Designation: D 470 – 99

An American National Standard

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

This standard is issued under the fixed designation D 470; 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.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 These test methods cover procedures for testing crosslinked insulations and jackets for wire and cable. To determine the test to be made on the particular insulation or jacket, reference should be made to the product specification for that type. These test methods do not apply to the class of products known as flexible cords.

1.2 *This standard does not purport to address all of the safety problems, 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 Section 4.

1.3 Whenever two sets of values are presented, in different units, the values in the first set are the standard, while those in the parentheses are for information only.

1.4 In many instances the insulation or jacket 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 and not to test the conductor or completed cable.

1.5 The procedures appear in the following sections:

	Sections
AC and DC Voltage Withstand Tests	22 to 29
Capacitance and Dissipation Factor Tests	38 to 44
Cold Bend	128
Cold Bend, Long-Time Voltage Test on Short Specimens	51 to 57
Double AC Voltage Test on Short Specimens	45 to 50
Electrical Tests of Insulation	17 to 64
Heat Distortion Test	127
Horizontal Flame Test	100 to 104
Insulation Resistance Tests on Completed Cable	30 to 37
Mineral Filler Content, Determination of	111 to 115
Ozone Resistance Test	87 to 99
Partial-Discharge Test	58 to 64
Physical Tests of Insulation and Jacket Compounds	5 to 16
Surface Resistivity Test	116 to 120
Track Resistance Test	129 to 132
U-Bend Discharge Test	121 to 125
Water Absorption Test	65 to 71
Water Absorption Test, Accelerated	72 to 86
Water Absorption Test on Fibrous Coverings	105 to 110

2. Referenced Documents

2.1 *ASTM Standards:*

D 149 Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials at Commercial Power Frequencies[2]

D 150 Test Methods for AC Loss Characteristics and Permittivity (Dielectric Constant) of Solid Electrical Insulating Materials[2]

D 257 Test Methods for D-C Resistance or Conductance of Insulating Materials[2]

D 412 Test Methods for Vulcanized Rubber and Thermoplastic Rubbers and Thermostatic Elastomers—Tension[3]

D 454 Test Method for Rubber Deterioration by Heat and Air Pressure[3]

D 572 Test Method for Rubber Deterioration by Heat and Oxygen[3]

D 573 Test Method for Rubber—Deterioration in an Air Oven[3]

D 1193 Specification for Reagent Water[4]

D 1711 Terminology Relating to Electrical Insulation[2]

D 2132 Test Method for Dust-and-Fog Tracking and Erosion Resistance of Electrical Insulating Materials[2]

D 3755 Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials Under Direct-Voltage Stress[5]

D 5025 Specification for a Laboratory Burner Used for Small-Scale Burning Tests on Plastic Materials[6]

D 5207 Practice for Calibration of 20 and 125 mm Test Flames for Small-Scale Burning Tests on Plastic Materials[6]

D 5423 Specification for Forced-Convection Laboratory Ovens for Evaluation of Electrical Insulation[5]

[1] These test methods are under the jurisdiction of ASTM Committee D-9 on Electrical and Electronic Insulating Materials and are the direct responsibility of Subcommittee D09.18 on Solid Insulations, Non-Metallic Shieldings, and Coverings for Electrical and Telecommunications Wire and Cables.

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[2] *Annual Book of ASTM Standards*, Vol 10.01.

[3] *Annual Book of ASTM Standards*, Vol 09.01.

[4] *Annual Book of ASTM Standards*, Vol 11.01.

[5] *Annual Book of ASTM Standards*, Vol 10.02.

[6] *Annual Book of ASTM Standards*, Vol 08.03.

2.2 *ICEA Standard:*

T-24-380 Guide for Partial-Discharge Procedure[7]

3. Terminology

3.1 *Definitions*—For definitions of terms used in these test methods, refer to Terminology D 1711.

3.2 *Definition of Term Specific to this Standard:*

3.2.1 *aging (act of), n*—exposure of material to air or oil at a temperature and 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 *Mercury metal vapor poisoning has long been recognized as a hazard in industry. The exposure limits are set by governmental agencies and are usually based upon recommendations made by the American Conference of Governmental Industrial Hygienists.*[8] *The concentration of mercury vapor over spills from broken thermometers, barometers, and other instruments using mercury can easily exceed these exposure limits. Mercury, being a liquid with high surface tension and quite heavy, will disperse into small droplets and seep into cracks and crevices in the floor. This increased area of exposure adds significantly to the mercury vapor concentration in air. The use of a commercially available emergency spill kit is recommended whenever a spill occurs. Mercury vapor concentration is easily monitored using commercially available sniffers. Make spot checks periodically around operations where mercury is exposed to the atmosphere. Make thorough checks after spills.* See 8.3.2 and 8.3.3.

4.2 *High Voltage*:

4.2.1 *Lethal voltages may be present during these tests. It is essential that the test apparatus, and all associated equipment that may be electrically connected to it, be properly designed and installed for safe operation. Solidly ground all electrically conductive parts that any person might come in contact with 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; may have acquired an induced charge during the test; may retain a charge even after disconnection of the voltage source. Thoroughly instruct all operators in the proper way to conduct tests safely. When making high voltage tests, particularly in compressed gas or in oil, the energy released at breakdown may 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*. See Sections 20, 27, 33, 42, 48, 54, 62, 68, 76, 118, 123 and 130.

4.3 *Ozone*:

4.3.1 *Ozone is a physiologically hazardous gas at elevated concentrations. The exposure limits are set by governmental agencies and are usually based upon recommendations made by the American Conference of Governmental Industrial Hygienists.*[8] *Ozone is likely to be present whenever voltages exist which are sufficient to cause partial, or complete, discharges in air or other atmospheres that contain oxygen. Ozone has a distinctive odor which is initially discernible at low concentrations but sustained inhalation of ozone can cause temporary loss of sensitivity to the scent of ozone. Because of this it is important to measure the concentration of ozone in the atmosphere, using commercially available monitoring devices, whenever the odor of ozone is persistently present or when ozone generating conditions continue. Use appropriate means, such as exhaust vents, to reduce ozone concentrations to acceptable levels in working areas.* See Section 90.

PHYSICAL TESTS OF INSULATIONS AND JACKETS

5. Significance and Use

5.1 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 data for research and development, engineering design, quality control, and acceptance or rejection under specifications.

6. Physical Tests

6.1 Physical tests shall include determination of the following:

6.1.1 Tensile strength,

6.1.2 Tensile stress,

6.1.3 Ultimate elongation,

6.1.4 Permanent set,

6.1.5 Accelerated aging,

6.1.6 Tear resistance,

6.1.7 Effects of oil immersion, and

6.1.8 Thickness of insulations and jackets.

7. Sampling

7.1 *Number of Samples*—Unless otherwise required by the detailed product specification, wire and cable shall be sampled for the physical tests, other than the tests for insulation and jacket thickness, as follows:

7.1.1 *Sizes Less than 250 kcmil (127 mm^2)*—One sample shall be selected for each quantity ordered between 2000 and 50 000 ft (600 and 15 000 m) of wire or cable and one additional sample for each additional 50 000 ft. No sample shall be selected from lots of less than 2000 ft.

7.1.2 *Sizes of 250 kcmil (127 mm^2) and Over*—One sample shall be selected for each quantity ordered between 1000 and 25 000 ft (300 and 7600 m) of wire or cable and one additional sample for each additional 25 000 ft. No sample shall be selected from lots of less than 1000 ft.

7.2 *Size of Samples*—Samples shall be at least 6 ft (2 m) in length when the wire size is less than 250 kcmil (127 mm^2), and at least 3 ft (1 m) in length when the wire size is 250 kcmil or over.

[7] Available from the Insulated Cable Engineers Assoc., P.O. Box 440, South Yarmouth, MA 02664.

[8] American Conference of Governmental and Industrial Hygienists, 6500 Glenway Ave., Building D-7, Cincinnati, OH 45211.

8. Test Specimens

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

	Number of Test Specimens
For Determination of Initial Properties (Unaged):	
Tensile strength, tensile stress, and ultimate elongation	3
Permanent set	3
For Aging Tests:	
Air pressure, heat, or oxygen pressure	3
Air oven	3
For Oil Immersion	3

One specimen of each three shall be tested and the other two specimens held in reserve, except that when only one sample is selected all three specimens shall be tested and the average of the results reported. For the tear test, six individual specimens as described in 8.5 shall be used.

8.2 *Size of Specimens*—In the case of wire and cable smaller than AWG 6 (13.3 mm^2) having an insulation thickness less than 0.090 in. (2.29 mm), the test specimen may be the entire section of the insulation. When the full cross section is used, the specimens shall not be cut longitudinally. In the case of wire and cable of AWG 6 and larger, or in the case of wire and cable smaller than AWG 6 having an insulation thickness greater than 0.090 in., specimens approximately square in section with a cross section not greater than 0.025 in.^{2} (16 mm^2) shall be cut from the insulation. In extreme cases, it may be necessary to use a segmental specimen.

8.2.1 The test specimens shall be approximately 6 in. (150 mm) in length. Specimens for tests on jackets shall be taken from the completed wire or cable and cut parallel to the axis of the wire or cable. With the exception of the tear tests, the test specimen shall be either a segment or sector cut with a suitable sharp instrument or a shaped specimen cut out with a die and shall have a cross-sectional area not greater than 0.025 in.^{2} (16 mm^2) after irregularities, corrugations, and reinforcing cords or wires have been removed by buffing.

8.3 *Preparation of Specimens*:

8.3.1 The test specimen is to have no surface incisions and be as free as possible from other imperfections. Remove surface irregularities, such as corrugations due to stranding, etc., so that the test specimen will be smooth and of uniform thickness.

8.3.2 The removal of the insulation can be greatly accelerated, and in most cases a test specimen which is an entire section can be obtained free from surface incisions and imperfections, by means of mercury. **Caution**: see 4.1. Introduce the mercury at one end of the specimen between the insulation and the tinned surface of the conductor, with the specimen inclined on a support with the end to which the mercury is applied at the top. The separation of the insulation results from the amalgamation of the tin of the conductor with the mercury. The amalgamation is assisted by first immersing and rubbing the tinning on the exposed end of the conductor in the mercury. Removal of the insulation may also be facilitated by stretching the conductor to the breaking point in a tensile-strength machine.

8.3.3 **Caution**—Mercury is a hazardous material. See 4.1. Care should be exercised to keep mercury from the hands. The use of rubber gloves is recommended for handling specimens as in 8.3.2.

8.4 *Specimens of Thin-Jacketed Insulation*—In the case of wires or cables having a thin jacket crosslinked directly to the insulation, it is usually necessary to prepare die-cut specimens of the jacket and insulation. Make an effort to separate the jacket from the insulation by slitting the covering through to the conductor and pulling the jacket and insulation apart by pliers. (This procedure may be facilitated by immersing the sample in hot water for a few minutes just prior to pulling off the jacket.) If the jacket cannot be removed, prepare specimens by buffing. Equip the buffing apparatus with a cylindrical table arranged so that it can be advanced very gradually. Remove the conductor from two short lengths of wire by slitting the covering. Stretch one length of covering into the clamps of the buffing apparatus so that it lies flat, with the jacket toward the wheel. The jacket is buffed off, with due care not to buff any further than necessary, or overheat the material. Repeat the process with the other length of covering, except that the insulation is buffed off. Die-cut specimens may be prepared from the buffed pieces after they have been allowed to recover for at least 30 min. (In the case of specimens from small wires, it may be necessary to use a die having a constricted portion ⅛ in. (3.18 mm) wide.) Jackets with a thickness of less than 0.030 in. (0.76 mm) shall not be tested.

8.5 *Specimen for the Tear Test*—Cut the specimen with a sharp knife or die. After irregularities, corrugations, and reinforcing cords or wires have been removed, the test specimen shall conform to the dimensions shown in Fig. 1. The thickness of the test specimen shall be not greater than 0.150 in. (3.81 mm) and not less than 0.040 in. (1.02 mm). Split the specimen longitudinally with a new razor blade to a point 0.150 in. from the wider end.

8.6 *Condition and Age*—In accordance with Section 7, take samples of the insulated wire and cable for physical and accelerated aging tests after crosslinking. Perform tests between 24 h and 60 days after crosslinking unless agreed to by the manufacturer. Do not heat, immerse in water, or subject the specimens to any mechanical or chemical treatment not specifically prescribed in these methods, unless agreed upon by

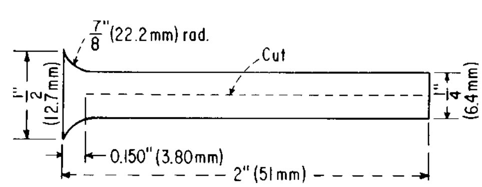


FIG. 1 Test Specimens for Tear Test

the producer and the purchaser. Age specimens having cable tape applied prior to crosslinking with such tape removed.

9. Measurement of Thickness of Specimens

9.1 Make the measurement of thickness for cables with unbonded components with either a micrometer or microscope, but, for cables with bonded components, use only a microscope. The micrometer and microscope shall be capable of making measurements accurate to at least 0.001 in. (0.025 mm).

9.1.1 *Micrometer Measurements*—When a micrometer is used, take the average thickness of the insulation as one-half of the difference between the mean of the maximum and minimum diameters over the insulation at one point and the average diameter over the conductor or any separator measured at the same point. Take the minimum thickness of the insulation as the difference between a measurement made over the conductor or any separator plus the thinnest insulation wall, and the diameter over the conductor or any separator. Make the first measurement after slicing off the thicker side of the insulation. Do not include the thickness of any separator in the thickness of insulation.

9.1.1.1 If the wire or cable has a jacket, remove the jacket and determine the minimum and maximum thickness of the jacket directly with a micrometer. Take the average of these determinations as the average thickness of the jacket.

9.1.2 *Microscope Measurements*—When a microscope is used, determine the maximum and minimum thickness from a specimen cut perpendicular to the axis of the sample so as to expose the full cross-section. Take the average of these determinations as the average thickness.

9.2 *Number of Thickness Measurements*— When the lot of wire to be inspected consists of two coils or reels, or less, at least one determination of the thickness is made on each coil or reel. When the lot consists of more than two coils or reels and less than 20 coils or reels, make at least one determination of the thickness on each of two coils or reels taken at random. If the lot consists of 20 or more coils or reels, select more than 10 % of the coils or reels at random and make at least one determination of the thickness on each coil or reel so selected.

10. Calculation of Area of Specimens

10.1 When the total cross section of the insulation is used, take 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.

10.2 When a slice cut from the insulation by a knife held tangent to the wire is used, and the slice so cut has the cross section of a segment of a circle, calculate the area as that of the segment of a circle whose diameter is that of the insulation. The height of the segment is the thickness of insulation on the side from which the slice is taken. (The values may be obtained from a table giving the areas of segments of a unit circle for the ratio of the height of the segment to the diameter of the circle.)

10.3 When the cross section of the 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.

10.4 When the conductor is large and the insulation thin, and a portion of a sector of a circle is used, calculate the area as thickness times the width. This applies either to a straight test specimen or to one stamped out with a die, and assumes that corrugations have been removed.

10.5 When the conductor is large and the insulation thick, and a portion of a sector of a circle is used, calculate the area as the proportional part of the area of the total cross section.

10.6 Determine the dimensions of aged specimens before beginning the aging cycle.

11. Physical Test Procedures

11.1 Determine the physical properties in accordance with Test Methods D 412, except as specified in the following:

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

11.3 For all physical tests, except the set test, mark the specimens with gage marks 1 in. (25 mm) apart and place in the jaws of the testing machine with a maximum distance between the jaws of 4 in. (100 mm). For the set test mark the specimens with gage marks 2 in. (50 mm) apart.

11.4 *Set Test*—Make a set test on a separate test specimen having a length of approximately 6 in. (150 mm) and mark with gage marks 2 in. (50 mm) apart. Place the specimen in the jaws of the testing machine with a maximum distance between jaws of 4 in. (100 mm) and stretch at the rate of 20 in. (500 mm)/min (jaw speed) until the gage marks are 6 in. (150 mm) apart. Release the test specimen within 5 s, and determine the distance between bench marks 1 min after the beginning of release. The set is the difference between this length and the original 2-in. (50-mm) gage length, expressed as a percentage.

11.5 *Tear Test*—Make a tear test on a minimum of six individual test specimens prepared as described in 8.5. Place the two halves of the split end of the test specimen in the jaws of the tension testing machine and separate the jaws at the rate of 20 in. (500 mm)/min. Determine the tear resistance by dividing the load in pounds (or kilograms) required to tear the section by the thickness of the test specimen in inches (or millimeters). Consider the average of the results obtained on all test specimens as the value of the tear resistance.

12. Aging Test Procedures

12.1 Age specimens in accordance with Test Method D 572 or D 573, and Specification D 5423 except as specified in 12.2 and 12.3.

12.2 The test period and temperature of aging is as prescribed in the product specification.

12.3 Between 16 and 96 h after the completion of the aging process, subject the aged specimens to tensile strength and ultimate elongation tests in accordance with 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 Oil-Resistant Jackets*—Immerse buffed die-cut specimens in ASTM Oil No. 2, IRM 902, or equivalent at 121 ± 1°C for 18 h. At the end of the 18 h remove the specimens from the oil and allow to rest at room temperature for a period of 4 ± ½ h. Determine the tensile strength and elongation at the same time that the original properties are determined (see Section 11).

13.2 *Calculations for Tensile Strength and Measurement of Elongation*—The calculations for tensile strength are based on the cross sectional area of the specimen obtained before immersion in the oil. Likewise, the elongation is based on the original distance between the gage marks applied to the specimen before immersion in the oil.

14. Retests

14.1 If any specimen fails to conform to the values specified for any test, either before or after aging, repeat that test on two additional specimens from the same sample, except that when the value of tear resistance from the first set of six specimens fails to conform, test two additional sets. Failure of either of the retests indicates nonconformity of the sample to the requirement specified.

15. Report

15.1 Report the following information:

15.1.1 Manufacturer's name,

15.1.2 Manufacturer's lot number, if applicable,

15.1.3 Calculated values of thickness, tensile strength, tensile stress, ultimate elongation, set, and tear resistance,

15.1.4 All observed and recorded data on which the calculations are based,

15.1.5 Date of vulcanization of the rubber, if known,

15.1.6 Dates of all tests,

15.1.7 Ambient temperatures during the period of physical testing,

15.1.8 Type of testing machine used,

15.1.9 Method of aging, and

15.1.10 Time and temperature of aging.

16. Precision and Bias

16.1 This test method has been in use for many years, but no information has been presented to ASTM upon which to base a statement of precision. No activity has been planned to develop such information.

16.2 This test method has no bias because the values for this test is determined solely in terms of the test method itself.

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 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 test in accordance with ICEA T-24-380. The partial discharge, ac voltage, insulation resistance, and dc voltage tests are performed on entire lengths of completed cable.

19. Order of Testing

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

20. Hazards

20.1 **Caution**—These tests involve the use of high voltages. See 4.2.

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 electrically withstand 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 *Single-Conductor Cables without Shield, Sheath, or Armor*:

26.1.1 Apply the specified voltage between the conductor and water while the cable is still immersed in the water and after it has been immersed for at least 6 h.

26.2 *Fibrous-Covered Cables without Metallic Sheath, Metallic Shield, or Metallic Armor*:

26.2.1 Test single-conductor cables of this type prior to the application and saturation of the fibrous covering. Apply the specified voltage between the conductor and the water while the cable is still immersed in water and after it has been immersed for at least 6 h.

26.2.2 Test multiple-conductor cables of this type after the application and saturation of the fibrous covering and after assembly. Without immersing the cable in water (dry test), apply the specified voltage between each conductor and all other conductors.

26.3 *Jacketed Cables and Integral Insulation and Jacket without Metallic Sheath, Metallic Shield, or Metallic Armor*:

26.3.1 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 while they are still immersed in water and after they have been immersed for at least 1 h.

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

26.3.3 Test each conductor of multiple-conductor cable with overall jacket against all other conductors connected to the grounded water tank.

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

26.4.1 Test all cables of this type with the 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(s) 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 between each conductor and ground.

27. Procedure

27.1 **Caution—**These tests involve the use of high voltages. See 4.2.

27.2 Where the insulation on a single-conductor cable or on individual conductors of a multiple-conductor cable is covered with a crosslinked or thermoplastic jacket, either integral with, or separate from, the insulation, or where the thickness of 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 insulation.

27.3 *AC Tests*:

27.3.1 Test each insulated conductor for 5 min at the ac withstand voltage given in Table 1A, Table 1C, and Table 1D. This test may be omitted for non-shielded conductors rated up to 5000 V if the dc voltage 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 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 voltage given in Table 1B, Table 1C, and Table 1D.

27.4.2 Upon completion of the insulation resistance test, test each non-shielded conductor rated up to 5000 V for 5 min at the dc withstand voltage given in Table 1B. Omit this test for non-shielded conductors rated up to 5000 V if the ac voltage test described in 27.3 was performed.

27.4.3 Do not apply a starting dc test voltage (initial voltage) greater than 3.0 times the rated ac voltage of the cable under test. The test voltage may be of either polarity.

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 information is presented about the precision of this test method because the test result is non-quantitative.

29.2 No information is presented about the bias of this test method because the test result is non-quantitative.

TABLE 1 A Conductor Sizes, Insulation Thicknesses, and AC Test Voltages for Rubber Insulations

NOTE 1—These tables are intended for test voltage purposes only. The conductor sizes and insulation thicknesses given in each voltage class are not necessarily suitable for all types of cable or conditions of service where mechanical stresses govern.

NOTE 2—To limit the maximum voltage stress on the insulation at the conductor to a safe value, the minimum size of the conductor shall be in accordance with Table 1A. For cables or conditions of service where mechanical stresses govern, such as in submarine cables or long vertical risers, these minimum conductor sizes may not be strong enough.

NOTE 3—Where the insulated conductor or conductors are covered by rubber or thermoplastic jackets, either integral with the insulation or separate therefrom, or where the thickness of the insulation is increased for nonsheathed submarine cables or for mechanical reasons, the test voltage shall be determined by the size of the conductor and rated voltage of the cable and not by the apparent thickness of the insulation.

NOTE 4—The actual operating voltage shall not exceed the rated circuit voltage by more than 5 % during continuous operation or 10 % during emergencies lasting not more than 15 min.

NOTE 5—The selection of the cable insulation level to be used in a particular installation shall be made on the basis of the applicable phase-to-phase voltage and the general system category as outlined in the following paragraphs:

100 % Level—Cables in this category may be applied where the system is provided with relay protection such that ground faults will be cleared as rapidly as possible, but in any case within 1 min. While these cables are applicable to the great majority of cable installations which are on grounded systems, they may be used also on other systems for which the application of cables is acceptable provided the above clearing requirements are met in completely de-energizing the faulted section.

In common with other electrical equipment, the use of cables is not recommended on systems where the ratio of the zero to positive phase reactance of the system at the point of cable application lies between −1 and −40 since excessively high voltages may be encountered in the case of ground faults.

133 % Level—This insulation level corresponds to that formerly designated for ungrounded systems. Cables in this category may be applied in situations where the clearing time requirements of the 100 % level category cannot be met, and yet there is adequate assurance that the faulted section will be de-energized in a time not exceeding 1 h. Also they may be used when additional insulation strength over the 100 % level category is desirable.

173 % Level—Cables in this category should be applied on systems where the time required to de-energize a grounded section is indefinite. Their use is recommended also for resonant grounded systems. Consult the manufacturer for insulation thicknesses.

NOTE 6—Do not use single-conductor cables in sizes AWG 9 and smaller for direct earth burial.

NOTE 7—Where additional insulation thickness is desired, it shall be the same as for the 133 % insulation level.

NOTE 8—These thicknesses are based on unipass construction. Where cable is provided with a protective covering, these insulation thicknesses shall be 90 mils (2.29 mm) for all conductor sizes listed.

NOTE 9—For 133 % insulation level (ungrounded neutral), the minimum conductor size is AWG 1.

Rated Circuit Voltage, Phase-to-Phase, V	Conductor Size, AWG or kcmil (mm^2)	Insulation Thickness				AC Test Voltage, kV			
		100 % Insulation Level (Grounded Neutral)		133 % Insulation Level (Ungrounded Neutral)		Other Than Ozone-Resisting Insulations		Ozone-Resisting Insulations	
		in.	mm	in.	mm	100 % Insulation Level (Grounded Neutral)	133 % Insulation Level (Ungrounded Neutral)	100 % Insulation Level (Grounded Neutral)	133 % Insulation Level (Ungrounded Neutral)
0 to 600	18 to 16 (0.823 to 1.31)	0.030	0.76	0.030	0.76	1.0	1.0	1.0	1.0
	14 to 9 (2.08 to 6.63)	0.045	1.14	0.045	1.14	3.0	3.0	4.5	4.5
	8 to 2 (8.37 to 33.6)	0.060	1.52	0.060	1.52	3.5	3.5	6.0	6.0
	1 to 4/0 (42.4 to 107)	0.080	2.03	0.080	2.03	4.0	4.0	7.5	7.5
	225 to 500 (114 to 253)	0.095	2.41	0.095	2.41	5.0	5.0	8.5	8.5
	525 to 1000 (266 to 507)	0.110	2.79	0.110	2.79	6.0	6.0	10.0	10.0
	1000 (over 507)	0.125	3.18	0.125	3.18	7.0	7.0	11.5	11.5
601 to 1000	14 to 8 (2.08 to 8.37)	0.060	1.52	0.060	1.52	5.0	5.0	6.0	6.0
	7 to 2 (10.6 to 33.6)	0.080	2.03	0.080	2.03	6.0	6.0	7.5	7.5
	1 to 4/0 (42.4 to 107)	0.095	2.41	0.095	2.41	7.5	7.5	8.5	8.5
	225 to 500 (114 to 253)	0.110	2.79	0.110	2.79	9.0	9.0	10.0	10.0
	525 to 1000 (266 to 507)	0.125	3.18	0.125	3.18	10.0	10.0	11.5	11.5
	1000 (over 507)	0.140	3.56	0.140	3.56	11.5	11.5	11.5	11.5
1001 to 2000	14 to 8 (2.08 to 8.37)	0.080	2.03	0.080	2.03	6.0	6.0	7.5	7.5
	7 to 2 (10.6 to 33.6)	0.095	2.41	0.095	2.41	7.5	7.5	8.5	8.5
	1 to 4/0 (42.4 to 107)	0.110	2.79	0.110	2.79	9.0	9.0	10.0	10.0
	225 to 500 (114 to 253)	0.125	3.18	0.125	3.18	10.0	10.0	11.5	11.5
	500 (over 253)	0.140	3.56	0.140	3.56	11.5	11.5	11.5	11.5
2001 to 5000	8 to 4/0 (8.37 to 107)	0.155	3.94	0.155	3.94	...	...	13.0	13.0
	225 to 1000 (114 to 507)	0.170	4.32	0.170	4.32	...	...	13.0	13.0
	1000 (over 507)	0.190	4.83	0.190	4.83	...	...	13.0	13.0
5001 to 8000	6 (13.6 and over)	0.190	4.83	0.250	6.35	...	...	18	22
8001 to 15 000	2 (33.6 and over)	0.300	7.62	...	...	...	...	27.0	...
	1 (42.4 and over)	...	...	0.420	10.67	...	...	...	33
15 001 to 25 000	1 (42.4 and over)	0.450	11.43	...	...	...	...	38.0	...
25 001 to 28 000	1 (42.4 and over)	0.500	12.70	...	...	...	...	42.0	...

TABLE 1 B Conductor Sizes, and DC Test Voltages for Rubber Insulations

Rated Circuit Voltage, Phase-to-Phase, V	Conductor Size, AWG or kcmil (mm^2)	DC Test Voltage, kV			
		Other than Ozone-Resisting Insulations		Ozone-Resisting Insulations	
		100 % Insulation Level (Grounded Neutral)	133 % Insulation Level (Ungrounded Neutral)	100 % Insulation Level (Grounded Neutral)	133 % Insulation Level (Ungrounded Neutral)
0 to 600	18 to 16 (0.823 to 1.31)	...	...	...	...
	14 to 9 (2.08 to 6.63)	9.0	9.0	13.5	13.5
	8 to 2 (8.37 to 33.6)	10.5	10.5	18.0	18.0
	1 to 4/0 (42.4 to 107)	12.0	12.0	22.5	22.5
	225 to 500 (114 to 253)	15.0	15.0	25.5	25.5
	525 to 1000 (266 to 507)	18.0	18.0	30.0	30.0
	over 1000 (over 507)	21.0	21.0	34.5	34.5
601 to 1000	14 to 8 (2.08 to 8.37)	15.0	15.0	18.0	18.0
	7 to 2 (10.6 to 33.6)	18.0	18.0	22.5	22.5
	1 to 4/0 (42.4 to 107)	22.5	22.5	25.5	25.5
	225 to 500 (114 to 253)	27.0	27.0	30.0	30.0
	525 to 1000 (266 to 507)	30.0	30.0	34.5	34.5
	over 1000 (over 507)	33.0	33.0	34.5	34.5
1001 to 2000	14 to 8 (2.08 to 8.37)	18.0	18.0	22.5	22.5
	7 to 2 (10.6 to 33.6)	22.5	22.5	25.5	25.5
	1 to 4/0 (42.4 to 107)	27.0	27.0	30.0	30.0
	225 to 500 (114 to 253)	30.0	30.0	34.5	34.5
	over 500 (over 253)	33.0	33.0	34.5	34.5
2001 to 5000	8 to 4/0 (8.37 to 107)	...	...	35.0	35.0
	225 to 1000 (114 to 507)	...	...	35.0	35.0
	over 1000 (over 507)	...	...	35.0	35.0
5001 to 8000	6 and over (13.6)	...	...	45.0	45.0
8001 to 15 000	2 and over (33.6)	...	...	70.0	...
	1 and over (42.4)	...	...	...	80.0
15 001 to 25 000	1 and over (42.4)	...	...	100.0	...
25 001 to 28 000	1 and over (42.4)	...	...	105.0	...

TABLE 1 C Conductor Sizes, Insulation Thicknesses, and Test Voltages for Crosslinked Polyethylene Insulation

Rated CIrcuit Voltage, Phase-to-Phase, V	Conductor Size, AWG or kcmil (mm^2)	Insulation Thickness for 100 and 133 % Insulation Levels (Grounded and Ungrounded Neutral)				AC Test Voltage, kV for 100 and 133 % Insulation Levels (Grounded and Ungrounded Neutral)		DC Test Voltage, kV for 100 and 133 % Insulation Levels (Grounded and Ungrounded Neutral)	
		Column A		Column B		Column A	Column B	Column A	Column B
		in.	mm	in.	mm				
0 to 600	14 to 9 (2.08 to 6.63)	0.045	1.19	0.030	0.76	4.0	4.0	12.0	12.0
	8 to 2 (8.37 to 33.6)	0.060	1.57	0.045	1.14	5.5	5.5	16.5	16.5
	1 to 4/0 (42.4 to 107)	0.080	1.98	0.055	1.40	7.0	7.0	21.0	21.0
	225 to 500 (114 to 253)	0.095	2.39	0.065	1.65	8.0	8.0	24.0	24.0
	525 to 1000 (266 to 507)	0.110	2.77	0.080	2.03	10.0	10.0	30.0	30.0
601 to 2000	14 to 9 (2.08 to 6.63)	0.060	1.52	0.045	1.14	5.5	5.5	16.5	16.5
	8 to 2 (8.37 to 33.6)	0.070	1.78	0.055	1.40	7.0	7.0	21.0	21.0
	1 to 4/0 (42.4 to 107)	0.090	2.29	0.065	1.65	8.0	8.0	24.0	24.0
	225 to 500 (114 to 253)	0.105	2.67	0.075	1.90	9.5	9.5	28.5	28.5
	525 to 1000 (266 to 507)	0.120	3.05	0.090	2.29	11.5	11.5	34.5	34.5
		100 % Insulation Level (Grounded Neutral)		133 % Insulation Level (Ungrounded Neutral)		100 % Insulation Level (Grounded Neutral)	133 % Insulation Level (Ungrounded Neutral)	100 % Insulation Level (Grounded Neutral)	133 % Insulation Level (Ungrounded Neutral)
Unshielded Unipass									
2001 to 5000	8 to 4/0 (8.37 to 107)	0.110	2.79	0.110	2.79	13	13	35	35
	225 to 500 (114 to 253)	0.120	3.05	0.120	3.05	13	13	35	35
	525 to 1000 (266 to 507)	0.130	3.30	0.130	3.30	13	13	35	35
Shielded									
2001 to 5000	8 to 1000 (8.37 to 507)	0.090	2.29	0.090	2.29	13	13	35	35
5001 to 8000	6 to 1000 (13.6 to 507)	0.115	2.92	0.140	3.56	18	22	45	45
8001 to 15 000	2 to 1000 (33.6 to 507)	0.175	4.45	0.215	5.46	27	33	70	80
15 001 to 25 000	1 to 1000 (42.4 to 507)	0.260	6.60	0.345	8.76	38	49	100	125
25 001 to 28 000	1 to 1000 (42.4 to 507)	0.280	7.11	...	...	42	...	105	...
28 001 to 35 000	1/0 to 1000 (53.5 to 507)	0.345	8.76	...	...	49	...	125	...

TABLE 1 D Conductor Sizes, Insulation Thicknesses, Test Voltages, and Corona Extinction Levels for Ethylene Rubber Insulation

Rated Circuit Voltage, Phase-to-Phase, V	Conductor Size, AWG or kcmil (mm^2)	Insulation Thickness				AC Test Voltage		DC Test Voltage	
		100 % Insulation Level		133 % Insulation Level		100 % Insulation Level, kV	133 % Insulation Level, kV	100 % Insulation Level, kV	133 % Insulation Level, kV
		in.	mm	in.	mm				
0 to 600	14 to 9 (2.08 to 6.63)	0.030	0.76	0.030	0.76	4.0	4.0	12.0	12.0
	8 to 2 (8.37 to 33.6)	0.045	1.14	0.045	1.14	5.5	5.5	16.5	16.5
	1 to 4/0 (42.4 to 107)	0.055	1.40	0.055	1.40	7.0	7.0	21.0	21.0
	225 to 500 (114 to 253)	0.065	1.65	0.065	1.65	8.0	8.0	24.0	24.0
	525 to 1000 (266 to 507)	0.080	2.03	0.080	2.03	10.0	10.0	30.0	30.0
601 to 2000	14 to 9 (2.08 to 6.63)	0.045	1.14	0.045	1.14	5.5	5.5	16.5	16.5
	8 to 2 (8.37 to 33.6)	0.055	1.40	0.055	1.40	7.0	7.0	21.0	21.0
	1 to 4/0 (42.4 to 107)	0.065	1.65	0.065	1.65	8.0	8.0	24.0	24.0
	225 to 500 (114 to 253)	0.075	1.90	0.075	1.90	9.5	9.5	28.5	28.5
	525 to 1000 (266 to 507)	0.090	2.29	0.090	2.29	11.5	11.5	34.5	34.5
2001 to 5000	8 to 1000 (8.37 to 507)	0.090	2.29	0.090	2.29	13	13	35	35
5001 to 8000	6 to 1000 (13.6 to 507)	0.115	2.92	0.140	3.56	18	22	45	45
8001 to 15 000	2 to 1000 (33.6 to 507)	0.175	4.45	...	...	27	...	70	...
	1 to 1000 (42.4 to 507)	...	...	0.215	5.46	...	33	...	80
15 001 to 25 000	1 to 1000 (42.4 to 507)	0.260	6.60	0.345	8.76	38	49	100	125
25 001 to 28 000	1 to 1000 (42.4 to 507)	0.280	7.11	...	...	42	...	105	...
28 001 to 35 000	1/0 to 1000 (53.5 to 507)	0.345	8.76	...	...	49	...	125	...

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 significant for short specimens or when atmospheric humidity is high. It is usually desirable for a cable to have a high value of insulation resistance. This test is used for product acceptance to specification requirements, but can also be useful for quality control purposes in indicating consistency of manufacture. See Test Methods D 257 for a more complete discussion of the significance of insulation resistance tests.

31. Apparatus

31.1 *Megohm Bridge*—Use a megohm bridge or other equipment described in Test Methods D 257. Make the measurement at a voltage of 100 to 500 Vdc.

32. Sampling, Test Specimens, and Test Units

32.1 The specimen consists of entire lengths of completed cable.

33. Procedure

33.1 **Caution—**This test involves the use of high voltages. See 4.2.

33.2 Unless otherwise specified in the product specification:

33.2.1 Perform this test only after performing the completed cable ac voltage tests as specified in 27.3,

33.2.2 Perform this test only before performing the completed cable dc voltage tests as specified in 27.4, and

33.2.3 Perform this test in accordance with Test Methods D 257, and as follows:

33.2.4 Where the voltage tests are made on wire or cable immersed in water, measure the insulation resistance while the cable is still immersed.

33.3 *Single-Conductor Cables*:

33.3.1 For single-conductor cables test between the conductor and its metallic sheath or between the conductor and surrounding water.

33.3.2 *Multiple-Conductor Cables*:

33.3.2.1 For cables having unshielded conductors, test between each conductor and all other conductors, and between each conductor and the overall sheath or surrounding water.

33.3.2.2 For cables having shielded conductors, test between each conductor and its shield.

33.3.3 Connect the conductor of the specimen under test to the negative terminal of the test equipment, and take readings after an electrification time of 1 min. On short sections of wire or cable, use a guard circuit to prevent end leakage. Maintain the temperature of the water from 10 to 30°C (50 to 85°F).

34. Calculation

34.1 Calculate the minimum insulation resistance in megohms-1000 ft (305 m) at a temperature of 60°F (15.6°C) for each coil, reel, or length of wire or cable as follows:

$$R = K \log D/d \tag{1}$$

where:

R = minimum insulation resistance in megohms-1000 ft,
K = constant for the grade of insulation (see 34.1.1),
D = diameter over the insulation, and
d = diameter under the insulation.

34.1.1 Obtain the constant K for the grade of insulation in the cable under test by reference to the product specification for that type.

34.1.2 Where a nonconducting separator is applied between the conductor and the insulation, or where an insulated conductor is covered with a non-metallic jacket, the insulation resistance shall be at least 60 % of that required for the primary insulation based on the thickness of that insulation.

34.1.3 When the length of the cable tested differs from 1000 ft (305 m), correct the measured value of insulation resistance to megohms-1000 ft by multiplying by the ratio $L/1000$ ($L/305$) where L is the length in feet (metres).

34.2 The insulation resistance of wire and cable varies widely with temperature. If the temperature at the time measurement was made differs from 60°F (15.6°C), adjust the resistance to that at 60°F by multiplying the measured value by the proper correction factor from Table 2. Use the coefficient furnished by the manufacturer for the particular insulation or determine it in accordance with Section 35.

35. Determining Temperature Coefficients for Insulation Resistance

35.1 Select three specimens, preferably of AWG 14 solid wire with a 0.045 in. (1.14 mm) wall of insulation, as representative of the insulation under consideration. Use sufficient length to yield insulation resistance values under 25 000 MΩ at the lowest water-bath temperature.

35.2 Immerse the three specimens in a water bath equipped with heating, cooling, and circulating facilities, with the ends of the specimens extended 2 ft (0.6 m) above the surface of the water and properly prepared for minimum leakage. Leave the specimens in the water at room temperature for 16 h before adjusting the bath temperature to 10°C, or transfer the specimens to a 10°C test temperature bath.

35.3 Measure the resistance of the conductor at suitable intervals of time until it remains unchanged for at least 5 min. The insulation is then at the temperature of the bath as read on the bath thermometer. Take insulation resistance readings in accordance with Sections 32 to 34.

35.4 Expose the three specimens to successive water-bath temperatures of 10, 16, 22, 28, and 35°C, returning to 28, 22, 16, and 10°C. Take insulation resistance readings at each temperature after equilibrium is established. Average all the readings taken at each temperature.

35.5 Using semi-log paper (log R versus T), plot the average readings obtained in 35.4.

35.6 *Calculations*:

35.6.1 Using the semi-log plot from 35.5, determine the insulation resistance at 60°F (15.6°C) and at 61°F (16.1°C). Obtain the 1°F coefficient per degree by dividing the insulation resistance at 60°F by the insulation resistance at 61°F.

35.6.2 If a more precise value is desired for the 1°F coefficient per degree, subject the numerical values used in 35.5 to regression analysis in order to determine the parameters of the best fitting curve. The slope parameter is related to the 1°F coefficient per degree.

36. Report

36.1 Report the following information:

36.1.1 Manufacturer's name,

36.1.2 Manufacturer's lot number, if applicable,

36.1.3 Description of the cable construction,

36.1.4 Specimen length,

36.1.5 Whether or not a guard circuit was used,

36.1.6 Whether or not the cable was immersed in water,

36.1.7 Test temperature (air or water as applicable),

TABLE 2 Temperature Correction Factors for Insulation Resistance at 60°F

Temperature		1°F Coefficient									
°F	°C	1.03	1.04	1.05	1.06	1.07	1.08	1.09	1.10	1.11	1.12
50	10.0	0.75	0.68	0.62	0.56	0.51	0.46	0.42	0.38	0.35	0.32
51	10.6	0.77	0.70	0.65	0.59	0.54	0.50	0.46	0.42	0.39	0.36
52	11.1	0.79	0.73	0.68	0.63	0.58	0.54	0.50	0.47	0.43	0.40
53	11.7	0.82	0.76	0.71	0.67	0.62	0.58	0.55	0.51	0.48	0.45
54	12.2	0.84	0.79	0.75	0.70	0.67	0.63	0.60	0.56	0.54	0.51
55	12.8	0.87	0.82	0.78	0.75	0.71	0.68	0.65	0.62	0.60	0.57
56	13.3	0.89	0.86	0.82	0.76	0.76	0.74	0.71	0.69	0.66	0.64
57	13.9	0.92	0.89	0.87	0.84	0.82	0.80	0.78	0.76	0.73	0.71
58	14.4	0.94	0.93	0.91	0.90	0.88	0.86	0.85	0.83	0.82	0.80
59	15.0	0.97	0.96	0.96	0.95	0.94	0.93	0.92	0.91	0.90	0.89
60	15.6	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
61	16.1	1.03	1.04	1.05	1.06	1.07	1.08	1.09	1.10	1.11	1.12
62	16.7	1.06	1.08	1.10	1.13	1.15	1.17	1.19	1.21	1.24	1.27
63	17.2	1.09	1.13	1.16	1.19	1.23	1.26	1.30	1.34	1.38	1.42
64	17.8	1.13	1.17	1.22	1.26	1.31	1.36	1.41	1.47	1.53	1.58
65	18.3	1.16	1.22	1.28	1.34	1.40	1.47	1.54	1.62	1.70	1.78
66	18.9	1.20	1.27	1.35	1.42	1.50	1.59	1.69	1.78	1.88	1.98
67	19.4	1.23	1.32	1.41	1.51	1.62	1.72	1.84	1.96	2.09	2.21
68	20.0	1.27	1.37	1.48	1.60	1.72	1.85	1.99	2.15	2.31	2.48
69	20.6	1.31	1.43	1.55	1.69	1.84	2.00	2.18	2.36	2.57	2.77
70	21.1	1.35	1.48	1.63	1.79	1.97	2.17	2.38	2.60	2.85	3.10
71	21.7	1.39	1.54	1.72	1.90	2.11	2.34	2.59	2.87	3.17	3.48
72	22.2	1.43	1.60	1.80	2.02	2.26	2.53	2.82	3.15	3.52	3.90
73	22.8	1.47	1.67	1.89	2.14	2.42	2.72	3.08	3.46	3.90	4.37
74	23.3	1.52	1.74	1.98	2.27	2.58	2.94	3.35	3.81	4.31	4.88
75	23.9	1.56	1.80	2.08	2.40	2.76	3.18	3.65	4.19	4.78	5.47
76	24.4	1.61	1.87	2.19	2.54	2.96	3.43	3.98	4.61	5.30	6.12
77	25.0	1.66	1.95	2.30	2.70	3.17	3.70	4.34	5.08	5.88	6.85
78	25.6	1.71	2.02	2.41	2.86	3.39	4.00	4.73	5.59	6.51	7.68
79	26.1	1.76	2.11	2.53	3.03	3.62	4.33	5.16	6.14	7.27	8.59
80	26.7	1.81	2.19	2.66	3.21	3.87	4.67	5.61	6.72	8.07	9.65
81	27.2	1.87	2.28	2.80	3.40	4.15	5.04	6.12	7.43	8.98	10.80
82	27.8	1.92	2.37	2.94	3.60	4.43	5.45	6.69	8.18	9.92	12.10
83	28.3	1.98	2.47	3.08	3.82	4.73	5.89	7.28	9.00	11.00	13.60
84	28.9	2.04	2.57	3.32	4.05	5.04	6.35	7.92	9.00	12.2	15.2
85	29.4	2.10	2.67	3.40	4.30	5.42	6.84	8.67	10.8	13.5	17.0

36.1.8 Measured value for insulation resistance,
36.1.9 Computed value for insulation resistance, and
36.1.10 1°F coefficient, if used.

37. Precision and Bias

37.1 This test method has been in use for many years, but no information has been presented to ASTM upon which to base a statement of precision. No activity has been planned to develop such information.

37.2 This test method has no bias because the value for this test is determined solely in terms of the test method itself.

CAPACITANCE AND DISSIPATION FACTOR TESTS

38. Significance and Use

38.1 This test is applicable only to power cables rated 5001 V and above.

38.2 It is desirable for a cable to have a low value of capacitance to reduce charging current to a minimum. A low dissipation factor minimizes circuit losses. While the initial values are important, changes in capacitance and dissipation factor with aging and absorption of moisture in service may be much more significant.

39. Apparatus

39.1 See Section 66.

40. Sampling

40.1 Take one sample from the first 10 000 to 20 000 ft (3000 to 6000 m) of each cable construction and one additional sample for each additional 100 000 ft (30 500 m). No testing is necessary for manufacturing lots smaller than 10 000 ft. Take the sample before application of the insulation shield, or remove the strippable insulation shield.

41. Test Specimen

41.1 Use a 13 ft (4 m) specimen for cables rated 15 000 V and less, and 17 ft (5 m) specimen for cables rated above 15 000 V.

42. Procedure

42.1 **Caution—**This test involves the use of high voltages. See 4.2.

42.2 Measure the capacitance and dissipation factor at 49 to 61 Hz, at the ac voltage equal to the rated line-to-ground voltage (or rated voltage to ground) of the cable under test.

42.3 Immerse the middle 10 ft $\pm$ 0.5 in. (3.05 m $\pm$ 13 mm) of the specimen in the water tank filled with tap water for at least 24 h, keeping the portion of each end above the water. Then, with the water as the ground electrode, apply the voltage between the conductor and the water.

42.4 Measure and record the capacitance and dissipation factor for each specimen tested.

43. Report

43.1 Report the following information:
43.1.1 Manufacturer's name,
43.1.2 Manufacturer's lot number, if applicable,
43.1.3 Description of the cable construction,
43.1.4 The measurement temperature,
43.1.5 Measured capacitance,
43.1.6 Calculated capacitance per unit length (picofarads per ft or per metre), and
43.1.7 Measured dissipation factor.

44. Precision and Bias

44.1 This test method has been in use for many years, but no information has been presented to ASTM upon which to base a statement of precision. No activity has been planned to develop such information.

44.2 This test method has no bias because the value for this test is determined solely in terms of the test method itself.

DOUBLE AC VOLTAGE TEST ON SHORT SPECIMENS

45. Significance and Use

45.1 The double AC voltage test, properly interpreted, provides information on the ability of the insulation material to withstand a higher voltage than is normally called for in AC voltage withstand testing. This test provides data for research and development, engineering design, quality control, and acceptance or rejection under specifications.

46. Apparatus

46.1 *AC Apparatus*—See 23.1. Voltage source must be capable of providing 100 kV.

46.2 *Grounded Water Tank*—See 23.3.

47. Test Specimen

47.1 This test is applicable only to power cable rated 5001 V and above. The test specimen shall be taken either from the cable in process or from the completed cable. One test specimen shall be taken for the first 5000 to 20 000 ft (1500 to 6000 m) of each cable construction and one additional specimen for each additional 100 000 ft (30 000 m). The gross length of each specimen shall be 17 ft (5.18 m) for cables rated 15 000 V and below and 22 ft (6.71 m) for cables rated above 15 000 V.

48. Procedure

48.1 **Caution—**This test involves the use of high voltages. See 4.2.

48.2 Immerse 10 ft (3.05 m) of the test specimen, with any outer coverings removed except tape in which the insulation is crosslinked, in water at room temperature for at least 1 h prior to making the test.

48.3 After the specimen has been immersed for at least 1 h, it shall withstand for 5 min a test voltage, which is twice the ac test voltage given in Table 1A, Table 1C, or Table 1D.

48.3.1 The initially applied voltage shall be not greater than the rated voltage, and the rate of increase shall be approximately uniform and shall reach full voltage between 10 and 60 s.

48.4 The test shall be made on the same specimen used in 48.2. Starting with the voltage at which the test described in 48.3 was made, the voltage shall be raised in steps of approximately 20 % of the immediately preceding voltage until failure occurs, the voltage to be kept constant at each step for 5 min.

49. Report

49.1 Report the following information:

49.1.1 Manufacturer's name,

49.1.2 Manufacturer's lot number, if applicable,

49.1.3 Description of the cable construction,

49.1.4 Voltage and time of application, and

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

50. Precision and Bias

50.1 This test method has been in use for many years, but no information has been presented to ASTM upon which to base a statement of precision. No activity has been planned to develop such information.

50.2 This test method has no bias because the value for this test is determined solely in terms of the test method itself.

COLD-BEND, LONG-TIME VOLTAGE TEST ON SHORT SPECIMENS

51. Significance and Use

51.1 This test, properly interpreted, provides information of the ability of the insulation material to retain its integrity when flexed at a low temperature and then subjected to a voltage withstand test. This test may provide data for research and development, engineering design, quality control, and acceptance or rejection under specifications.

52. Apparatus

52.1 *AC Apparatus*—See 23.1.

52.2 *Grounded Water Tank*—See 23.3.

52.3 *Cold Box*—A cold box capable of maintaining the required temperature ± 2°C.

52.4 *Mandrels*—A set of mandrels conforming to Table 3.

53. Test Specimen

53.1 This test is applicable only to power cable rated 5001 V and above. The test specimen shall be taken from the completed cable which may be either single or multiple conductor. One test specimen shall be taken from the first 5000 to 20 000 ft (1500 to 6000 m) of each cable construction and one additional specimen for each additional 100 000 ft (30 000 m). The gross length of each specimen shall be 13 ft (3.96 m) for cables rated 15 000 V and below and 17 ft (5.18 m) for cables rated above 15 000 V.

54. Procedure

54.1 **Caution**—This test involves the use of high voltages. See 4.2.

54.2 Subject each test specimen to a temperature of −10°C for a period of 2 h. Within 30 s of removing the specimen from the cold chamber, bend the specimen 180° around a nonmetallic cylindrical mandrel and then straighten it. See Table 3 for the mandrel diameters. Then bend it 180° around the mandrel in the opposite direction. Hold the cable during bending operations in such a way that it cannot revolve around its own axis. Complete the bends within 1 min.

TABLE 3 Mandrel Diameters for Cold-Bend, Long-Time Voltage Test

Thickness of Conductor Insulation		Mandrel Diameter as a Multiple of Outside Diameter of the Cable	
mm	in.	Less than 500 kcmil (253 mm^2)	500 kcmil (253 mm^2) and Over
up to 4.83	0.190	8	10
5.21 to 7.87	0.205 to 0.310	10	12
8.38 and over	0.330 and over	12	12

54.3 Immediately following the bending test and while still bent, the cable shall withstand the applicable ac test voltage given in Table 1A, Table 1C, or Table 1D continuously for 2 h between each conductor and all of the other conductors and also between each conductor and an enclosing grounded surface. Three-conductor cables shall be tested with grounded three-phase voltage or with single-phase voltage. For shielded cables, the shields shall be grounded. Nonshielded cables shall be tested in a grounded water bath or in a foil.

55. Acceptance on Basis of Tests on Short Specimens

55.1 If all of the test specimens conform to the requirements of this test, the lot of cable to which they apply shall be considered acceptable so far as these particular requirements are concerned.

55.2 If any specimen fails to conform to the requirements of this test, that length of cable from which the specimen was taken shall be rejected, and another test specimen shall then be taken from each of two other lengths of cable in the lot. If either such specimen fails to pass this test, the lot shall be rejected. If both such second specimens pass this test, the lot of cable (except the length which was rejected because of failure of the first specimen) shall be accepted.

55.3 Failure of any cable length shall not prohibit the manufacturer from resubmitting the same length of cable for inspection, providing that it be so designated.

56. Report

56.1 Report the following information:

56.1.1 Manufacturer's name,

56.1.2 Manufacturer's lot number, if applicable,

56.1.3 Type of test,

56.1.4 Time and place of test,

56.1.5 Test voltages,

56.1.6 Duration of each test, and

56.1.7 Results of each test, including location of any failure.

57. Precision and Bias

57.1 This test method has been in use for many years, but no information has been presented to ASTM upon which to base a statement of precision. No activity has been planned to develop such information.

57.2 This test method has no bias because the value for this test is determined solely in terms of the test method itself.

PARTIAL-DISCHARGE EXTINCTION LEVEL TEST

58. Scope

58.1 This test applies to the detection and measurement of partial discharges occurring in the following types of electric cables:

58.1.1 Single-conductor shielded cables and assemblies thereof, and

58.1.2 Multiple-conductor cables with individually shielded conductors.

59. Significance and Use

59.1 Measurement of the partial discharge extinction voltage provides useful information regarding the possibility of discharges at a cable's operating voltage. This measurement may contribute to a knowledge of the expected life of the cable since the presence of partial discharges frequently results in significant reductions in life. Some materials are more susceptible to such discharge damage than others. The partial discharge extinction level is useful for quality control purposes, and this test is also used for product acceptance to specification requirements.

60. Apparatus

60.1 See ICEA T-24-380 for a description of the required apparatus.

61. Sampling, Test Specimens, and Test Units

61.1 The specimen consists of entire lengths of completed cable.

62. Procedure

62.1 **Caution**—This test involves the use of high voltages. See 4.2.

62.2 Prior to the ac voltage test, perform the partial-discharge test in accordance with ICEA T-24-380 except as modified in the following sections.

62.3 Apply an ac test voltage between the conductor and the metallic component of the insulation shield. Increase the applied voltage sufficiently to indicate detector response to partial discharge, but do not exceed the ac test voltage specified in Table 1A, Table 1C, or Table 1D. Then lower the voltage at a rate not greater than 2000 V/s to determine the partial-discharge extinction level (see 62.4).

62.4 The partial-discharge extinction level is that voltage at which apparent charge transfer falls to 5 pC or less.

62.5 If the existence of discharges is not evident after the voltage has been raised to a value 20 % above the specified minimum extinction value, consider the cable to have met the requirements for this test.

62.6 Do not maintain the applied voltage for more than 3 min during any single test.

63. Report

63.1 Report the following information:

63.1.1 Manufacturer's name,

63.1.2 Manufacturer's lot number, if applicable,

63.1.3 Description of the cable construction,

63.1.4 Partial discharge extinction voltage,

63.1.5 Whether or not discharges are evident at a voltage which is 20 % higher than the specified minimum extinction value, and

63.1.6 Method of end preparation.

64. Precision and Bias

64.1 This test method has been in use for many years, but no information has been presented to ASTM upon which to base a statement of precision. No activity has been planned to develop such information.

64.2 This test method has no bias because the value for this test is determined solely in terms of the test method itself.

WATER ABSORPTION TEST

65. Significance and Use

65.1 Perform the water absorption test only when requested by the purchaser. Water absorption tests, properly interpreted, provide information with regard to the water absorption properties of the insulation. Water absorption tests can also give an indication of the surface condition of the insulation. The water absorption test values give an indication of how the insulation will perform in a wet environment. Water absorption tests may provide data for research and development, engineering design, quality control, and acceptance or rejection under specifications. See Test Methods D 150 for a more complete discussion of the significance of capacitance measurements.

66. Apparatus

66.1 *Water Tank*—An electrically isolated water tank of sufficient length to contain a 10-ft (3.05-m) length of cable. The tank contains a heater of sufficient capacity to maintain the specified water temperature. The tank has a tightly fitting cover placed directly above the water surface, with suitable water-tight bushings for the ends of the specimen.

66.2 *Capacitance Bridge*—See Test Methods D 150 for apparatus for measuring capacitance.

67. Test Specimen

67.1 Take a 15-ft (4.6-m) test specimen of the insulated wire or cable after crosslinking and prior to the application of any coverings except the tape applied before crosslinking. Remove such tape before making the test.

68. Procedure

68.1 **Caution**—This test involves the use of high voltages. See 4.2.

68.2 *Immersion of Specimen*—Immerse the middle 10 ft (3.05 m) of the test specimen in the water tank filled with tap water, maintained at room temperature but at not less than 70°F (21°C), for a period of 14 days, keeping the 2½-ft (0.76-m) portion of each end above the water.

68.3 *Capacitance Measurements at 60-Hertz*—Using suitable 60-Hz equipment, measure the capacitance. Make measurements between the conductor and the water while the cable is still immersed in water and after it has been totally immersed for periods of 1, 7, and 14 days, with the same water temperature applying for each measurement.

69. Calculation

69.1 Using the capacitance measurements from 68.3, calculate the permittivity at 60 Hz as follows:

$$\text{Permittivity} = 13\,600\ C\ \log_{10} D/d \tag{2}$$

where:

C = capacitance in microfarads of a 10 ft (3.05 m) specimen,
D = diameter over the insulation, and
d = diameter under the insulation.

70. Report

70.1 Report the following information:
70.1.1 Manufacturer's name,
70.1.2 Manufacturer's lot number, if applicable,
70.1.3 Description of the cable construction,
70.1.4 Conductor size,
70.1.5 Insulation thickness,
70.1.6 Temperature of the water during the test, and
70.1.7 Permittivity at 60-Hz after 1, 7, and 14 days.

71. Precision and Bias

71.1 This test method has been in use for many years, but no information has been presented to ASTM upon which to base a statement of precision. No activity has been planned to develop such information.

71.2 This test method has no bias because the value for this test is determined solely in terms of the test method itself.

ACCELERATED WATER ABSORPTION TEST

Electrical Method

72. Scope

72.1 Do not perform these tests on:

72.1.1 Cables which have a nonconductive separator between the conductor and the insulation,

72.1.2 Cables having insulations less than 0.045 in. (1.14 mm) thick, or

72.1.3 Insulations with coverings that are not removable without damage to the insulation.

73. Significance and Use

73.1 See Section 65.

74. Apparatus

74.1 *Water Tank*—See Section 66.
74.2 *Capacitance Bridge*—See Section 66.

75. Test Specimen

75.1 Select the sample of insulated wire or cable after crosslinking and prior to the application of any coverings other than the tape applied before the crosslinking process. Obtain a 15 ft (4.6 m) specimen from this sample. From this specimen, remove the tape applied before crosslinking.

76. Procedure

76.1 **Caution—**This test involves the use of high voltages. See 4.2.

76.2 *Immersion of Specimen*—After a minimum of 48 h following crosslinking, immerse the middle 10 ft (3.05 m) of the specimen in the water tank filled with tap water, keeping the 2.5-ft (0.76-m) portion of each end above the water. Keep the specimen immersed for a period of 14 days, while maintaining the temperature of the water at 50 ± 1°C or 75 ± 1°C, as specified in the applicable insulation specification.

76.3 *Capacitance Tests at 60-Hz*—Using suitable 60-Hz equipment, measure the capacitance at an average stress of 80 V/mil (3.2 kV/mm). Make measurements between the conductor and the water while the cable is still immersed in water after it has been totally immersed for periods of 1, 7, and 14 days. After 1, 7, and 14 days' total immersion, calculate the specimen dissipation factor at average stresses of 40 and 80 V/mil (1.6 and 3.2 kV/mm) at 60 Hz. Give each value to the nearest 0.001. Express the increase in capacitance from 1 to 14 days and from 7 to 14 days as a percentage of the 1 and 7-day values, respectively.

77. Calculation

77.1 *Permittivity*—Calculate the permittivity at 60 Hz (see 69.1) using the capacitance measurement from 76.3.

77.2 *Stability Factor*—The stability factor is an arithmetical difference between the percentage dissipation factor measured at 60-Hz average stresses of 80 and 40 V/mil (3.2 and 1.6 kV/mm) respectively, after immersion in water at a temperature of 50 ± 1.0°C, or at 75 ± 1.0°C as specified in the applicable insulation specification for a specified period.

77.3 *Alternate Stability Factor*—The alternate stability factor is the 14-day stability factor minus the 1-day stability factor.

78. Report

78.1 Report the following information:
78.1.1 Manufacturer's name,
78.1.2 Manufacturer's lot number, if applicable,
78.1.3 Description of the cable construction,
78.1.4 Conductor size,
78.1.5 Insulation thickness,
78.1.6 Temperature of the water during the test,
78.1.7 Permittivity at 60-Hz after 1, 7, and 14 days,
78.1.8 Stability factor, and
78.1.9 Alternate stability factor.

79. Precision and Bias

79.1 This test method has been in use for many years, but no information has been presented to ASTM upon which to base a statement of precision. No activity has been planned to develop such information.

79.2 This test method has no bias because the value for this test is determined solely in terms of the test method itself.

Gravimetric Method

80. Significance and Use

80.1 This test method may give inaccurate results in tests of compounds containing volatile ingredients, due to loss of these ingredients during drying. Also see 65.1.

81. Apparatus

81.1 *Vacuum Oven*—A vacuum oven capable of maintaining a vacuum of 5 mm of mercury or less and a temperature of 70 ± 2°C.

81.2 *Dessicator*—A dessicator of sufficient size to hold the specimen. The bottom of the dessicator is to be filled with indicating calcium chloride.

81.3 *Lintless Cloth*—A clean cloth that will not leave lint on the specimen.

81.4 *Mandrel*—A mandrel at least 3 times the diameter of the specimen.

81.5 *Balance*—A balance capable of weighing to the nearest mg.

81.6 *Immersion Vessel*—A container of borosilicate glass, stainless steel, or vitreous-enameled steel with a tight-fitting cover with holes for the ends of the specimens.

82. Test Specimen

82.1 From a sample of insulated conductor selected after crosslinking, prepare a test specimen by first removing all outer coverings. If the weight of the total specimen will be less than 100 g, cut a specimen of the insulated conductor measuring 11 in. (280 mm) in length. For heavier specimens, cut a segment of insulation from the conductor measuring 4 in. (102 mm) in length and of suitable width; buff this insulation segment to remove all corrugations.

83. Procedure

83.1 *Preparation of Specimen*—Clean the surface of the test specimen by scrubbing with a lintless cloth moistened with water. Dry the sepcimen for 48 h in a vacuum of 5 mm of mercury or less over calcium chloride at 70 ± 2°C. Cool in a dessicator to room temperature. Weigh the specimen to the nearest 1 mg, and designate this weight as *A*. Designate the insulation area in square inches (or square millimetres) of a 10-in. (250-mm) length of wire, or the total area in square inches (or square millimetres) of the segment, *S*. Bend the insulated wire in the shape of a "U" around a mandrel at least three times the diameter of the specimen, and insert the ends in tight-fitting holes in the cover of the immersion vessel so that 10 in. (250 mm) of the specimen is immersed when the vessel is completely filled with water and the cover applied.

83.2 *Immersion of Specimen*—Immerse the test specimen in freshly boiled distilled water at a temperature of 70 ± 1°C or 82 ± 1°C, as specified in the applicable insulation specification. Continue the immersion for a period of 168 h. Maintain the vessel completely full of water during the immersion period. Completely submerge the specimen. After submersion for 168 h, cool the water to room temperature. Then remove the specimen and shake off the adhering water. Blot the specimen lightly with a lintless cloth and within 3 min weigh to the nearest 1 mg. Designate this weight as *B*. Dry the specimen for 48 h in a vacuum of 5 mm of mercury or less over calcium chloride at 70 ± 2°C. Cool the specimen to room temperature. Weigh the specimen to the nearest 1 mg and designate this as *C*.

84. Calculation

84.1 Calculate all results in terms of milligrams per square inch (milligrams per square millimetre) of surface as follows:

$$\text{Water absorption (if } C \text{ is less than } A) = (B - C)/S \tag{3}$$

$$\text{Water absorption (if } C \text{ is greater than } A) = (B - A)/S \tag{4}$$

$$\text{Water soluble matter (if } C \text{ is less than } A) = (A - C)/S \tag{5}$$

where:

A = weight of the specimen before submersion, mg,
B = weight of the specimen after submersion, mg,
C = constant weight of the specimen after drying in vacuum, mg, and
S = total area of the specimen of insulated wire used, in.^{2} (mm^2).

85. Report

85.1 Report the following information:

85.1.1 Manufacturer's name,

85.1.2 Manufacturer's lot number, if applicable,

85.1.3 Description of the cable construction,

85.1.4 Conductor size,

85.1.5 Insulation thickness,

85.1.6 Test temperature, and

85.1.7 Water absorption (milligrams per square inch or milligrams per square centimetre).

86. Precision and Bias

86.1 This test method has been in use for many years, but no information has been presented to ASTM upon which to base a statement of precision. No activity has been planned to develop such information.

86.2 This test method has no bias because the value for this test is determined solely in terms of the test method itself.

OZONE RESISTANCE TEST

87. Significance

87.1 Ozone resistance testing, properly interpreted, provides information regarding the resistance of the insulation to ozone attack which may be encountered in the operation of high-voltage cable. Ozone resistance tests may provide data for research and development, engineering design, quality control, and acceptance or rejection under specifications. For determination of ozone concentrations see Sections 93 to 99.

88. Apparatus

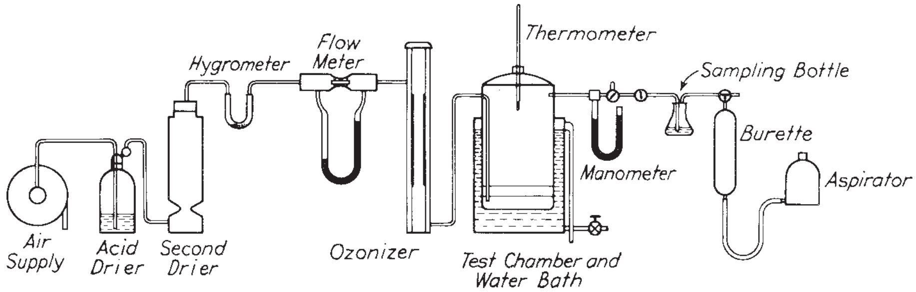
88.1 The apparatus consists of the following:

88.1.1 A device for generating a controlled amount of ozone,

88.1.2 A means for circulating ozonized air under controlled conditions of humidity and temperature through a chamber containing the specimens for test, and

88.1.3 A means for determining the percentage of ozone concentration (Sections 93 to 99).

88.2 A convenient form of apparatus is shown in Fig. 2. Air flows from an air pump, or compressed air supply through a series of chambers as indicated. The acid drier consists of two 500-mL gas washing bottles filled to 30 % of capacity with



NOTE 1—If the acid in the first acid drier should carry over into the second acid drier, a scrubber bottle may be inserted between the two drier bottles.

FIG. 2 Apparatus for Ozone Resistance Test

H_2SO_4 (sp gr 1.84). In series with this is a second drier containing anhydrous calcium chloride or anhydrous calcium sulfate, and a U-tube hygrometer containing a small quantity of anhydrous copper sulfate which is used as an indicator of moisture. The rate of air flow is indicated by a calibrated flowmeter having a capacity of at least 25 ft^3/h (12 L/s). Ozonization of the air is accomplished in a generator consisting of a pair of concentric electrodes, separated by a thin glass dielectric, between which voltage may be applied. This generator is supplied by a potential transformer, equipped with variable voltage control, of 20 to 30-kV rating. Make the test chamber just largeenough to accommodate the largest specimens for test and of a material not attacked by ozone. Excessive size results in greater delay in obtaining the desired ozone concentration. A chamber 18 to 20 in. (460 to 510 mm) in length, and having a capacity of 2000 to 5000 $in.^3$ (30 to 80 L) is generally required. A convenient form of chamber is a glass jar, having a full-size cover. This permits easy access to the interior and also the inspection of specimens, without opening the chamber during test. Place a filter consisting of a layer of loose mineral wool held between two perforated grills near the bottom of the test chamber. Introduce the ozonized air from the generator to the space below this filter. Control the temperature by keeping the apparatus in an air-conditioned room or by partially immersing the chamber in a water bath, either connected to a hot-and-cold water system or provided with thermostatically controlled electric heaters. Insert a thermometer into the cover of the test chamber with its bulb as near the test specimens as practicable. Discharge from the test chamber is accomplished by a double cock arrangement, one acting as a direct discharge into the outside atmosphere and the other, when normally closed, acting as a bypass test-cock. Insert a manometer in the outlet pipe to indicate pressure in the test chamber.

89. Test Specimens

89.1 Select two specimens for the ozone test beyond a point not less than 5 ft (1.52 m) from the end of the reel or coil to be tested. Remove any nonadherent protective coverings applied to the insulation. However, do not remove any tapes or jackets applied directly to the insulation prior to crosslinking and left in place during crosslinking, and consequently adherent to insulation in the completed cable.

89.2 Examine each specimen to make sure it is free from mechanical defects, such as cuts, dents, tears, loose threads, etc. Bend one specimen in the direction and plane of the existing curvature of the cable around a mandrel and through the specified angle in accordance with 89.3 and 89.4. Bend the other specimen similarly but in the reverse direction and plane of the existing curvature.

89.3 Bend the specimen without twisting at room temperature (not less than 20°C) around a brass, aluminum, or suitably treated wooden mandrel of the specified diameter, as shown in the following table and Fig. 3, binding it with twine or tape where the ends cross. If the cable is too rigid to permit crossing of the ends, bend it in the form of a "U" and tie to obtain at least a 180° bend of the proper diameter (see Fig. 3).

Cable Outside Diameter	Mandrel Diameter
Less than ½ in. (12.7 mm)	4 × cable OD
½ in. (12.7 mm) but less than ¾ in. (19.1 mm)	5 × cable OD
¾ in. (19.1 mm) but less than 1¼ in. (32.0 mm)	6 × cable OD
1¼ in. (32.0 mm) but less than 1¾ in. (44.5 mm)	8 × cable OD
1¾ in. (44.5 mm) and above	10 × cable OD

89.4 Wipe the surface of the insulation on each specimen with a clean cloth to remove dirt or sweat. Place the bent specimens on their mandrels in a desiccator for 30 to 45 min after bending to remove surface moisture and until placed in the ozone chamber.

90. Procedure

90.1 **Caution**—See 4.3.

90.2 Circulate the air through the test apparatus at a constant rate of flow between 10 to 20 ft^3/h (4.7 to 9.4 L/s) as indicated

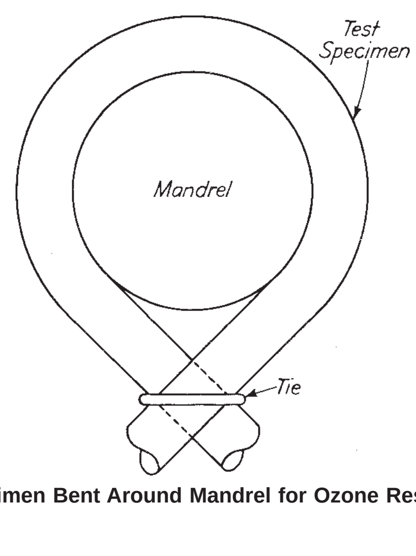


FIG. 3 Specimen Bent Around Mandrel for Ozone Resistance Test

on the flowmeter for at least 15 min prior to bending of the specimens. Maintain a pressure of approximately ½ in. (12.5 mm) of water above atmospheric in the test chamber. Control the pressure by the degree of closure of the discharge cock. After generating the ozone for at least 15 min, make a check on the percentage of ozone concentration (see 97.2). Regulate the voltage of the ozone generator or the rate of flow of air so as to give a concentration of ozone as specified in the product specification. Regulate the temperature of the air in the test chamber to 25 ± 2°C. When the ozone chamber is in equilibrium operation for at least 45 min, place the specimens in the test chamber. Take care not to handle the insulation. Support the specimens in an approximately vertical plane midway between the top and bottom, with the free ends down to, but not touching, the bottom.

90.3 After exposing the specimens for 3 h, take them out of the chamber, and examine them with the unaided eye for cracks in the bent portion. Cracks occurring on the 180° sector including the tie, that is, where the specimen is not curved to conform to the mandrel, are not failures.

90.4 Acceptable insulation shows no cracking or surface checking visible to the unaided eye.

91. Report

91.1 Report the following information:

91.1.1 Manufacturer's name,

91.1.2 Manufacturer's lot number, if applicable,

91.1.3 Description of the cable construction,

91.1.4 Conductor/cable diameter,

91.1.5 Concentration of ozone, %,

91.1.6 Exposure period, h, and

91.1.7 Whether or not the specimens show cracking of surface.

92. Precision and Bias

92.1 No information is presented about the precision of this test for measuring ozone because the test result is non-quantitative.

92.2 No information is presented about the bias of this test method for measuring ozone because the test result is non-quantitative.

DETERMINATION OF OZONE CONCENTRATION

93. Significance and Use

93.1 These test methods for the determination of ozone concentration are for use in connection with the Ozone Resistance Test, Sections 87 to 92.

Chemical Analysis

94. Reagents

94.1 *Purity of Reagents*—Use reagent grade chemicals in all tests. Unless otherwise indicated, the intention is that all reagents conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society, where such specifications are available.[9] Other grades are permitted, provided it is first ascertained that the reagent is of sufficiently high purity to permit its use without lessening the accuracy of the determination.

94.2 *Purity of Water*—Unless otherwise indicated, references to water are in accordance with Specification D 1193.

94.3 *Acetic Acid (10 %)*.

94.4 *Iodine, Standard Solution*—Place in a weighing tube 2 g of potassium iodide (KI) and 10 mL of water, and weigh the tube and solution. Add iodine directly to the solution in the weighing tube on the balance pan until the total iodine in solution is about 0.1 g. Accurately weigh the solution with the added iodine. Determine the amount of iodine added to the solution. Remove the weighing tube, pour the solution into a beaker, wash the weighing tube held over the beaker with distilled water, pour the solution from the beaker into a volumetric flask, rinse the beaker into a 1000-mL volumetric flask with distilled water, and dilute the solution in the flask to 1 L. This solution is stable for a week if kept in a cool, dark place in a well-stoppered, brown bottle. Discard the solution after one week and prepare fresh solution.

94.5 *Potassium Iodide Solution* (10 g/L)—Dissolve about 20 g of pure potassium iodide (KI) in 2 L of water.

94.6 *Sodium Thiosulfate Solution* (0.24 g/L)—Prepare a sodium thiosulfate ($Na_2S_2O_3$) solution of approximately the same strength as the standard iodine solution by placing about 0.24 g of $Na_2S_2O_3 \cdot 5H_2O$ in a 1000-mL volumetric flask, and dilute to 1 L. Since this solution gradually loses its strength, standardize it against the standard iodine solution on the day tests are run. Calculate the strength of the $Na_2S_2O_3$ solution in accordance with 97.1.

94.7 *Starch Indicator Solution* (1 g/200 mL)—Stir 1 g of soluble starch into 40 mL of cold water, heat to boiling, while stirring constantly, until starch is completely dissolved, dilute with cold water to about 200 mL, and add 2 g of crystallized zinc chloride ($ZnCl_2$). Let the solution settle and then pour off the supernatant liquid for use. Renew every 2 or 3 days. A fresh solution of 1 g of soluble starch in 100 mL of boiling water may also be used. When using these starch solutions as an indicator, add a few drops of acetic acid (CH_3COOH, 10 %) to the solution being titrated.

95. Collection of Sample

95.1 Place a 100-mL portion of KI solution (1 %), slightly acidified with 10 % acetic acid, in the sampling bottle and connect the latter to the sampling cock and gas buret as shown in Fig. 2. Then open the two-way stopcock on the buret to the air and fill the buret to the mark with water by lifting the aspirator bottle. Close the stopcock to the air, open it to the sampling bottle, and then open the sampling cock on the test chamber. Lower the aspirator bottle until the buret is emptied. When this point is reached, 500 mL of gas will have bubbled

[9] *Reagent Chemicals, American Chemical Society Specifications*, American Chemical Society, Washington, DC. For suggestions on the testing of reagents not listed by the American Chemical Society, see *Analar Standards for Laboratory Chemicals*, BDH Ltd., Poole, Dorset, U.K., and the *United States Pharmacopeia and National Formulary*, U.S. Pharmacopeial Convention, Inc. (USPC), Rockville, MD.

through the KI solution. Then close the stopcocks and withdraw the bottle for titration.

96. Analysis of Sample

96.1 Add to the solution in the bottle a few drops of starch solution as an indicator, and then titrate with the standardized $Na_2S_2O_3$ solution.

97. Calculation

97.1 *Sodium Thiosulfate Solution*—Calculate the strength of the $Na_2S_2O_3$ solution as follows:

$$E = (F \times C)/S \tag{6}$$

where:
E = iodine equivalance of $Na_2S_2O_3$ solution, mg of iodine/mL of $Na_2S_2O_3$ solution,
F = millilitres of the iodine solution,
C = concentration of iodine, mg/mL, and
S = millilitres of $Na_2S_2O_3$ solution used to titrate the solution.

97.2 *Ozone*—Since 1 mg of iodine is equivalent to 0.1 mL of ozone at room temperature and pressure (within the accuracy of this method of analysis at average room temperature and pressure), calculate the ozone as follows:

$$O = E \times 0.1 \tag{7}$$

where:
O = millilitres of ozone at room temperature and pressure equivalent to 1 mL of $Na_2S_2O_3$ solution used, and
E = iodine equivalent of $Na_2S_2O_3$ solution, mg of iodine/mL of $Na_2S_2O_3$ solution.

then:

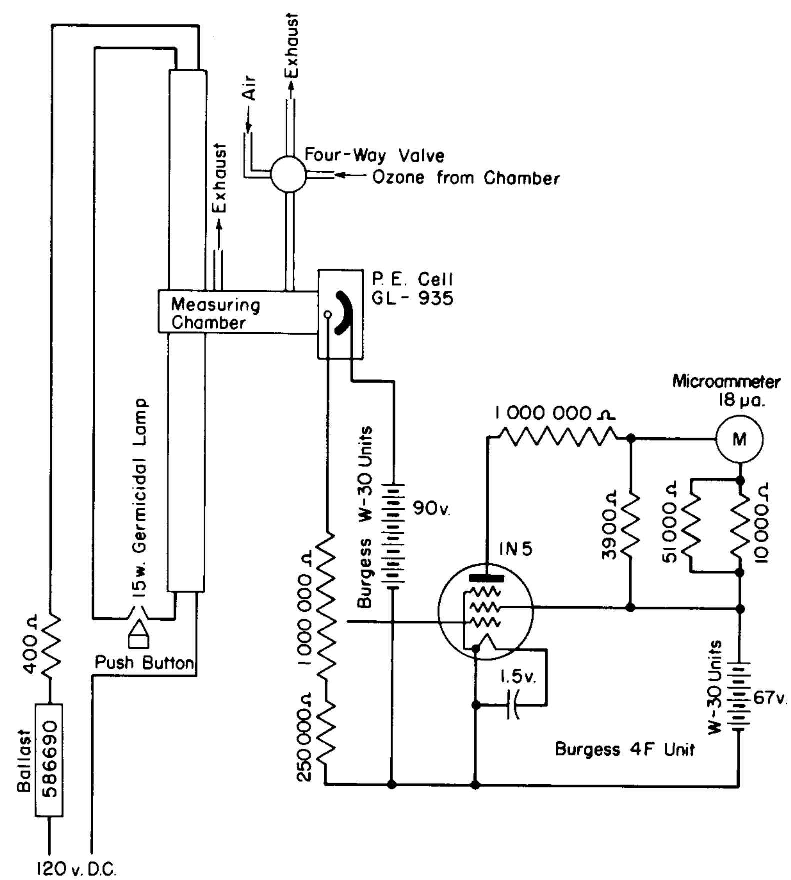
$$\text{Ozone, \%} = [(S \times O) / M] \times 100 \tag{8}$$

where:
S = millilitres of $Na_2S_2O_3$ solution used to titrate the solution,
O = millilitres of ozone at room temperature and pressure equivalent to 1 mL of $Na_2S_2O_3$ solution used, and
M = millilitres of the sample collected.

Direct Measurement with an Ozonometer

98. Procedure

98.1 This method is based on the absorption of 2537 Å radiation by ozone. The equipment is composed of a source of 2537 Å radiation and a photoelectric cell located on the opposite sides of a measuring cell through which the ozone atmosphere to be measured is passed. The amount of 2537 Å radiation that is available for activating the photoelectric cell is dependent on the concentration of ozone in the measuring chamber. The current generated in the photoelectric cell is



NOTE 1—Resistor values in microammeter shunt will vary with the meter used and with the concentration scale desired.

FIG. 4 Electronic Ozonometer

amplified sufficiently to be read directly on a sensitive microammeter. Fig. 4 shows a suggested schematic arrangement of this apparatus. The microammeter can be marked to read directly in percentage ozone. Calibrate this instrument by comparison with results obtained with the chemical method (Sections 94 to 97). The advantage in using this method is that after obtaining a calibration the ozone concentration is continuously readable on the microammeter without drawing a sample from the test chamber and thus upsetting equilibrium.

99. Precision and Bias

99.1 This test method has been in use for many years, but no information has been presented to ASTM upon which to base a statement of precision. No activity has been planned to develop such information.

99.2 This test method has no bias because the value for this test is determined solely in terms of the test method itself.

HORIZONTAL FLAME TEST

100. Significance

100.1 Use this test to measure and describe the properties of materials, products, or assemblies in response to heat and flame under controlled laboratory conditions. Do not use it to describe or appraise the fire hazard or fire risk of materials, products, or assemblies under actual fire conditions. However, results of this test are useful as elements of a fire risk assessment which takes into account all of the factors pertinent to an assessment of the fire hazard of a particular end use.

100.2 This test measures the ability of the insulation to extinguish itself when the source of ignition is removed. It also measures the characteristic of the insulation to minimize spread of fire caused by dripping of flaming particles.

101. Apparatus

101.1 *Test Chamber*—Construct the test chamber of sheet metal, 12 in. (300 mm) in width, 14 in. (350 mm) in depth, 24 in. (600 mm) in height, and open at the top. Construct the test chamber with a closable front door, hinged or sliding with a glass window for observing the flame application, which provides a draft restricted, four-sided enclosure when the door is closed. Make three circular draft holes located in a row, parallel to the lower edge of each of the two side panels. Make these draft holes approximately 1 in. (25 mm) above the bottom surface of the chamber and 1.13 in. (29 mm) in diameter. Construct draft holes free of obstructions to air flow.

101.2 *Burner*—Use a burner meeting the requirements of Specification D 5025 and having the flame calibrated in accordance with Practice D 5207.

101.3 *Gas*—Use a supply of 99.97 % methane at a pressure of 4 to 6 in. of water (1 to 1.5 kPa).

101.4 *Timing Device*—Use a timing device that records the time in seconds.

101.5 *Cotton*—Untreated surgical cotton 0.25 to 1 in. (6 to 25 mm) thick.

102. Procedure

102.1 Conduct the test in a room generally free from drafts of air. A ventilated hood is permitted if air currents do not affect the flame. Cover the floor of the test chamber with surgical cotton so that the upper surface of the cotton is 9 to 9½ in. (229 to 241 mm) below the axis of the sample. Center a test specimen 10 in. (250 mm) in length in a horizontal position on supports 8 in. (200 mm) apart. Adjust the height of the flame, with the burner vertical, to 4 to 5 in. (100 to 130 mm) with an inner blue cone 1½ in. (38.0 mm) in height. Then bring the burner in a vertical position up to the specimen so that the inner blue cone just touches the underside of the specimen at a point midway between the supports. In this position direct the flame against the specimen for a period of 30 s and then remove it. During and after the application of the flame, record the distance the flame travels from the point of application, the duration of the flaming of the specimen after the flame is removed, and whether the cotton lining the floor of the test chamber is ignited by sparks or flaming drops of burning material.

103. Report

103.1 Report the following information:

103.1.1 Manufacturer's name,

103.1.2 Manufacturer's lot number, if applicable,

103.1.3 Description of the cable specimen,

103.1.4 The distance the flame travels from the point of application of the external flame,

103.1.5 Duration in seconds of flaming of the specimen after the external flame is removed, and

103.1.6 Whether or not the cotton lining on the floor of the test chamber was ignited during the test.

104. Precision and Bias

104.1 This test method has been in use for many years, but no information has been presented to ASTM upon which to base a statement of precision. No activity has been planned to develop such information.

104.2 This test method has no bias because the value for this test is determined solely in terms of the test method itself.

WATER ABSORPTION TEST ON FIBROUS COVERINGS

105. Significance and Use

105.1 Water absorption testing of fibrous coverings, properly interpreted, provides information as to how much water a fibrous covering will absorb. Water absorption testing may provide data for research and development, design engineering, quality control, and acceptance or rejection under specifications.

106. Apparatus

106.1 *Desiccator*, containing anhydrous calcium chloride.

106.2 *Set of Mandrels*, having diameters as shown in Table 4.

106.3 *Balance*, quick-damping, accurate to 10 mg.

106.4 *Constant-Temperature Bath*, agitated, of distilled water, maintained at a temperature of 21 ± 0.5°C. The bath shall be either fitted with a cover to keep out dust, or placed within a tight enclosure during the test. If, at any time, the water

TABLE 4 Diameter of Mandrel for Bending Specimens in Water Absorption Test

NOTE 1—The values in the table apply throughout to conductors having two fibrous coverings. For AWG 14, 12, 10, and 8 conductors having one fibrous covering the mandrel diameters shall be 5⁄16in. (7.9 mm), 3⁄8 in. (9.5 mm), 9⁄16 in. (14.3 mm), and 11⁄16 in. (17.5 mm), respectively.

Size of Wire, AWG or kcmil (mm^2)	Diameter of Mandrel		Size of Wire, AWG or kcmil (mm^2)	Diameter of Mandrel	
	in.	mm		in.	mm
14 (2.08)	3⁄8	9.5	450 (228)	65⁄8	168.0
12 (3.31)	9⁄16	14.3	500 (253)	63⁄4	171.0
10 (5.26)	5⁄8	15.9	550 (279)	101⁄2	265.0
8 (8.37)	3⁄4	19.0	600 (304)	11	280.0
6 (13.3)	11⁄4	32.0	650 (329)	111⁄4	285.0
4 (21.2)	13⁄8	35.0	700 (355)	111⁄2	290.0
2 (33.6)	19⁄16	39.0	750 (380)	12	305.0
1 (42.4)	211⁄16	68.0	800 (405)	121⁄4	310.0
0 (53.5)	27⁄8	73.0	850 (431)	121⁄2	320.0
00 (67.4)	3	76.0	900 (456)	127⁄8	325.0
000 (85.0)	31⁄4	83.0	950 (481)	131⁄4	335.0
0000 (107.2)	31⁄2	89.0	1000 (507)	131⁄2	345.0
250 (127)	53⁄16	132.0	1250 (634)	171⁄2	445.0
300 (152)	51⁄2	140.0	1500 (760)	181⁄2	470.0
350 (177)	51⁄8	149.0	1750 (887)	193⁄4	500.0
400 (203)	61⁄4	159.0	2000 (1010)	201⁄2	520.0

becomes dirty, or shows the presence of a surface film of dust or wax, it shall be replaced by fresh water.

107. Procedure

107.1 Before cutting a test specimen to size, condition the coil or wire to a room temperature of not less than 70°F (21°C). Reduce the handling and flexing of wire samples to the absolute minimum necessary in testing.

107.2 Cut a 24 ± 1⁄4-in. (610 ± 6.4-mm) specimen of wire from the coil or other sample of wire, and bend around a mandrel of the diameter indicated in Table 4. For AWG 2 (33.6 mm^2) or smaller wires, make as many turns of the test specimen about the mandrel as will permit it to conform closely to the mandrel, with a 2 to 21⁄2-in. (51 to 64-mm) straight length of the specimen at each end. Adjacent turns shall not touch each other but shall be separated about 1⁄8 to 1⁄4 in. (3.20 to 6.4 mm). For wire sizes larger than AWG 2 (33.6 mm ^{2}), make a simple U-turn of the specimen about the mandrel.

107.3 Remove the specimen from the mandrel without disturbing its form, and place it in the desiccator over anhydrous calcium chloride at a room temperature of not less than 70°F (21°C) for at least 18 h. Then remove it from the desiccator, weigh to the nearest 10 mg, and record the weight as W.

107.4 Immerse the specimen in the distilled water bath, with 1 ± 11⁄2 in. (25.4 ± 12.7 mm) of each end of the coil or U-bend projecting above the surface of the water. After 24 h of immersion, remove the specimen from the bath, shake vigorously for 5 s to remove adherent moisture, weigh again, and record this weight as W_1. Complete the weighing within 2 min after removal from the bath. Then remove all fibrous coverings other than tape from the full length of the specimen, and weigh the conductor, insulation, and tape, if any, recording the weight as W_2.

108. Calculation

108.1 Express the water absorption of the specimen as a percentage of the moisture absorbed by the fibrous covering, and do not correct for the portion of the wire projecting above the water. Calculate the percentage of absorption (to 0.1 %) as follows:

$$\text{Water absorption, \%} = [100 \times (W_1 - W)] / (W - W_2) \quad (9)$$

109. Report

109.1 Report the following information:

109.1.1 Manufacturer's name,

109.1.2 Manufacturer's lot number, if applicable,

109.1.3 Description of specimen,

109.1.4 The weight of the specimen before immersion,

109.1.5 The weight of the specimen after immersion,

109.1.6 The weight of the specimen with all fibrous coverings removed, and

109.1.7 The percent water absorption.

110. Precision and Bias

110.1 This test method has been in use for many years, but no information has been presented to ASTM upon which to base a statement of precision. No activity has been planned to develop such information.

110.2 This test method has no bias because the value for this test is determined solely in terms of the test method itself.

DETERMINATION OF MINERAL FILLER CONTENT

111. Significance and Use

111.1 Determination of mineral filler content, properly interpreted, provides information as to the amount of filler used in the braid material. These values can be used to provide information about the braid material's properties. The amount of filler may provide data for research and development, engineering design, quality control, and acceptance or rejection under specifications.

112. Apparatus

112.1 *Balance*—A balance capable of weighing to the nearest 0.01 g.

112.2 *Crucible*—A porcelain or nickel crucible large enough to hold the specimen.

112.3 *Burner or Furnace*—A burner or furnace capable of applying heat to a crucible to ash the contents of the crucible.

113. Procedure

113.1 Determine the mineral filler content as follows: Remove the outer braid, together with adhering compound, from a 6-in. (152-mm) section of finished wire or cable. Weigh it, and record the weight as *A*. Then ash the weighed specimen, and record the weight of ash as *B*. Determine all weights to the nearest 0.01 g. The percentage of mineral filler may be obtained by dividing *B* by *A* and multiplying by 100.

113.2 In constructions involving two or more over-all braid coverings, determine the mineral filler content of the complete braid coverings by the method specified in 113.1 for the outer braid. Use a 6-in. (152-mm) section of the completed braid covering from the finished wire or cable together with all adhering compound for the test.

114. Report

114.1 Report the following information:

114.1.1 Manufacturer's name,

114.1.2 Manufacturer's lot number, if applicable,

114.1.3 Description of specimen,

114.1.4 The weight of the specimen before ashing,

114.1.5 The weight of the ash, and

114.1.6 The percent mineral filler.

115. Precision and Bias

115.1 This test method has been in use for many years, but no information has been presented to ASTM upon which to base a statement of precision. No activity has been planned to develop such information.

115.2 This test method has no bias because the value for this test is determined solely in terms of the test method itself.

SURFACE RESISTIVITY TEST

116. Significance and Use

116.1 The surface resistivity test, properly interpreted, provides information about this property of the insulation in situations similar to those described in the test. The values obtained in this test may be used to provide data for research and development, design engineering, quality control, and acceptance or rejection under specifications.

117. Apparatus

117.1 *Megohm Bridge*—Use a megohm bridge as described in Test Methods D 257 capable of making the measurement at a voltage of 250 to 500 V dc.

118. Procedure

118.1 **Caution**—This test involves the use of high voltages. See 4.2.

118.2 Test specimens of completed single-conductor non-shielded jacketed power cable rated 2001 through 5000 V phase-to-phase in accordance with the following methods:

118.3 Immerse a specimen of cable in water at room temperature for 48 h with the ends extending at least 12 in. (30 cm). At the end of this period, remove the specimen from the water. Wipe off the excess surface moisture with blotting paper and allow the specimen to remain at room temperature for 10 min. Wind two 1-in. (25-mm) wide foil electrodes around the cable surface with a 6-in. (152-mm) spacing. Apply a 250 to 500 V dc potential between the two electrodes. Measure the surface resistance of the cable between the two electrodes, using equipment described in Test Methods D 257, at a potential of 250 to 500 V dc. Calculate the surface resistivity, *P*, as follows:

$$P = 0.524\,RD \tag{10}$$

where:

P = surface resistivity, MΩ,

R = surface resistance, MΩ per 6-in. (152 mm) spacing, and

D = cable diameter, in. (mm).

119. Report

119.1 Report the following information:

119.1.1 Manufacturer's name,

119.1.2 Manufacturer's lot number, if applicable, and

119.1.3 The value of the surface resistivity.

120. Precision and Bias

120.1 This test method has been in use for many years, but no information has been presented to ASTM upon which to base a statement of precision. No activity has been planned to develop such information.

120.2 This test method has no bias because the value for this test is determined solely in terms of the test method itself.

U-BEND DISCHARGE TEST

121. Significance and Use

121.1 The U-bend discharge test, properly interpreted, provides information about insulation performance in situations similar to those described in the test. This test may be used to provide data for research and development, design engineering, quality control, and acceptance or rejection under specifications.

122. Apparatus

122.1 *AC Apparatus*—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.

122.2 *Metal Plate*—A smooth metal plate of dimensions sufficient to allow contact of the apex of the "U" of the specimen with it.

122.3 *Mandrels*—Mandrels conforming to Table 5.

123. Procedure

123.1 **Caution**—This test involves high voltages. See 4.2.

123.2 *U-Bend Discharge*—Bend a specimen of the completed cable in the form of a "U," 180° around a mandrel

TABLE 5 Mandrel Size for U-Bend Discharge Test

Conductor Size, AWG or kcmil (mm^2)	Diameter of Mandrel as a Multiple of the Outside Diameter of Cable
8 to 2 (8.37 to 33.6)	6
1 to 3/0 (42.4 to 85.0)	8
4/0 to 500 (107.2 to 253)	10
Over 500 (253)	12

having a diameter as specified in Table 5. Mount the specimen with the apex of the "U" above and in contact with a smooth metal plate and with the legs of the "U" perpendicular to the plate. After not less than 30 min nor more than 45 min following the bending, apply a source of 60-Hz ac potential of 100 V/mil (4 MV/m) of nominal thickness between the conductor and the metal plate. Maintain this potential continuously for at least 6 h. Test at room temperature.

124. Report

124.1 Report the following information:

124.1.1 Manufacturer's name,

124.1.2 Manufacturer's lot number, if applicable,

124.1.3 Whether the cable withstood the required voltage for the specified time.

125. Precision and Bias

125.1 This test method has been in use for many years, but no information has been presented to ASTM upon which to base a statement of precision. No activity has been planned to develop such information.

125.2 This test method has no bias because the value for this test is determined solely in terms of the test method itself.

THERMAL TESTS

126. Significance

126.1 Thermal tests, properly interpreted, provide information with regard to the way the insulation will behave when flexed or subjected to pressure under extremes of temperature. Thermal tests may provide data for research and development, engineering design, quality control, and acceptance or rejection under specifications.

127. Heat Distortion Test

127.1 *Apparatus*:

127.1.1 *Oven*—A forced convection oven meeting the requirements of Specification D 5423.

127.1.2 *Dial Micrometer*—A dial micrometer having a ⅜in. (9.5 mm) diameter foot with the gage weighing 85 g.

127.2 *Test Specimen*:

127.2.1 *Insulated Conductors, 4/0 AWG (107 mm²) and Smaller*—Measure the initial diameter of a 1-in. (25-mm) specimen of the insulated conductor with a micrometer caliper having a flat surface on both the anvil and spindle. Measure the diameter of the uninsulated conductor also, and calculate the original thickness of the insulation, T_1 as follows:

$$T_1 = (D - C) / 2 \tag{11}$$

where:

T_1 = original thickness of the insulation,
D = initial diameter of the insulated conductor, and
C = diameter of the uninsulated conductor.

127.2.2 *Insulated Conductors Larger than 4/0 AWG (107 mm²*—Prepare a smooth sample approximately 8 in. (200 mm) long, trimmed or buffed to a thickness of 0.05 ± 0.01 in. (1.3± 0.1 mm). From this sample prepare test specimens 1 in. (25 mm) long and 9⁄16 in. (14.3 mm) wide. Measure the thickness of the specimen, T_1, with a dial micrometer having a ⅜-in. (9.5-mm) diameter foot with no loading other than the 85 g of the gage.

127.3 *Procedure*—Place the dial micrometer with the load as indicated in Table 6 in an oven that has been preheated to the specified temperature. At the end of 1 h period, place the specimen in the oven, allowing both the micrometer and test specimen to remain in the oven for 1 h. At the end of this 1 h period, place the specimen directly under the foot of the micrometer and allow it to remain in the oven under load for 1 h. At the end of this period read the dial of the micrometer for:

127.3.1 The value, F, for insulated conductors 4/0 AWG (107 mm²) and smaller, and calculate the thickness of the insulation, T_2, as follows:

$$T_2 = (F - C) / 2 \tag{12}$$

where:

T_2 = thickness of the insulation after the heat distortion test,
F = final outside diameter as read from the gage, and
C = diameter of the uninsulated conductor.

127.3.2 The value of T_2 for insulated conductors larger than 4/0 (107 mm²) and jackets.

127.4 *Calculation*—Calculate the distortion as follows:

$$\text{Distortion} = [T_1 - T_2)/T_1] \times 100 \tag{13}$$

127.5 *Report*:

127.5.1 Report the following information:

127.5.1.1 Manufacturer's name,

127.5.1.2 Manufacturer's lot number, if applicable,

127.5.1.3 Description of specimen,

127.5.1.4 Load on the gage, and

127.5.1.5 Percent distortion.

127.6 *Precision and Bias*:

127.6.1 This test method has been in use for many years, but no information has been presented to ASTM upon which to base a statement of precision. No activity has been planned to develop such information.

127.6.2 This test method has no bias because the value for this test is determined solely in terms of the test method itself.

128. Cold Bend

128.1 *Significance and Use*—See Section 126.

128.2 *Apparatus*:

TABLE 6 Gage Force for Heat Distortion Test

Conductor Sizes, AWG (mm^2)	Load on Gage, g
8 (8.37)	500
6 (13.3) to 1 (42.4)	750
1/0 (53.5) to 4/0 (107)	1000
Buffed samples from conductors larger than 4/0 (107)	2000

128.2.1 *Cold Box*—A cold box capable of maintaining the required temperature ± 2°C.

128.2.2 *Mandrels*—Mandrels as specified in Table 7.

128.3 *Test Specimen*—The specimen is of sufficient length to be wrapped around the specified mandrel for 6 turns and have enough length for handling of the insulated conductor during the wrapping step.

128.4 *Procedure*—The insulation shall not show any cracks when a specimen of insulated conductor that has been subjected to −25 + 1°C for 1 h is, upon removal from the cooling chambers, immediately wound around a mandrel for at least six adjacent turns for sizes 3/0 AWG (85.0 mm ^{2}) and smaller, or for sizes larger than 3/0 AWG bent 180° around a mandrel. The mandrel diameter shall be in accordance with Table 7. Bend at an approximately uniform rate so that the time consumed is not more than 1 min.

128.5 *Report*:

128.5.1 Report the following information:

128.5.1.1 Manufacturer's name,

128.5.1.2 Manufacturer's lot number, if applicable,

128.5.1.3 Description of specimen, and

128.5.1.4 The presence or absence of cracks.

128.6 *Precision and Bias*:

128.6.1 This test method has been in use for many years, but no information has been presented to ASTM upon which to base a statement of precision. No activity has been planned to develop such information.

128.6.2 This test method has no bias because the value for this test is determined solely in terms of the test method itself.

TRACK RESISTANCE

TABLE 7 Mandrel Diameters for Cold Bend Test

Insulated Conductor Diameter, in. (mm)	Diameter of Mandrel as a Multiple of $D + d$[A]
Less than 0.501 (12.7)	3
0.501 to 1.000 (12.7 to 25.4)	5
1.001 to 1.500 (25.4 to 38.1)	7
1.501 to 2.000 (38.2 to 51.0)	9

[A] D = diameter of the insulated conductor, and d = diameter of the bare conductor.

129. Significance and Use

129.1 Track resistance tests, properly interpreted, provide information about the tracking properties of the insulation in situations similar to those described in the tests. The values obtained in these tests are useful to provide data for research and development, design engineering, quality control, and acceptance or rejection under specifications.

130. Procedure

130.1 **Caution**—This test involves the use of high voltages. See 4.2.

130.2 Determine the track resistance in accordance with Method A (Dust and Fog) as described in 130.3 or Method B (Dip-Track) as described in 130.4 as follows.

130.3 *Method A:*[10]

130.3.1 *Apparatus*—See Test Method D 2132 for a description of the required apparatus.

130.3.2 *Test Specimens*—Use three test specimens of insulated conductor, each 5.5 in. (140 mm) in length.

130.3.3 *Procedure*:

130.3.3.1 Perform the test in accordance with Test Method D 2132 except as modified herein.

130.3.3.2 Apply seven electrodes to each test specimen, with a 0.75-in. (19-mm) minimum space between each electrode. Each electrode shall consist of at least one turn of a 12 AWG (3.31 mm^2) coated copper wire wrapped tightly around the insulated conductor.

130.3.3.3 Place three test specimens horizontally in the test chamber at right angles to the axis of the spray and equidistant from the nozzle. Dust the upper half of each specimen. Remove the dust for approximately a 0.03-in. (0.79-mm) width immediately adjacent to both sides of three electrodes that are to be energized.

130.3.3.4 Ground the end electrodes, each alternate electrode, and the conductor in each test specimen. Apply a 60-Hz potential to the remaining three electrodes of each specimen.

130.3.3.5 Raise the test potential to 1500 V and adjust the fog deposit to give a current between 4 and 10 mA. Failure occurs when the circuit breaker trips.

130.4 *Method B:*[11]

130.4.1 *Test Specimen*—The test specimen shall be a strip approximately 2.0 in. (50 mm) in length and at least 0.060 in. (1.52 mm) thick, and shall be taken from the outside of the insulation. The conductor shield shall be removed.

130.4.2 *Apparatus*—Attach an electrode near one end of the specimen and to the surface that was the outside surface of the insulation.

130.4.3 *Procedure*:

130.4.3.1 Immerse the specimen in a 0.1 % solution of ammonium chloride (NH_4Cl) at ground potential until the electrode contacts the surface of the solution and then withdraws 1.0 in. (25 mm) of its immersed length. Repeat this procedure four times per minute for a minimum of ten cycles and a maximum of fifty cycles or until failure occurs. Failure occurs when an arc is maintained for two successive cycles between the electrode and solution across 1.0 in. (25 mm) of specimen.

130.4.3.2 Apply a 60-Hz test potential to the electrode attached to the specimen. The tracking voltage is the voltage at which no failures occur on five consecutive test specimens.

131. Report

131.1 Report the following information:

131.1.1 Manufacturer's name,

131.1.2 Manufacturer's lot number, if applicable,

[10] For further information see Duffy, E. K., Jovanovitch, S., and Marwick, I. J., "Discharge Resistant Characteristics of Polyethylenes of Wire and Cable," *IEEE Transactions on Power Apparatus and Systems*, IEPSA, 1965, Vol 84, p. 815, Paper 31 TP6.

[11] For further information see Wallace, C. F., and Bailey, C. A.," Dip-Track Test," *IEEE Transactions on Electrical Insulation*, IEPSA, December 1967, Vol E1-2, No. 3, p. 137, Paper 31 TP66-360.

131.1.3 Method used to perform the test (A or B),

131.1.4 Description of the cable construction,

131.1.5 Conductor size,

131.1.6 Insulation thickness,

131.1.7 Method used (A or B),

131.1.8 Time to failure for each specimen (if Method A is used), and

131.1.9 Tracking voltage (if Method B is used).

132. Precision and Bias

132.1 This test method has been in use for many years, but no information has been presented to ASTM upon which to base a statement of precision. No activity has been planned to develop such information.

132.2 This test method has no bias because the value for this test is determined solely in terms of the test method itself.

133. Keywords

133.1 capacitance; cold bend; crosslinked insulation; dielectric withstand; dissipation factor; flammability; heat distortion; heat exposure (aging); horizontal flame test; insulation resistance; mineral filler content; oil immersion; ozone resistance; partial-discharge extinction level; permittivity; set test; surface resistivity; tear test; track resistance; u-bend discharge; water absorption tests