



# Standard Test Methods for Thermoplastic Insulations and Jackets for Wire and Cable<sup>1</sup>

This standard is issued under the fixed designation D 2633; 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 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, ~~reference should be made~~ 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 presented, in different units, the values in the first set are the standard, while those 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 hazards see Sections 4 and 63.

1.5 The procedures appear in the following sections:

Procedure	Sections
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
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

## 2. Referenced Documents

### 2.1 ASTM Standards:<sup>2</sup>

- D 149 Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials at Commercial Power Frequencies
- D 150 Test Methods for AC Loss Characteristics and Permittivity (Dielectric Constant) of Solid Electrical Insulation
- D 257 Test Methods for DC Resistance or Conductance of ~~Insulation~~<sup>2</sup> Insulating Materials
- D 374 Test Methods for Thickness of Solid Electrical Insulation
- D 471 Test Method for Rubber Property-Effect of Liquids
- D 573 Test Method for Rubber-Deterioration in an Air Oven
- D 638 Test Method for Tensile Properties of Plastics
- D 1711 Terminology Relating to Electrical Insulation

<sup>1</sup> These methods are under the jurisdiction of ASTM Committee D09 on Electrical and Electronic Insulating Materials and are the direct responsibility of Subcommittee D09.18 on Solid Insulations, Non-Metallic Shieldings, and Coverings for Electrical and Telecommunication Wires and Cables.

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<sup>2</sup> For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto: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.

- D 1248 Specification for Polyethylene Plastics Extrusion Materials ~~For~~ Wire and Cable
- D 2132 Test Method for Dust-and-Fog Tracking and Erosion Resistance of Electrical Insulating Materials
- D 3755 Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials Under Direct-Voltage Stress
- D 5025 Specification for a Laboratory Burner Used for Small-Scale Burning Tests on Plastic Materials
- D 5207 Practice for ~~Calibration~~Confirmation of 20mm (50W) and 125mm (500W) Test Flames for Small-Scale Burning Tests on Plastic Materials
- D 5423 Specification for Forced-Convection Laboratory Ovens for Evaluation of Electrical Insulation
- E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
- 2.2 *Federal Standard:*  
Federal Specification for Tape; Paper, Gummed (Kraft) (PPP-T-45D) <sup>3</sup>
- 2.3 *ICEA Standard:*  
T-24-380 Guide for Partial-Discharge Procedure<sup>4</sup>

### 3. Terminology

- 3.1 *Definitions:* For definitions of terms used in these test methods, refer to Terminology ~~D1711~~D 1711.
- 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 *Symbol:*
  - 3.3.1 kcmil = thousands of circular mils.

### 4. Hazards

- 4.1 *Mercury:*
  - 4.1.1 **Caution:** Mercury metal vapor poisoning has long been recognized as a hazard. When using equipment containing or requiring the use of mercury, take all precautions and care to avoid the escape of mercury vapor or the spillage of mercury. Maximum limits for mercury concentrations in industrial atmospheres are set by governmental agencies. These limits are usually based upon recommendations made by the American Conference of Governmental Industrial Hygienists. It is possible for the concentration of mercury vapors accompanying spills from broken thermometers, barometers, and other instruments using mercury to exceed these limits. Mercury, being a heavy liquid with high surface tension, readily disperses into small droplets after spills, lodging in cracks and crevices. Resultant increased surface area of the mercury due to this dispersion promotes higher mercury concentrations in the surrounding air. Mercury vapor concentrations are readily measured using commercially available instrumentation. To monitor environmental hazards it is advisable to make periodic checks for mercury content at locations where mercury is exposed to the atmosphere. Use a spill kit for clean-up whenever spillage occurs. After spills and clean-up, make thorough checks for mercury vapor concentrations in the atmosphere. See 8.4.

4.2

4.1 *High Voltage:*

- 4.2.1.1 **Caution/Warning:** ~~Lethal~~—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. Solidly ground all electrically conductive parts which it is possible for a person to contact during the test. 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. Thoroughly instruct all operators as to the correct procedures for performing tests safely. 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. 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,

<sup>2</sup> Annual Book of ASTM Standards, Vol 09.01.

<sup>3</sup> Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

<sup>4</sup> Annual Book of ASTM Standards, Vol 08.01.

<sup>4</sup> Available from The Insulated Cable Engineers Association, Inc. (ICEA), P.O. Box 1568, Carrollton, GA 30112, <http://www.icea.net>.

- 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 may 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<sup>2</sup>)*—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<sup>2</sup>) 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<sup>2</sup>). 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 test	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<sup>2</sup>) 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 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.<sup>2</sup> (1.6 mm<sup>2</sup>) from the insulation. ~~In extreme cases, it may be necessary to~~ 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.<sup>2</sup>.

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. Usually, in the case of insulated tinned conductor, a complete test specimen can be obtained, free from surface incisions and imperfections, by use of mercury. The mercury is introduced at one end of the specimen between the insulation and the tinned surface of the conductor. The specimen is inclined on a support. Introduce the mercury at the top. Amalgamation of the mercury and tin causes the insulation to separate. Amalgamation is aided by immersing and rubbing the tinned wire on the exposed end of the conductor in the mercury. **Caution:** See 4.1.~~

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 Method A or B of Test Methods D 374 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, an optical micrometer may be used.~~ 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 D 638, 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 D 1248 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 D 573, except as specified in 12.2, 12.3, and 12.4.

12.2 Use an oven that meets the requirements given in Specification D 5423 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 D 471, at  $158 \pm 1.8$  °F ( $70 \pm 1$  °C) for 4 h.

13.1.1 When using insulated conductors in sizes smaller than 6 AWG (13.3 mm<sup>2</sup>), 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<sup>2</sup>) and larger.

13.1.3 Buffed die-cut specimens of the jacket.

13.2 After a 4 h exposure period to ASTM Oil No. 2, IRM902, or its equivalent, remove the specimens from the oil. Blot specimens to remove excess oil, and condition at room temperature for a period of 16 to 96 h. Determine the tensile strength and elongation at the same time that the original properties are determined.

13.3 *Calculations for Tensile Strength and Measurement of Elongation*—Base the calculations for tensile strength on the cross-sectional area of the specimen obtained before immersion in the oil. Base the calculation for ultimate elongation on the original distance between the gauge marks applied to the specimen before immersion in the oil.

## 14. Retests

14.1 Any specimens that fail to conform to the values specified for any test, either before or after aging, are required to have two additional specimens retested from the same sample. Failure of the retests indicates nonconformity of the sample to the requirement specified.

## 15. Report

15.1 Report the following information:

15.1.1 Identification of the wire or cable sampled and tested by manufacturer, lot number if applicable, gauge, sheath type, reel number, length, etc.,

15.1.2 Identification of the material sampled and tested by how it was used (insulation, jacket, etc.) and by type (for example, polyethylene as specified in Specification D 1248),

15.1.3 Date of testing,

15.1.4 Name and location of testing laboratory and the person responsible for the testing,

15.1.5 Remarks indicating the method or procedure used and the deviation, if any, from the standard procedure,

15.1.6 Indication of the variance in test measurements such as high, low, standard deviation, etc., and

15.1.7 Minimum, maximum, and average values as applicable and any other information that is appropriate to the test being performed.

15.2 The test results shall be reported as calculated or observed values rounded to the nearest unit in the last right hand place of figures used in the wire or cable specification to express the limiting value. (See the rounding method of Practice E 29.)

## 16. Precision and Bias

16.1 These test methods have been in use for many years. No statement of precision has been made, and no activity is planned to develop such a statement.

16.2 A statement of bias is not possible due to a lack of a standard reference material.

## ELECTRICAL TESTS OF INSULATION

### 17. Significance and Use

17.1 Electrical tests, properly interpreted, provide information with regard to the electrical properties of the insulation. The electrical test values give an indication as to how the insulation will perform under conditions similar to those observed in the tests. Electrical tests may provide useful data for research and development, engineering design, quality control, and acceptance or rejection under specifications.

### 18. Types of Voltage Tests

18.1 Perform voltage withstand tests using either alternating or direct current, or both, applied in accordance with Test Methods D 149 and D 3755, and as specified in the following sections. Perform the partial discharge, ac voltage, insulation resistance, and dc voltage tests on entire lengths of completed cable.

### 19. Order of Testing

19.1 Perform the partial discharge, ac voltage withstand, insulation resistance, and dc voltage withstand tests in that order when any of these tests are required. The sequence of other testing is not specified.

### 20. Hazards

20.1 These tests involve the use of high voltages. See 4.24.1.

### 21. Sampling, Test Specimens, and Test Units

21.1 The specimen is defined in each test method.

## AC AND DC VOLTAGE WITHSTAND TESTS

### 22. Significance and Use

22.1 Voltage withstand tests are useful as an indication that the cable ~~can~~ is capable of electrically withstanding the intended rated voltage with adequate margin. These tests are normally performed in the factory and are used for product acceptance to specification requirements.

### 23. Apparatus

23.1 *AC Apparatus*—For ac tests, use a voltage source and a means of measuring the voltage that is in conformance with the voltage source and voltage measurement sections of the apparatus section of Test Method D 149. Use a power supply having a frequency of 49 to 61 Hz.

23.2 *DC Apparatus*—For dc tests, use any source of dc, but if using rectified alternating current, limit the dc ripple to 4 %. Measure the voltage with an electrostatic voltmeter or, in the case of the rectifying equipment, with suitable low-voltage indicators, provided the latter are so connected that their indications are independent of the test load. See Test Method D 3755.

23.3 *Grounded Water Tank*—For tests requiring immersion in water, a metal water tank connected to ground or a tank of other material containing a grounded metal plate or bar is required.

## 24. Sampling, Test Specimens, and Test Units

24.1 The specimen consists of entire lengths of completed cable.

## 25. Rate of Voltage Application

25.1 Increase the applied voltage (from zero unless otherwise specified), at a uniform rate, from the initial value to the specified full test voltage within 60 s.

## 26. Application of Voltage to Cable

26.1 *Cables Without Metallic Sheath, Metallic Shield, or Metallic Armor:*

26.1.1 When single-conductor cables of this type are twisted together into an assembly of two or more conductors without an overall jacket or covering, apply the specified voltage between each conductor and the water. Test such assemblies after immersion for at least 1 h and while still immersed.

26.1.2 Test all other single and multiple conductor cables of this type, after immersion in water for at least 6 h and while still immersed.

26.1.3 Test each conductor against all other conductors connected to the grounded water tank.

26.2 *Cables with Metallic Sheath, Metallic Shield, or Metallic Armor:*

26.2.1 Test all cables of this type with the metallic sheaths, shields, or armors grounded, without immersion in water, at the specified test voltage. For cables having a metallic sheath, shield, or armor over the individual conductor(s), apply the specified test voltage between the conductor and ground. For multiple-conductor cables with nonshielded individual conductors having a metallic sheath, shield, or armor over the cable assembly, apply the specified test voltage between each conductor and all other conductors and ground.

## 27. Procedure

27.1 **Caution** ~~Warning~~—These tests involve the use of high voltages. See 4.24.1.

27.2 Where the insulation on a single-conductor cable or on individual conductors of a multiple-conductor cable is covered with a thermoplastic jacket, either integral or separate from the insulation, or where the insulation is increased for mechanical reasons, determine the test voltage by the size of the conductor and the rated voltage of the cable and not by the apparent thickness of the insulation.

27.3 *AC Tests:*

27.3.1 Test each insulated conductor for 5 min at the ac withstand voltage given in the applicable product specification. This test ~~may be omitted~~ is not necessary for non-shielded conductors rated up to 5000 V, if the dc ~~withstand~~ withstand test described in 27.4 is to be performed.

27.3.2 Do not apply a starting ac voltage (initial voltage) greater than the rated ac voltage of the cable under test.

27.4 *DC Tests:*

27.4.1 Do not apply a starting dc voltage greater than 3.0 times the rated ac voltage of the cable. The test voltage ~~may~~ is ~~permitted~~ to be of either polarity.

27.4.2 Upon completion of the insulation resistance test, test each insulated conductor rated for service at 5001 V and above for 15 min at the dc ~~withstand~~ withstand voltage withstand given in the applicable product specification.

27.4.3 For cables rated up to 5000 V, upon completion of the insulation resistance test, test each insulated conductor without shielding over the insulation for 5 min at the dc withstand voltage given in the applicable product specification, unless the ac ~~withstand~~ withstand test described in 27.3 was performed.

## 28. Report

28.1 Report the following information:

28.1.1 Manufacturer's name,

28.1.2 Manufacturer's lot number, if applicable,

28.1.3 Description of the cable construction,

28.1.4 Voltage and time of application,

28.1.5 Whether or not the cable was immersed in water, and

28.1.6 Whether or not the cable withstood the required voltage for the specified time.

## 29. Precision and Bias

29.1 No statement is made about either the precision or bias of this test since the result merely states whether there is conformance to the criteria for success specified in the procedure.

### INSULATION RESISTANCE TESTS ON COMPLETED CABLE

## 30. Significance and Use

30.1 The insulation resistance of a cable is primarily a measurement of the volume resistance of the insulating material, although surface resistance across the ends ~~can be~~ is often significant for short specimens or when atmospheric humidity is high. It is usually