Designation: D2633 – 21

Standard Test Methods for Thermoplastic Insulations and Jackets for Wire and Cable[1]

This standard is issued under the fixed designation D2633; 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 procedures for the testing of thermoplastic insulations and jackets used on insulated wire and cable. To determine the test to be made on the particular insulation or jacket compound, refer to the product specification for that type. These test methods do not apply to the class of products known as flexible cords. The electrical tests on insulation and water-absorption tests do not apply to the class of products having a separator between the conductor and the insulation.

1.2 These test methods pertain to insulation or jacket material for electrical wires and cables. In many instances the insulation or jacket material cannot be tested unless it has been formed around a conductor or cable. Therefore, tests are done on insulated or jacketed wire or cable in these test methods solely to determine the relevant property of the insulation or jacket material and not to test the conductor or completed cable.

1.3 Whenever two sets of values are stated, in different units, the values in the first set are regarded as standard, while the values in parentheses are provided for information only and are not considered standard.

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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.* For specific hazards see Section 4 and for fire test safety caveats see Test Method D8354.

1.5 These test methods appear in the following sections:

Test Method	Section(s)
Cold Bend Test	75 to 77
Dielectric Strength Retention Test	45 to 51
Electrical Tests of Insulation	17 to 29
Heat Distortion Test	74
Heat Shock Test	73
Insulation Resistance Test	30 to 37
Partial-discharge Extinction Level Test	38 to 44
Physical Tests of Insulation and Jackets	5 to 16
Flammability	63 (Test Method D8354)
Surface Resistivity Test	64 to 67
Thermal Tests	72 to 77
Track Resistance Test	78 to 81
U-bend Discharge Test	68 to 71
Vertical Flame Test	63
Water Absorption Tests, Accelerated	52 to 62

1.6 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

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

D150 Test Methods for AC Loss Characteristics and Permittivity (Dielectric Constant) of Solid Electrical Insulation

D257 Test Methods for DC Resistance or Conductance of Insulating Materials

D374/D374M Test Methods for Thickness of Solid Electrical Insulation

D471 Test Method for Rubber Property—Effect of Liquids

D573 Test Method for Rubber—Deterioration in an Air Oven

D638 Test Method for Tensile Properties of Plastics

D1248 Specification for Polyethylene Plastics Extrusion Materials for Wire and Cable

D1711 Terminology Relating to Electrical Insulation

D2132 Test Method for Dust-and-Fog Tracking and Erosion Resistance of Electrical Insulating Materials

D3755 Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials Under Direct-Voltage Stress

[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 D09.07 on Electrical Insulating Materials.

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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**

D5423 Specification for Forced-Convection Laboratory Ovens for Evaluation of Electrical Insulation
D8354 Test Method for Flammability of Electrical Insulating Materials Used for Sleeving or Tubing
E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
2.2 *Federal Standard:*[3]
PPP-T-45D Federal Specification for Tape; Paper, Gummed (Kraft)
2.3 *ICEA Standard:*[4]
T-24-380 Guide for Partial-Discharge Procedure

3. Terminology

3.1 *Definitions:*
3.1.1 For definitions of terms used in these test methods, refer to Terminology D1711.
3.2 *Definitions of Terms Specific to This Standard:*
3.2.1 *aging (act of), n*—exposure of material to air or oil at a temperature and a time as specified in the relevant material specification for that material.

3.3 *Symbols:*
3.3.1 kcmil = thousands of circular mils.

4. Hazards

4.1 *High Voltage:*
4.1.1 (**Warning—**Lethal voltages are a potential hazard during the performance of this test. It is essential that the test apparatus, and all associated equipment electrically connected to it, be properly designed and installed for safe operation.)
4.1.2 Solidly ground all electrically conductive parts which it is possible for a person to contact during the test.
4.1.3 Provide means for use at the completion of any test to ground any parts which were at high voltage during the test or have the potential for acquiring an induced charge during the test or retaining a charge even after disconnection of the voltage source.
4.1.4 Thoroughly instruct all operators as to the correct procedures for performing tests safely.
4.1.5 When making high voltage tests, particularly in compressed gas or in oil, it is possible for the energy released at breakdown to be sufficient to result in fire, explosion, or rupture of the test chamber. Design test equipment, test chambers, and test specimens so as to minimize the possibility of such occurrences and to eliminate the possibility of personal injury. If the potential for fire exists, have fire suppression equipment available. Design test equipment, test chambers, and test specimens so as to minimize the possibility of such occurrences and to eliminate the possibility of personal injury. See 20.1, 27.1, 33.1, 42.1, 48.1, 55.1, 65.1, 69.1, and 79.1.

PHYSICAL TESTS OF INSULATIONS AND JACKETS

5. Scope

5.1 Physical tests include determination of the following properties of insulations and jackets:
5.1.1 Thickness,
5.1.2 Tensile strength,
5.1.3 Ultimate elongation,
5.1.4 Accelerated aging,
5.1.5 Effects of oil immersion,
5.1.6 Accelerated water absorption,
5.1.7 Flame test evaluation,
5.1.8 Heat shock,
5.1.9 Heat distortion, and
5.1.10 Cold bend.

6. Significance and Use

6.1 Physical tests, properly interpreted, provide information with regard to the physical properties of the insulation or jacket. The physical test values give an approximation of how the insulation will physically perform in its service life. Physical tests provide useful data for research and development, engineering design, quality control, and acceptance or rejection under specifications.

7. Sampling

7.1 *Number of Samples*—Unless otherwise required by the detailed product specification, sample the wire and cable to do the physical tests other than the tests for insulation and jacket thickness, as follows:
7.1.1 *For Sizes of Less Than 250 kcmil (127 mm^2)*—Select one sample for each quantity ordered between 2000 ft (600 m) and 50 000 ft (15 200 m) of wire or cable. Select one additional sample for each additional 50 000 ft thereafter. Do not select a sample from lots of less than 2000 ft.
7.1.2 *For Sizes of 250 kcmil (127 mm^2) and Over*—Select one sample for each quantity ordered between 1000 ft (300 m) and 25 000 ft (7600 m) of wire or cable. Select one additional sample for each additional 25 000 ft thereafter. Do not select a sample from lots of less than 1000 ft.

7.2 *Size of Samples*—Choose samples at least 6 ft (2 m) in length when the wire size is less than 250 kcmil (127 mm^2). Select a sample at least 3 ft (1 m) in length when the wire size is 250 kcmil or larger.

8. Test Specimens

8.1 *Number of Specimens*—From each of the samples selected in accordance with Section 7, prepare test specimens as follows:

Test	Number of Test Specimens
For Determination of Original Tensile Strength and Ultimate Elongation	3
For Aging	3
For Oil Immersion	3

When only one or two samples are selected, test all three specimens of each sample, and report the average result of each. Otherwise, test one specimen of each three and hold the other two specimens in reserve.

8.2 *Size of Specimens*—When testing wire smaller than 6 AWG (13.3 mm^2) which has an insulation thickness less than 0.095 in. (2.41 mm), test the entire specimen cut from the section of the insulation. When testing wire of 6 AWG and

[3] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.
[4] Available from The Insulated Cable Engineers Association, Inc. (ICEA), P.O. Box 2694, Alpharetta, GA 30023, http://www.icea.net.

larger, or wire smaller than 6 AWG having an insulation thickness greater than 0.095 in., cut specimens approximately square in section, with a cross section not greater than 0.025 in.^{2} (1.6 mm^2) from the insulation. If necessary, use a segmented or sector-shaped specimen. Make the test specimens approximately 6 in. (150 mm) long. Take the jacket compound test specimens from the complete wire assembly. Cut the specimens parallel to the axis of the wire. Cut a test specimen (either a segment or sector) with a suitable sharp instrument. Alternatively, use a die to prepare a shaped specimen with a cross-sectional area not greater than 0.025 in.^{2}

8.3 *Preparation of Specimens*—Prepare specimens having smooth uncut surfaces. Remove irregularities and corrugations by buffing, planing, or skiving so that the test specimen is smooth and uniform in thickness. Remove reinforcing cords or wires carefully. Do not heat, immerse in water, or subject specimens to any mechanical or chemical treatment not specifically prescribed in these test methods. Additional treatments must be agreed upon by the producer and the purchaser.

8.4 Insulation removal is often facilitated by stretching the conductor to the breaking point in a tensile-strength machine, or by cutting the insulation through to the conductor, longitudinally, and carefully removing it.

9. Measurement of Thickness of Specimens

9.1 Make thickness measurements of the insulation with any type of micrometer reading to 0.001 in. (0.025 mm) and suitable for measurements of this characteristic. See Test Methods D374/D374M for appropriate measuring devices. Apparatus A is preferred, Apparatus C and Apparatus D are acceptable, but Apparatus B is not recommended. The average thickness of the insulation is calculated as one half the difference between the mean of the maximum and minimum diameters over the insulation at one point and the average diameter of the conductor measured at the same point. The minimum thickness of the insulation is calculated as the difference between a measurement made over the conductor plus the thinnest insulation wall, and the diameter of the conductor. (Make the first measurement after slicing off the thicker side of the insulation.) When the wire or cable has a jacket, remove the jacket and determine its minimum and maximum thickness by micrometer measurement. Take the average of these determinations as the average thickness of the jacket.

9.2 If the procedures given in 9.1 cannot be followed conveniently, use of an optical micrometer is permitted.

9.3 *Number of Thickness Measurements*—When the lot of wire to be inspected consists of two or fewer coils or reels, make at least one determination of the thickness on each coil or reel. When the lot is greater than two coils or reels and fewer than 20 coils or reels, make at least one determination of the thickness on each of two coils or reels selected at random. For lots greater than 20 coils or reels, randomly select a minimum of 10 % of the coils or reels. Make at least one determination of thickness on each coil or reel selected.

10. Physical Test Procedures

10.1 Determine the physical properties in accordance with Test Method D638, except as specified in 10.2, 10.3, and 10.4.

10.2 Test the specimens at a temperature of 68 to 82 °F (20 to 28 °C).

10.3 Mark specimens for all physical tests with gauge marks 1 in. (25 mm) apart. Place a specimen in the jaws of the testing machine. The maximum distance between the jaws is 2 in. (50 mm).

10.4 Test insulation or jacketing at a jaw separation speed as specified in Specification D1248 or other applicable product specification.

11. Calculation of Area of Specimens

11.1 Calculate the area of a test specimen as follows:

11.1.1 When the total cross-section of the insulation is used, calculate the area as the difference between the area of the circle whose diameter is the average outside diameter of the insulation and the area of the conductor. Calculate the area of a stranded conductor from its maximum diameter.

11.1.2 Where the specimen is a slice cut from the insulation by a knife held tangent to the wire, and the resulting cross-section of that slice is not a segment of a circle, calculate the area from a direct measurement of the volume or from the specific gravity and the weight of a known length of the specimen having a uniform cross-section.

11.1.3 When a portion of a sector of a circle is taken from a large conductor, calculate the area as the thickness times the width. (This applies either to a die cut specimen or one from which all corrugations have been removed.)

11.1.4 Determine the dimensions of specimens to be aged before the aging cycle is begun.

12. Aging Test

12.1 Age specimens in accordance with Test Method D573, except as specified in 12.2, 12.3, and 12.4.

12.2 Use an oven that meets the requirements given in Specification D5423 for Type II ovens.

12.3 The product specification defines the test period and temperature of heat aging.

12.4 Test the tensile strength and ultimate elongation of the specimens between 16 and 96 h after completion of heat aging. Use the procedure described in Section 11. Perform physical tests on both aged and unaged specimens at the same time.

13. Oil Immersion Test

13.1 *Oil Immersion Test for Poly(Vinyl Chloride) Insulation and Jacket*—Immerse the following test specimens in ASTM Oil No. 2, IRM902, or equivalent, described in Table 1 of Test Method D471, at 158 ± 1.8 °F (70 ± 1 °C) for 4 h.

13.1.1 When using insulated conductors in sizes smaller than 6 AWG (13.3 mm^2), do not immerse the ends of the specimens.

13.1.2 Buffed die-cut specimens of the insulation in sizes 6 AWG (13.3 mm^2) and larger.

13.1.3 Buffed die-cut specimens of the jacket.