Designation: D115 – 14

# Standard Test Methods for Testing Solvent Containing Varnishes Used for Electrical Insulation[1]

This standard is issued under the fixed designation D115; 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.

## 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 | 38 – 42 |
| Dielectric Strength | 43 – 48 |
| Drainage | 26 – 32 |
| Flash Point | 18 – 20 |
| Nonvolatile Matter | 21 – 25 |
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| Specific Gravity | 9 – 12 |
| Temperature Index | 49 – 50 |
| Time of Drying | 33 – 37 |
| Varnish Compatibility | 51 – 53 |
| Viscosity | 13 – 17 |

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 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.

NOTE 1—There is no equivalent IEC standard.

## 2. Referenced Documents

2.1 *ASTM Standards:*[2]

D56 Test Method for Flash Point by Tag Closed Cup Tester

D93 Test Methods for Flash Point by Pensky-Martens Closed Cup Tester

D149 Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials at Commercial Power Frequencies

D202 Test Methods for Sampling and Testing Untreated Paper Used for Electrical Insulation

D287 Test Method for API Gravity of Crude Petroleum and Petroleum Products (Hydrometer Method)

D295 Test Methods for Varnished Cotton Fabrics Used for Electrical Insulation

D374 Test Methods for Thickness of Solid Electrical Insulation (Withdrawn 2013)[3]

D580 Specification for Greige Woven Glass Tapes and Webbings

D1475 Test Method For Density of Liquid Coatings, Inks, and Related Products

D1932 Test Method for Thermal Endurance of Flexible Electrical Insulating Varnishes

D2518 Specification for Woven Glass Fabrics for Electrical Insulation (Withdrawn 2013)[3]

D2519 Test Method for Bond Strength of Electrical Insulating Varnishes by the Helical Coil Test

D3145 Test Method for Thermal Endurance of Electrical Insulating Varnishes by the Helical Coil Method

D3251 Test Method for Thermal Endurance Characteristics of Electrical Insulating Varnishes Applied Over Film-Insulated Magnet Wire

D3278 Test Methods for Flash Point of Liquids by Small Scale Closed-Cup Apparatus

D3487 Specification for Mineral Insulating Oil Used in Electrical Apparatus

D5032 Practice for Maintaining Constant Relative Humidity by Means of Aqueous Glycerin Solutions

D5423 Specification for Forced-Convection Laboratory Ovens for Evaluation of Electrical Insulation

E104 Practice for Maintaining Constant Relative Humidity by Means of Aqueous Solutions

## 3. Terminology

3.1 *Definitions:*

[1] These test methods are under the jurisdiction of ASTM Committee D09 on Electrical and Electronic Insulating Materials and are the direct responsibility of Subcommittee D09.01 on Electrical Insulating Varnishes, Powders and Encapsulating Compounds.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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

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

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

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

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.

3.2.3 *tack-free, adj*—condition when a varnish has reached the point that the surface can be touched lightly without a sensation of stickiness.

3.2.4 *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.

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

## 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 **Warning**—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*—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 2), 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 2—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.

7.2.1 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.

7.2.2 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.).

7.2.3 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 D374.

7.2.4 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.

7.2.5 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.

7.2.6 With baking varnishes, allow the specimens to drain at a temperature of 23 ± 1°C (73.5 ± 2°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 3). 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 D2518. The volatile content of the heat-cleaned fabric shall not exceed 0.1 % as determined in accordance with the organic content test of Specification D580 (Note 4). The strip form specimens shall be kept in a Standard Laboratory Atmosphere (see 7.2.1).

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 3—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 4—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 D374, 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:*

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 ± 1°C (73.5 ± 2°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 ± 1°C (73.5 ± 2°F). Refer to Test Method D1475. 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 D287.

## 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 ± 1°C (73.5 ± 2°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 *Rotational Viscometer* (Note 5)—The essential instrumentation required providing minimum rotational viscometer analytical capabilities for this method include:

14.1.1 *Drive Motor,* to apply a rotational displacement to the specimen at a rate of 2 to 60 r/min constant to ±1 %.

14.1.2 *Sensor,* to measure the torque developed by the specimen to within ±1 %.

14.1.3 *Coupling Shaft,* or other means to transmit the rotational displacement from the motor to the specimen.

14.1.4 *Geometry, Spindle or Tool,* to fix the specimen between the drive shaft and a stationary position.

NOTE 5—Each geometry typically covers a range of 1.5 decades of viscosity. The geometry is selected so that the measured viscosity is between 10 and 95 % of the range of the geometry.

14.1.5 *Guard,* to protect the geometry from mechanical damage.

NOTE 6—If the rotational viscometer is used without the guard, it must be recalibrated in a suitable container.

14.1.6 *Temperature Sensor,* to provide an indication of the specimen temperature, 19 to 27°C, to within ±0.01°C.

14.1.7 *Temperature Bath,* to provide a controlled isothermal temperature environment for the specimen.

14.1.8 *Temperature Controller,* capable of operating the temperature bath at an isothermal temperature over the range of 20 to 25°C constant to within ±1°C.

14.1.9 *Data Collection Device,* to provide a means of acquiring, storing, and displaying measured or calculated signals, or both. The minimum output signals required for rotational viscosity are torque, rotational speed, temperature, and time.

14.1.10 *Stand,* to support, level, and adjust the height of the drive motor, shaft, and geometry.

14.1.11 *Specimen Container,* to contain the test specimen during the test.

14.1.12 *Auxiliary Instrumentation,* considered useful in conducting this test method includes:

14.1.12.1 *Data Analysis Capability,* to provide viscosity, stress, or other useful parameters derived from the measured signals.

14.1.12.2 *Level,* to indicate the vertical plumb of the drive motor, shaft, and geometry.

## 15. Calibration

15.1 Ensure the calibration of the viscometer by comparing its determined value to that of a viscometry reference oil.

NOTE 7—Calibration reference oils are typically available from the instrument vendor.

## 16. Procedure

16.1 Place the required amount of the test specimen to be measured into the specimen container.

NOTE 8—The required amount will depend upon the size of the geometry and the container used. See the instrument operations manual for recommendations.

16.2 Adjust the temperature of the varnish to 23 ± 1°C (73.5 ± 2°F) and equilibrate for 10 min. (See Note 9.)

NOTE 9—Take precautions to avoid evaporation or formation of skin on the surface of the varnish.

16.3 Immerse the viscometer geometry and guard into the test specimen to the indicated level.

NOTE 10—The desired level is often indicated by a mark on the geometry shaft.

NOTE 11—Care should be taken to avoid air bubbles gathering under the geometry during immersion. If a bubble is observed, stir the geometry until the bubbles is released.

16.4 Turn on the motor and rotate the geometry at its lowest speed.

16.5 Increase the geometry speed to that required to produce a reading nearest the midpoint of the viscometer scale.

16.6 Stop the rotation of the geometry and wait for 1 min.

16.7 Restart the rotation of the geometry at the same rotational velocity as in step 16.5 and allow at least five revolutions of the geometry. Record the viscosity.

NOTE 12—SI units of viscosity are the Pa • s. The common units of Poise (P) are related to the SI units by the equivalency cP = mPa • s.

16.8 Remove the geometry from the test specimen and clean it with an appropriate solvent. (See Note 2.)

16.9 Safety dispose of the test specimen.

16.10 Test a second specimen by steps 16.1 – 16.9.

16.11 Determine the mean value for the viscosity determinations of steps 16.8 and 16.9. Report this mean viscosity value.

NOTE 13—The average deviation of a single observation from the mean shall not be greater than 2 %. If the values differ from the mean by more than 2 %, then check the instrument and method used and make additional tests until the average deviation from the mean does not exceed 2 %.

## 17. Report

17.1 Report the following information:

17.1.1 Complete identification of the varnish used,

17.1.2 Temperature of test,

17.1.3 Complete description of the rotational viscometer and its geometry,

17.1.4 Speed of rotation, and

17.1.5 Mean viscosity. For example: mean viscosity = (value) at 23°C with (supplier) model (value) and geometry (identification number) at (value) r/min.

# FLASH POINT

## 18. Significance and Use

18.1 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.

## 19. Procedure

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

19.1.1 Test Method D56,

19.1.2 Test Methods D93, or

19.1.3 Test Method D3278.

## 20. Report

20.1 Report the following information:

20.1.1 Identification of the varnish used, and

20.1.2 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

## 21. Significance and Use

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

21.2 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.

## 22. Apparatus

22.1 *Analytical Balance,* capable of weighing to ±0.1 mg.

22.2 *Forced-Convection Oven,* see Specification D5423 Type II for a representative oven.

22.3 *Weighing Dishes,* aluminum, approximately 51 mm (2 in.) in diameter, and 16 mm (⅝ in.) high on the sides.

22.4 *Desiccator.*

## 23. Procedure

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

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

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

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

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

23.6 Prepare a minimum of two specimens.

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

23.8 Within 30 min after preparation, place the dish and its contents in a 135 ± 2°C (275 ± 5°F) forced-convection oven for 3 h (±5 min). Other temperatures may be used when agreed upon between user and supplier.

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

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

## 24. Calculation

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

## 25. Report

25.1 Report the following information:

25.1.1 Identification of the varnish used,

25.1.2 Number of specimens tested and individual values,

25.1.3 Average percentage of nonvolatile matter of all specimens, and

25.1.4 Time and temperature for drying specimen.

## DRAINAGE

## 26. Significance and Use

26.1 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.

## 27. Procedure (Using Copper Strip)

27.1 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 ± 1°C (73.5 ± 2°F). Immerse up to a line previously drawn across the strip 25 mm (1 in.) from the top.

27.2 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 7.2.5 and 7.2.6.

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

## 28. Calculation

28.1 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:

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

## 29. Report

29.1 Report the following information:

29.1.1 Thickness of each film at the two points specified in Section 27.

## 30. Procedure (Using Glass Cloth)

30.1 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 ± 1/32 in.) and 150 ± 1.0 mm (6 ± 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.

## 31. Calculation

31.1 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.

## 32. Report

32.1 Report the following information:
32.1.1 Description of thinner, if used,
32.1.2 Curing time and temperature for each coat,
32.1.3 Average thickness of each specimen at the 25 mm (1 in.) line and at the 150 mm (6 in.) line,
32.1.4 Percent drainage of each specimen, and
32.1.5 Average percent drainage of the five specimens.

# TIME OF DRYING

## 33. Significance and Use

33.1 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.

## 34. Procedure (Using Copper Strips)

34.1 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.

34.2 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 D5423.

34.3 Consider the varnish dry (Note 14) 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 D202:

| | |
|---|---|
| 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 14—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."

## 35. Report

35.1 Report the following information:
35.1.1 Identification of the varnish used, and
35.1.2 Drying time and temperature.

## 36. Procedure (Using Glass Cloth)

36.1 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.

36.2 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 34.3. Adjust intervals to determine the drying time within a ½ h range.

## 37. Report

37.1 Report the following identification of varnish:
37.1.1 Curing time and temperature for the first coat,
37.1.2 Drying temperature for the second coat, and
37.1.3 Time to dry.

# BUILD

## 38. Significance and Use

38.1 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 as well as geometry, composition, and temperature of dipped service. This method determines the total effect without attempting to separate these several factors.

## 39. Procedure (Using Glass Cloth)

39.1 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.

39.2 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.

## 40. Report

40.1 Report the following information:
40.1.1 Curing time and temperature for each coat,
40.1.2 Average of the nine thickness measurements on each specimen, and
40.1.3 Average thickness of three specimens, which is considered the build on glass cloth of the varnish.

## 41. Procedure (Using Copper Strips)

41.1 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.

41.2 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.

41.3 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.

## 42. Report

42.1 Report the following information:

42.1.1 Curing time and temperature, and

42.1.2 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

## 43. Significance and Use

43.1 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.

## 44. Apparatus

44.1 *Apparatus for Applying and Measuring Test Voltages*—A description of this apparatus is found in Test Method D149. 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.

44.2 *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 (1/32 in.) (see Table number 1 of Test Method D149). 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 D295.

## 45. Test Specimens

45.1 The selection of the substrate to be used for these tests is based on the functional requirements of the varnish and the application.

45.2 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.).

45.3 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 ± 1°C (73.5 ± 2°F) and 50 % relative humidity.

45.4 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 ± 1°C (73.5 ± 2°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.

## 46. Conditioning

46.1 Condition two specimens at each of the following conditions:

46.1.1 At 96 h at the Standard Laboratory Atmosphere, and

46.1.2 At 96 h at the Standard Laboratory Temperature and 96 % relative humidity. This relative humidity can be accurately maintained as described in Practices E104 or Practice D5032.

## 47. Procedure

47.1 Determine the dielectric strength in accordance with Test Method D149 using the short time test. Increase the voltage from zero to breakdown at a uniform rate of 500 V/s.

47.1.1 Determine the dielectric strength immediately after removal of the specimens from the conditioning chamber, using electrodes as described in 44.2. Make all measurements at a temperature of 23 ± 1°C (73.5 ± 2°F).

47.2 *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.

47.3 *Glass Cloth Substrates:*

47.3.1 For tests requiring glass substrates, prepare two specimens in accordance with 36.2 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.

47.3.2 Measure dielectric breakdown at five points approximately 32 mm (1¼ 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.

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

### 48. Report

48.1 For copper specimens, report the following:
48.1.1 Identification of the varnish used,
48.1.2 Conditioning method,
48.1.3 Average copper thickness,
48.1.4 Individual film thicknesses (individual overall thickness readings minus average copper thickness),
48.1.5 Average film thickness,
48.1.6 Individual breakdown voltages, and
48.1.7 Average dielectric strength in V/mil (or KV/mm).

48.2 For glass cloth substrate, report the following:
48.2.1 Identification of the varnish used,
48.2.2 Curing time and temperature for each coat,
48.2.3 Conditioning used,
48.2.4 Average thickness of the two specimens,
48.2.5 Individual breakdown voltages, and
48.2.6 Average dielectric strength in V/mil (or kV/mm).

## TEMPERATURE INDEX

### 49. Procedure

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

49.1.1 Test Method D3251 (twisted pair), using thermal life of 20 000 h.

49.1.2 Test Method D1932 (curved electrode), using thermal life of 25 000 h.

49.1.3 Test Method D3145 (helical coils), using thermal life of 20 000 h.

49.2 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.

### 50. Report

50.1 Report the following information:
50.1.1 Identification of the varnish used, and
50.1.2 The report as specified under the report section of each method listed in 49.1.

## VARNISH COMPATIBILITY

### 51. Significance and Use

51.1 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.

### 52. Procedure

52.1 Designate the new varnish as varnish "A," and the standard, or varnish in use, as varnish "B."

52.2 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.

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

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

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

52.6 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.

### 53. Report

53.1 Report the following information:
53.1.1 Identification of the varnishes used,
53.1.2 Condition of the liquids blends, and any evidence of incompatibility,
53.1.3 Appearance of the cured specimens, and
53.1.4 Condition of the cured specimens, specifically, hardness, tack, flexibility, or other evidence of possible incompatibility in the cured state.

## OIL RESISTANCE

### 54. Significance and Use

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

### 55. Procedure

55.1 Prepare the test specimens from AWG No. 18 bare or film insulated, annealed copper wire in accordance with Test Method D2519.

55.2 Prepare a minimum of 12 test specimens.

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

55.4 Vertically suspend the other half of the specimens, immersed in an insulating oil, that meets Specification D3487. Other oils shall be permitted to be used for testing if agreed to by customer and supplier. Heat the oil containing the test specimen for 72 h at 105 to 110°C (220 to 230°F).

55.4.1 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.

55.5 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 D2519.

## 56. Report

56.1 Report the following information:

56.1.1 Identification of the varnish used,

56.1.2 Identification of the wire used,

56.1.3 Cure time and temperature for each coat of varnish used to prepare the coils,

56.1.4 Identification of oil used,

56.1.5 Time and temperature of immersion of coils in oil,

56.1.6 Table listing the individual values of bond strength and their averages for the reference samples and the oil-immersed samples,

56.1.7 Percent change in bond strength after immersion in oil, and

56.1.8 Results of visual inspection for abnormalities.

## 57. Keywords

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

## SUMMARY OF CHANGES

Committee D09 has identified the location of selected changes to this standard since the last issue (D115 – 07 (2012)) that may impact the use of this standard. (November 1, 2014.)

*(1)* Removed references to withdrawn Methods D1638.
*(2)* Revised Section 14.
*(3)* Added Section 15.
*(4)* Revised Sections 16 and 17.