8.2.2 Unjacketed Cable

In addition to marking the extruded insulation shield semiconducting, the extruded insulation shield outer surface shall be suitably marked throughout the cable length by surface print only, at regular intervals with no more than 6 inches (152 mm) of unmarked space between cable identification, with the following information:

Manufacturer's Identification or trade name
Size of Conductor
Conductor Material
Type of Insulation
Voltage Rating
Nominal Insulation Thickness (See Table 8-1)
Year of Manufacture

8.2.3 Optional Center Strand Identification

When center strand identification is requested by the purchaser, the center strand of each conductor shall be indented with the manufacturer's name and year of manufacture. This information is to be marked at regular intervals with no more than 12 inches (305 mm) between repetitions.

8.2.4 Optional Sequential Length Marking

When sequential length marking is requested by the purchaser, the information is to be marked at regular intervals of 2 feet (610 mm).

Table 8-1
Nominal Insulation Thickness

Rated Circuit Voltage, Phase-to-Phase Voltage	Conductor Size, AWG or kcmil (mm^2)	Nominal Insulation Thickness (mils)	
		100 Percent Level	133 Percent Level
2001-5000	8-1000 (8.37-507)	90	115
	1001-3000 (507-1520)	140	140
5001-8000	6-1000 (13.3-507)	115	140
	1001-3000 (507-1520)	175	175
8001-15000	2-1000 (33.6-507)	175	220
	1001-3000 (507-1520)	220	220
15001-25000	1-3000 (42.4-1520)	260	320
25001-28000	1-3000 (42.4-1520)	280	345
28001-35000	1/0-3000 (53.5-1520)	345	420
35001-46000	4/0-3000 (107-1520)	445	580

Part 9
TESTING AND TEST METHODS

9.1 TESTING

All cables shall be tested at the factory to determine their compliance with the requirements given in Parts 2, 3, 4, 5, 6, and 7. When there is a conflict between the test methods given in Part 9 and publications of other organizations to which reference is made, the requirements given in Part 9 shall apply.

The tests in Part 9 may not be applicable to all materials or cables. To determine which tests are to be made, refer to the parts in this publication that set forth the requirements to be met by the particular material or cable.

9.2 SAMPLING FREQUENCY

Sampling frequency shall be as indicated in Table 9-5 "Summary of Production Tests and Sampling Frequency Requirements".

9.3 CONDUCTOR TEST METHODS

9.3.1 Method for DC Resistance Determination

Measurements shall be made on the entire length of completed cable.

Except as noted above, this test shall be performed in accordance with ICEA T-27-581/NEMA WC-53.

9.3.2 Cross-Sectional Area Determination

Cross-Sectional area shall be determined in accordance with ICEA T-27-581/NEMA WC-53.

9.3.3 Diameter Determination

Diameter shall be determined in accordance with ICEA T-27-581/NEMA WC-53.

9.4 TEST SAMPLES AND SPECIMENS FOR PHYSICAL AND AGING TESTS

9.4.1 General

Physical and aging tests shall be those required by Parts 3, 4, 5, and 7.

9.4.2 Measurement of Thickness

The measurement of thickness for components having no minimum removability tension requirements shall be made with either a micrometer or an optical measuring device. For all other extruded components, the measurement of thickness shall be made only with an optical measuring device. The micrometer and optical measuring device shall be capable of making measurements accurate to at least 0.001 inch (0.025 mm).

9.4.2.1 Micrometer Measurements

When a micrometer measuring device is used, the component shall be removed and the minimum and maximum thickness determined.

9.4.2.2 Optical Measuring Device Measurements

When an optical measuring device is used, the maximum and minimum thickness shall be determined from a specimen cut perpendicular to the axis of the sample so as to expose the full cross-section.

9.4.3 Number of Test Specimens

From each of the samples selected, test specimens shall be prepared in accordance with Table 9-1.

Table 9-1
Test Specimens for Physical and Aging Tests

	Total Number of Test Specimens
For determination of unaged properties	
Tensile strength and ultimate elongation	3†
Permanent set	3†
For accelerated aging tests	3†
For oil immersion	3†
Heat shock	1
Heat distortion	3†
Cold bend	1
Stripping	1

†One test specimen out of three shall be tested and the other two specimens held in reserve, except that when only one sample is selected, then all three test specimens shall be tested and the average of the results reported.

9.4.4 Size of Specimens

The test specimens shall be prepared using either ASTM D 412 Die B, E, C or D.

In the case of wire and cable smaller than size 6 AWG having an insulation thickness of 90 mils (2.29 mm) or less, the test specimen shall be permitted to 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 size 6 AWG and larger, or in the case of wire and cable smaller than size 6 AWG having an insulation thickness greater than 90 mils (2.29 mm), specimens rectangular in section with a cross-section not greater than 0.025 square inch (16 mm^2) shall be cut from the insulation. In extreme cases, it may be necessary to use a segmental specimen.

Specimens for test on jacket compounds shall be taken from the completed cable and cut parallel to the axis of the cable. The test specimen shall be a segment cut with a sharp knife or a shaped specimen cut out with a die and shall have a cross-sectional area not greater than 0.025 square inch (16 mm^2) after irregularities, corrugations, and wires have been removed.

9.4.5 Preparation of Specimens of Insulation and Jacket

The test specimen shall have no surface incisions and shall be as free as possible from other imperfections. Where necessary, surface irregularities such as corrugations due to stranding shall be removed so that the test specimen will be smooth and of uniform thickness. If a jacket specimen passes the minimum requirement with irregularities, then their removal is not required.

9.4.6 Specimen for Aging Test

Specimens shall not be heated, immersed in water, nor subjected to any mechanical or chemical treatment not specifically described in this Standard.

9.4.7 Calculation of Area of Test Specimens

9.4.7.1 Where the total cross-section of the insulation is used, the area shall be taken as the difference between the area of the circle whose diameter is the average outside diameter of the insulation and the area of the circle whose diameter is the average outside diameter of the conductor shield.

9.4.7.2 Where a slice cut from the insulation by a knife held tangent to the wire is used and when the cross-section of the slice is a segment of a circle, the area shall be calculated as that of the segment of a circle whose diameter is that of the insulation. The height of the segment is the wall of insulation on the side from which the slice is taken.

When the cross-section of the slice is not a segment of a circle, the area shall be calculated 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.

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.

9.4.7.3 When the conductor is large and the insulation thin and when a portion of a sector of a circle has to be taken, the area shall be calculated as the thickness times the width.

This applies either to a straight test piece or to one stamped out with a die and assumes that corrugations have been removed.

9.4.7.4 When the conductor is large and the insulation thick and when a portion of a sector of a circle has to be taken, the area shall be calculated as the proportional part of the area of the total cross-section.

9.4.7.5 The dimensions of specimens to be aged shall be determined before the aging test.

9.4.8 Unaged Test Procedures

9.4.8.1 Test Temperature

Physical tests shall be made at room temperature. The test specimens shall be kept at room temperature for not less than 30 minutes prior to the test.

9.4.8.2 Type of Testing Machine

The testing machine shall be in accordance with ASTM D 412.

9.4.8.3 Tensile Strength Test

The tensile strength test shall be made with specimens prepared in accordance with 9.4.3 and 9.4.4. The length of all of the specimens for the test shall be equal. Gauge marks shall be 2 inches (50.8 mm) apart when using ASTM B or E Die size and 1 inch (25.4 mm) apart when using ASTM C or D Die size except that 1 inch (25.4 mm) gauge marks shall be used for polyethylene regardless of the die size. Specimens shall be placed in the jaws of the testing machine with a maximum distance between jaws of 4 inches (101.6 mm) except 2.5 inches (63.5 mm) for polyethylene. The specimen shall be stretched at the rate of 20 inches (508 mm) per minute jaw speed until it breaks.

The tensile and elongation determinations for compounds for which the compound manufacturer certifies that the base resin content is more than 50 percent by weight of high density polyethylene (having a density of 0.926 g/cm^3 or greater), or total base polyethylene resin content (having a density of 0.926 g/cm^3 or greater), shall be permitted to be tested at a jaw separation rate of 2 inches (51 mm) per minute as an alternate to 20 inches (508 mm) per minute.

Specimens shall break between the gauge marks to be a valid test. The tensile strength shall be calculated based on the area of the unstretched specimen. Specimen length, gauge mark distance, and jaw speed shall be recorded with the results.

9.4.8.4 Elongation Test

Elongation at rupture shall be determined simultaneously with the test for tensile strength and on the same specimen.

The elongation shall be taken as the distance between gauge marks at rupture less the original gauge length of the test specimen. The percentage of elongation at rupture is the elongation in inches divided by the original gauge length and multiplied by 100. Specimen length, gauge mark distance, and jaw speed shall be reported with results.

9.4.9 Aging Tests

9.4.9.1 Aging Test Specimens

Test specimens of similar size and shape shall be prepared from each sample selected, three for the determination of the initial or unaged properties, and three for each aging test required for the insulation or jacket being tested. Simultaneous aging of different compounds should be avoided. One specimen of each three shall be tested and the other two held as spares except that, where only one sample is selected, all three specimens shall be tested and the average of the results reported.

In the case of wire and cable 6 AWG and larger or with an insulation thickness of 90 mils (2.29 mm) or greater, samples shall be cut from the insulation with a cross-section not greater than 0.025 square inch (16 mm^2).

Die-cut specimens shall be smoothed before being subjected to the accelerated aging tests wherever the thickness of the specimen will be 90 mils (2.29 mm) or greater before smoothing.

The test specimens shall be suspended vertically in such a manner that they are not in contact with each other or with the side of the oven.

The aged specimens shall have a rest period of not less than 16 hours nor more than 96 hours between the completion of the aging tests and the determination of physical properties. Physical tests on both the aged and unaged specimens shall be made at approximately the same time.

9.4.9.2 Air Oven Test

The test specimens shall be heated at the required temperature for the specified period in an oven having forced circulation of fresh air. The oven temperature shall be controlled to ±1 °C.

9.4.9.3 Oil Immersion Test for Polyvinyl Chloride Jacket

The test specimens shall be immersed in ASTM No. 2 or IRM 902 oil, described in ASTM D 471, at 70 °C ± 1 °C for 4 hours. At the end of this time, the specimens shall be removed from the oil, blotted to remove excess oil, and allowed to rest at room temperature for a period of 16 to 96 hours. The tensile strength and elongation of the specimens shall then be determined in accordance with 9.4.8 at the same time that the original properties are determined.

9.4.10 Hot Creep Test

The hot creep test shall be determined in accordance with ICEA Publication T-28-562. The sample shall be taken from the inner 25 percent of the insulation.

9.4.11 Solvent Extraction

The solvent extraction shall be determined in accordance with ASTM D 2765.

9.4.12 Wafer Boil Test for Conductor and Insulation Shields

Any outer covering and the conductor shall be removed. A representative cross section containing the extruded conductor shield and insulation shield, shall be cut from the cable. The resulting wafer shall be at least 25 mils (0.64 mm) thick. The wafer may be further separated into concentric rings by careful separation of the shield from the insulation. This may include the use of a punch to separate the conductor shield or insulation shield from most of the insulation.

The resulting wafer(s) or rings shall then be immersed in boiling decahydronaphthalene with 1 percent by weight Antioxidant 2246 (or other reagents specified in ASTM D 2765, such as xylene) for 5 hours using the equipment specified in ASTM D 2765. (This solution may be reused for subsequent tests provided that it works as effectively as a fresh solution). The wafer(s) shall then be removed from the solvent and examined for shield/insulation interface continuity with a minimum 15-power magnification.

Total or partial separation of the semiconducting shields from the insulation is permissible. Partial loss of the shields is also permissible provided each shield is a continuous ring. If the conductor shield dissolves or cracks such that it does not maintain a continuous ring, the cable lot shall be rejected. If the insulation shield dissolves or cracks such that it does not maintain a continuous ring, the cable lot shall either be rejected by the manufacturer or a sample of insulation shield from the same lot shall be subjected to the requirements of 9.4.12.1 as a referee test.

9.4.12.1 Insulation Shield Hot Creep Properties

Hot creep and set properties shall be determined at 150 °C ± 2 °C in accordance with ICEA T-28-562 with the sample removed from the cable core. The degree of cross-linking shall be adequate to limit elongation and set to the values in Table 9-2.

Table 9-2
Insulation Shield Hot Creep Requirements

Physical Requirements	Extruded Insulation Shield
Maximum elongation	100%
Maximum set	5%

9.4.13 Amber, Agglomerate, Gel, Contaminant, Protrusion, Indent, Irregularity and Void Test

9.4.13.1 Sample Preparation

Samples shall be prepared by cutting a suitable length of cable helically or in some other convenient manner to produce 20 consecutive thin wafers consisting of the conductor shield, insulation and insulation shield. Wafers shall be approximately 25 mils (0.64 mm) thick. The cutting blade shall be sharp and shall produce wafers with uniform thickness and with very smooth surfaces. The sample shall be kept clean and shall be handled carefully to prevent surface damage and contamination.

9.4.13.2 Examination

The wafers shall be examined with 15 power magnification for voids, contaminants, gels, agglomerates, and ambers, as applicable, in the insulation. They shall also be examined for voids and protrusions between the insulation and the conductor and insulation shields and conductor shield irregularities. Unfilled insulations shall be examined using transmitted light. An optical coupling agent such as mineral oil, glycerin or silicone oil shall be used to enhance the observation of imperfections within the wafers. For mineral-filled cross-linked polyethylene insulation, EPR, and extruded shields, a reflected light method shall be used. For void count, as applicable, the volume of the insulation examined shall be calculated using any convenient technique. The results of this examination shall be recorded as pass or fail in the production test report.

9.4.13.3 Resampling for Amber, Agglomerate, Gel, Contaminant, Protrusion, Irregularity and Void Test

If after examination according to 9.4.13.2, the size and/or number (as applicable) of voids, contaminants, agglomerates, gels, ambers, irregularities or protrusions exceeds the specified limits, the lot shall be divided into shipping lengths. One sample shall be taken from the beginning and end of each shipping length. For the shipping length to pass, both samples shall meet the requirements of this section. If either of the two samples from the shipping length fails, the shipping length shall be rejected.

9.4.13.4 Protrusion, Indentation and Irregularity Measurement Procedure

To measure the size of protrusions, indentations and conductor shield irregularities in wafers examined in 9.4.13.2, the wafers shall be viewed in an optical comparator or similar device which displays the wafer so that a straight edge can be used to facilitate the measurement. Protrusion and indentations shall be measured as shown in Figure 9-1. Conductor shield irregularities shall be measured as shown in Figure 9-2. This procedure is used on cable wafers with the conductor, jacket and metallic shield removed.

Figure 9-1
Procedure to Measure Protrusions and Indentations

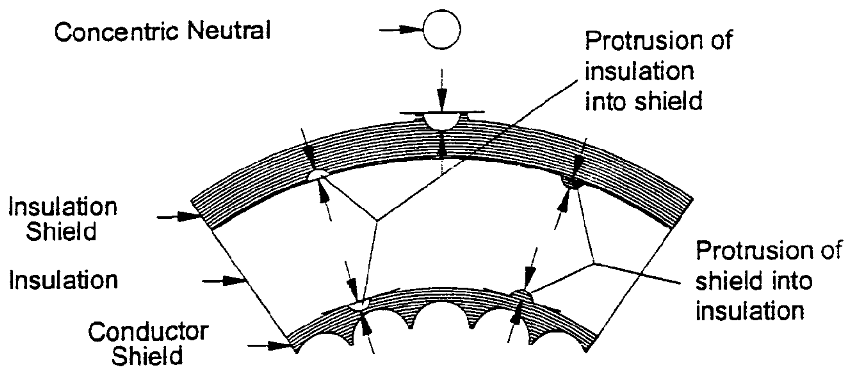
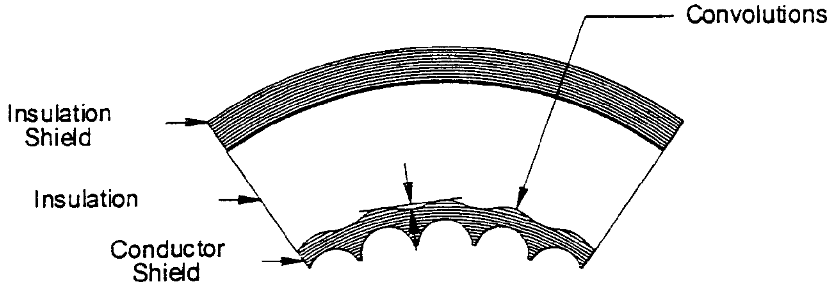


Figure 9-2
Procedure to Measure Irregularities



9.4.14 Physical Tests for Semiconducting Material Intended for Extrusion

9.4.14.1 Test Sample

One test sample shall be molded from each lot of semiconducting material intended for extrusion on the cable.

9.4.14.2 Test Specimens

For each test, three test specimens, each approximately 6 inches (152 mm) long and not greater than 0.025 square inch (16 mm^2) in cross-section, shall be cut out of the test sample with a die. All three test specimens shall be tested and the results averaged.

9.4.14.3 Elongation

This test shall be conducted in accordance with 9.4.8 and 9.4.9.

9.4.15 Retests for Physical and Aging Properties and Thickness

If any test specimen fails to meet the requirements of any test, either before or after aging, that test shall be repeated on two additional specimens taken from the same sample. Failure of either of the additional specimens shall indicate failure of the sample to conform to this Standard.

If the thickness of the insulation or of the jacket of any reel is found to be less than the specified value, that reel shall be considered as not conforming to this Standard, and a thickness measurement on each of the remaining reels shall be made.

When ten or more samples are selected from any single lot, all reels shall be considered as not conforming to this Standard if more than 10 percent of the samples fail to meet the requirements for physical and aging properties and thickness. If 10 percent or less fail, each reel shall be tested and shall be judged upon the results of such individual tests. Where the number of samples selected in any single lot is less than ten, all reels shall be considered as not conforming to this Standard if more than 20 percent of the samples fail. If 20 percent or less fail, each reel, or length shall be tested and shall be judged upon the results of such individual tests.

9.5 DIMENSIONAL MEASUREMENTS OF THE METALLIC SHIELD

Metallic shielding wire or strap shall be removed from no less than 6 inches (152 mm) of the insulated conductor. Measurements shall be made with a micrometer or other suitable instrument readable to at least 0.0001 inch (0.002 mm).

Round wires shall be measured at each end of the sample and near the middle of the sample. The average of the three measurements shall be taken as the diameter.

Flat straps shall be measured for width and thickness at each end of the sample and near the middle of the sample. The average of the three measurements for each dimension shall be taken as the width and thickness.

9.6 DIAMETER MEASUREMENT OF INSULATION AND INSULATION SHIELD

Measurement of the diameter over the insulation and the insulation shield shall be made with a diameter tape accurate to 0.01 inches (0.25 mm).

When there are questions regarding compliance to this Standard, measurements shall be made with an optical measuring device or with calipers with a resolution of 0.0005 inch (0.013 mm) and accurate to 0.001 inch (0.025 mm). At any given cross-section, the maximum diameter, minimum diameter, and two additional diameters which bisect the two angles formed by the maximum and minimum diameters shall be measured. The diameter for the cross-section shall be the average of the four values. This average diameter value shall be used to determine if the cable meets the minimum and maximum limits given in Appendix C. All diameter measurements shall be made on cable samples that contain the conductor.

9.7 TESTS FOR JACKETS

9.7.1 Heat Shock

Samples of polyvinyl chloride jacketed cable shall be wound tightly around a mandrel having a diameter in accordance with Table 9-3, held firmly in place, and subjected to a temperature of 121 °C ± 1 °C for 1 hour. At the end of the test period, the sample shall be examined without magnification.

Table 9-3
Bending Requirements for Heat Shock Test

Outside Diameter of Wire or Cable		Number of Adjacent Turns	Diameter of Mandrel as a Multiple of the Outside Diameter of Cable
Inches	mm		
0-0.750	0-19.05	6	3
0.751-1.500	19.08-38.10	180-degree bend	8
1.501 and larger	38.13 and larger	180-degree bend	12

9.7.2 Heat Distortion

Heat distortion testing shall be performed in accordance with ICEA T-27-581/NEMA WC-53.

9.7.3 Cold Bend

Cold bend testing shall be performed in accordance with ICEA T-27-581/NEMA WC-53. The mandrel shall have a diameter in accordance with the following table:

Table 9-4
Bending Requirements for Cold Bend Test

Outside Diameter of Wire or Cable		Diameter of Mandrel as a Multiple of the Outside Diameter of Cable
Inches	mm	
0-0.800	0-20.32	8
0.801 and larger	20.32 and larger	10

9.8 VOLUME RESISTIVITY

9.8.1 Conductor Shield (Stress Control)

The samples shall be cut in half longitudinally and the conductor removed. Four silver-painted electrodes shall be applied to the conductor stress control layer. The two potential electrodes shall be at least 2 inches (50.8 mm) apart. A current electrode shall be placed at least 1 inch (25.4 mm) beyond each potential electrode. When a high degree of accuracy is not required, this test may be made with only two electrodes spaced at least 2 inches (50.8 mm) apart.

The power of the test circuit shall not exceed 100 milliwatts. The test shall be made at the specified temperature with either ac or dc voltage.

The volume resistivity shall be calculated as follows:

$$\rho = \frac{R(D^2 - d^2)}{100L}$$

Where:
ρ = Volume resistivity in ohm-meters.
R = Measured resistance in ohms.
D = Diameter over the conductor stress control layer in inches.
d = Diameter over the conductor in inches.
L = Distance between potential electrodes in inches.

9.8.2 Insulation Shield

Four annular-ring electrodes shall be applied to the surface of the insulation shield layer. The two potential electrodes shall be at least 2 inches (50.8 mm) apart. A current electrode shall be placed at least 1 inch (25.4 mm) beyond each potential electrode. When a high degree of accuracy is not required, this test may be made with only two electrodes spaced at least 2 inches (50.8 mm) apart.

The power of the test circuit shall not exceed 100 milliwatts. The test shall be made at the specified temperature with either ac or dc voltage.

The volume resistivity shall be calculated as follows:

$$\rho = \frac{2R(D^2 - d^2)}{100L}$$

Where:
ρ = Volume resistivity in ohm-meters.
R = Measured resistance in ohms.
D = Diameter over the insulation shield layer in inches.
d = Diameter over the insulation in inches.
L = Distance between potential electrodes in inches.

9.8.3 Semiconducting Jacket Radial Resistivity Test

This procedure is designed for testing short samples of cable having semiconducting jackets in contact with concentric wire neutrals.

The resistance of the jacket is obtained from measuring the voltage drop across the sample at room temperature. This is created by passing a constant dc or 60 Hz ac current through the sample in a radial direction. The apparent resistivity of the jacket is calculated from the electrical measurement and geometry of the cable.

9.8.3.1 Sample Preparation

A sample of cable at least 6 inches (152 mm) long will be prepared as shown in Figure 9-3. The concentric wires form one measuring electrode and a 2-inch (50 mm) band of conducting paint covering the surface of the jacket provides the second measuring electrode. Two separate bands of conducting paint 1/2 inch (13 mm) wide and covering the surface of the jacket form the guard electrodes. The bands are separated approximately 1/8 inch (3.2 mm) from the measuring electrode.