



# Standard Test Methods for Testing Solvent Containing Varnishes Used for Electrical Insulation<sup>1</sup>

This standard is issued under the fixed designation D 115; 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 ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 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
Preparation of Test Specimens		7
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 Tester<sup>2</sup>
- D 93 Test Methods for Flash Point by Pensky-Martens Closed Tester<sup>2</sup>
- D 149 Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials at Commercial Power Frequencies<sup>3</sup>
- D 202 Test Methods for Sampling and Testing Untreated

### Paper Used for Electrical Insulation<sup>3</sup>

- D 287 Test Method for API Gravity of Crude Petroleum and Petroleum Products (Hydrometer Method)<sup>2</sup>
- D 295 Test Methods for Varnished Cotton Fabrics Used for Electrical Insulation<sup>3</sup>
- D 374 Test Methods for Thickness of Solid Electrical Insulation<sup>3</sup>
- D 580 Specification for Greige Woven Glass Tapes and Webbing<sup>4</sup>
- D 611 Test Methods for Aniline Point and Mixed Aniline Point of Petroleum Products and Hydrocarbon Solvents<sup>2</sup>
- D 1475 Test Method for Density of Paint, Varnish, Lacquer, and Related Products<sup>5</sup>
- D 1638 Method of Testing Urethane Foam Isocyanate Raw Materials<sup>6</sup>
- D 1932 Test Method for Thermal Endurance of Flexible Electrical Insulating Varnishes<sup>3</sup>
- D 2436 Specification for Forced-Convection Laboratory Ovens for Electrical Insulation<sup>3</sup>
- D 2518 Specification for Woven Glass Fabrics for Electrical Insulation<sup>7</sup>
- D 2519 Test Method for Bond Strength of Electrical Insulating Varnishes by the Helical Coil Test<sup>7</sup>
- D 3145 Test Method for Thermal Endurance of Electrical Insulating Varnishes by the Helical Coil Method<sup>7</sup>
- D 3251 Test Method for Thermal-Aging Characteristics of Electrical Insulating Varnishes Applied Over Film-Insulated Magnet Wire<sup>7</sup>
- D 3278 Test Method for Flash Point of Liquids by Small Scale Closed-Cup Apparatus<sup>5</sup>
- D 3487 Specification for Mineral Insulating Oil Used in Electrical Apparatus<sup>8</sup>
- D 5032 Practice for Maintaining Constant Relative Humidity by Means of Aqueous Glycerin Solutions<sup>7</sup>
- E 104 Practice for Maintaining Constant Relative Humidity by Means of Aqueous Solutions<sup>9</sup>

## 3. Terminology

### 3.1 Definitions:

<sup>1</sup> 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 D09.01 on Electrical Insulating Varnishes, Powders, and Encapsulating Compounds.

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<sup>2</sup> *Annual Book of ASTM Standards*, Vol 05.01.

<sup>3</sup> *Annual Book of ASTM Standards*, Vol 10.01.

<sup>4</sup> *Annual Book of ASTM Standards*, Vol 07.01.

<sup>5</sup> *Annual Book of ASTM Standards*, Vol 06.01.

<sup>6</sup> Discontinued. See 1991 *Annual Book of ASTM Standards*, Vol 08.02.

<sup>7</sup> *Annual Book of ASTM Standards*, Vol 10.02.

<sup>8</sup> *Annual Book of ASTM Standards*, Vol 10.03.

<sup>9</sup> *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 ± 1°C (73.5 ± 2°F) and 50 ± 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 ± 1°C (73.5 ± 2°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 (⅛ 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  $\pm 0.005$  mm ( $\pm 0.0002$  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  $105^\circ\text{C}$  ( $221^\circ\text{F}$ ) 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  $567 \pm 7$  g ( $20 \pm 0.25$  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  $\pm 0.1$  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  $150^\circ\text{C}$  ( $302^\circ\text{F}$ ) to remove moisture.

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

22.3 Weigh the dishes to  $\pm 0.1$  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  $\pm 0.1$  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 ( $\pm 5$  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  $\pm 0.1$  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  $0.127 \pm 0.008$  mm ( $0.005 \pm 0.0003$  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.