.2 Prepare a minimum of 12 test specimens.

54.3 Prior to immersion in the oil, set aside half of the test specimens for determination of bond strength.

54.4 Vertically suspend the other half of the specimens in the insulating oil. Use oil as specified in Specification D 3487, with the additional requirement of having an aniline point of least 65°C. The aniline point shall be determined by Test Methods D 611. Heat the oil containing the test specimen for 72 h at 105 to 110°C (220 to 230°F).

54.4.1 Remove the test specimen from the hot oil at the end of the heating period and allow it to drain in the vertical position for 1 to 1½ h.

54.5 Test for bond strength the retained samples and the oil-immersed samples under Standard Laboratory Conditions at room temperature in accordance with the provisions of Test Method D 2519.

55. Report

55.1 Report the following information:

- 55.1.1 Identification of the varnish used,
- 55.1.2 Identification of the wire used,
- 55.1.3 Cure time and temperature for each coat of varnish used to prepare the coils,
- 55.1.4 Identification of oil used,
- 55.1.5 Time and temperature of immersion of coils in oil.
- 55.1.6 Table listing the individual values of bond strength and their averages for the reference samples and the oil-immersed samples,
- 55.1.7 Percent change in bond strength after immersion in oil, and
- 55.1.8 Results of visual inspection for abnormalities.

56. Keywords

56.1 build; dielectric strength; drainage; flash point; non-volatile matter; oil resistance; solvent varnish; specific gravity; temperature index; time of drying; varnish; varnish compatibility; viscosity

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