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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~~	~~37 – 41~~
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~~Dielectric Strength~~	~~42 – 47~~
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~~Drainage~~	~~25 – 31~~
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~~Varnish Compatibility~~	~~50 – 52~~
Varnish Compatibility	51 – 53
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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 ~~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.

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)

[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.

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

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
~~D1638 Method of Testing Urethane Foam Isocyanate Raw Materials~~
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:*

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

3.1.2 *~~drainage~~—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~~ dip-coated panel after a specified time and temperature.

3.1.3 *flash ~~point~~—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~~—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] The last approved version of this historical standard is referenced on www.astm.org.

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~~—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~~—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,~~ 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~~ 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~~ 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,~~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)~~(356°F), due to oxidation.

7.2 *Copper ~~Base:~~ 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 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.~~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).~~ 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)~~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 ~~number~~ 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 ~~7.2.2~~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~~ 70 mm (9.5 by ~~2.75 in.).~~ 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,~~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 ~~or Method D1638~~.

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 ~~*Brookfield*~~*Rotational Viscometer* (Note 5)—~~Keep the viscometers calibrated over the range of viscosity of the varnishes to be tested by means of oils verified as to absolute viscosity at 23 ± 1°C (73.5 ± 2°F) by the National Institute of Standards and Technology. Use a calibration curve showing the relation between viscosity in absolute units and the instrument readings.~~The essential instrumentation required providing minimum rotational viscometer analytical capabilities for this method include:

~~NOTE 5—If the Brookfield viscometer is used without the guard, it must be restandardized in a suitable container.~~

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 ~~Determine the viscosity in accordance with Method~~Place the required amount of the test ~~D1638.~~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 ~~follow Method~~equilibrate for ~~D1638. Take precautions~~10 min. (See Note 9~~to avoid~~.)

NOTE 9—Take precautions to avoid evaporation or formation of skin on the surface of the varnish. ~~evaporation or formation of skin on the surface of the varnish. State results in terms of absolute viscosity, in centipoises.~~

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 ~~Test two specimens and report~~ Determine the mean ~~value, provided the average deviation of a~~value for the viscosity determinations of steps 16.8 and 16.9~~single observation from the mean is not~~ . 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 %.~~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 %.~~

17. Report

17.1 Report the following information:

17.1.1 ~~Identification~~ Complete identification of the varnish used,

17.1.2 Temperature of test,

17.1.3 ~~Model of Brookfield viscometer,~~Complete description of the rotational viscometer and its geometry,

17.1.4 Speed of rotation, and

~~16.1.5 Spindle number, and~~

17.1.5 ~~Viscosity in centipoises.~~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.)~~ 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.