Designation: D470 – 21

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

This standard is issued under the fixed designation D470; 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 U.S. 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, refer to the product specification for that type. These test methods do not apply to the class of products known as flexible cords.

1.2 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.

1.3 These test methods appear in the following sections:

Test Method	Section(s)
AC and DC Voltage Withstand Tests	22 to 29
Capacitance and Dissipation Factor Tests	38 to 44
Cold Bend	124
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	123
Horizontal Flame Test	100 (Test Method D7936)
Insulation Resistance Tests on Completed Cable	30 to 37
Mineral Filler Content, Determination of	107 to 111
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	112 to 116
Track Resistance Test	125 to 128
U-Bend Discharge Test	117 to 121
Water Absorption Test	65 to 71
Water Absorption Test, Accelerated	72 to 86
Water Absorption Test on Fibrous Coverings	101 to 106

1.4 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.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.* For specific hazards see Section 4.

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

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D149 Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials at Commercial Power Frequencies
D150 Test Methods for AC Loss Characteristics and Permittivity (Dielectric Constant) of Solid Electrical Insulation
D257 Test Methods for DC Resistance or Conductance of Insulating Materials
D412 Test Methods for Vulcanized Rubber and Thermoplastic Elastomers—Tension
D454 Test Method for Rubber Deterioration by Heat and Air Pressure
D572 Test Method for Rubber—Deterioration by Heat and Oxygen
D573 Test Method for Rubber—Deterioration in an Air Oven
D1193 Specification for Reagent Water
D1711 Terminology Relating to Electrical Insulation
D2132 Test Method for Dust-and-Fog Tracking and Erosion Resistance of Electrical Insulating Materials
D3755 Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials Under Direct-Voltage Stress
D5423 Specification for Forced-Convection Laboratory Ovens for Evaluation of Electrical Insulation

[1] These test methods are under the jurisdiction of ASTM Committee D09 on Electrical and Electronic Insulating Materials and are the direct responsibility of Subcommittee D09.07 on Electrical Insulating Materials.

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

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

D7936 Test Method for Flammability of Electrical Insulating Materials Intended for Wires or Cables When Burning in Horizontal Configuration

2.2 *ICEA Standard:*[3]

T-24-380 Guide for Partial-Discharge Procedure

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of terms used in these test methods, refer to Terminology D1711.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *aging (act of), n*—exposure of material to air or oil at a temperature and time as specified in the relevant material specification for that material.

3.3 *Symbols:*

3.3.1 *kcmil*—thousands of circular mils.

4. Hazards

4.1 *Mercury:*

4.1.1 (**Warning—**Mercury metal vapor poisoning has long been recognized as a hazard in industry. The maximum exposure limits are set by the American Conference of Governmental Industrial Hygienist.[4] 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 are a potential hazard during the performance of this test method. It is essential that the test apparatus, and all associated equipment electrically connected to it, be properly designed and installed for safe operation.

4.2.2 Solidly ground all electrically conductive parts which it is possible for a person to contact during the test.

4.2.3 Provide means for use at the completion of any test to ground any parts which were at high voltage during the test or have the potential for acquiring an induced charge during the test or retaining a charge even after disconnection of the voltage source.

4.2.4 Thoroughly instruct all operators as to the correct procedures for performing tests safely.

4.2.5 When making high voltage tests, particularly in compressed gas or in oil, it is possible for the energy released at breakdown to be sufficient to result in fire, explosion, or rupture of the test chamber. Design test equipment, test chambers, and test specimens so as to minimize the possibility of such occurrences and to eliminate the possibility of personal injury. If the potential for fire exists, have fire suppression equipment available. Design test equipment, test chambers, and test specimens so as to minimize the possibility of such occurrences and to eliminate the possibility of personal injury. See Sections 20, 27, 33, 42, 48, 54, 62, 68, 76, 114, 119 and 126.

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.*[4] *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 provide useful 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

[3] Available from The Insulated Cable Engineers Association, Inc. (ICEA), P.O. Box 2694, Alpharetta, GA 30023, http://www.icea.net.

[4] Available from American Conference of Governmental Industrial Hygienists (ACGIH), 1330 Kemper Meadow Dr., Cincinnati, OH 45240, http://www.acgih.org.

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.

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 shall 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, use of a segmental specimen is permitted.

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 often is greatly accelerated by using mercury. In most cases a test specimen which is an entire section is obtained, free from surface incisions and imperfections. (**Warning—**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. It is also possible to facilitate the removal of the insulation by stretching the conductor to the breaking point in a tensile-strength machine.

8.3.3 (**Warning—**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. (Immersing the sample in hot water for a few minutes just prior to pulling off the jacket often facilitates this procedure.) 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 shall be prepared from the buffed pieces after they have been allowed to recover for at least 30 min. Jackets with a thickness of less than 0.030 in. (0.76 mm) shall not be tested.

8.5 *Specimen for 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

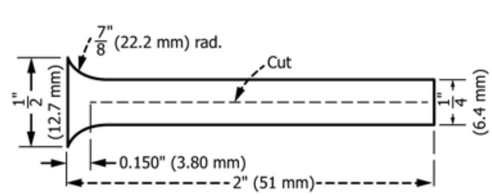

FIG. 1 Test Specimens for Tear Test