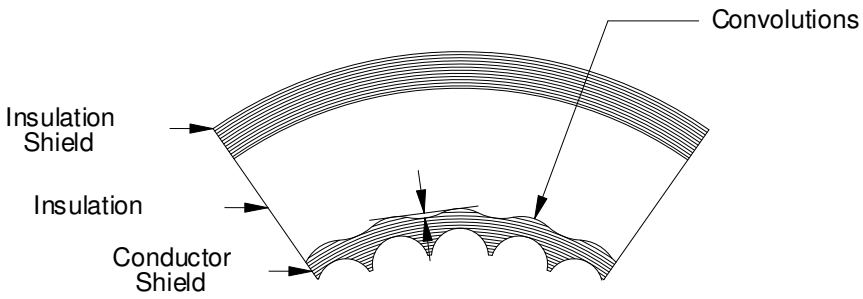

Figure 9-2
Procedure to Measure Irregularities

9.4.13.2Method B

9.4.13.2.1 Sample Preparation

A 13-inch (330-mm) long sample will be obtained and cut into a 12-inch (305-mm) specimen and a 1-inch (25-mm) specimen. This test shall be conducted on a 12-inch (305-mm) long specimen cut into two, 6-inch (152-mm) or three, 4-inch (102-mm) samples. If present, all outer layers shall be removed from the samples to the cable core. The ends shall be cut smooth to ensure transparency, and the conductor pressed out of the samples prior to heating cable core. The insulation shall be made transparent by heating the samples to approximately 120°C. The preferred method is to place the samples into an oil bath at a maximum temperature of 120°C until the insulation becomes transparent. If an oil bath is not used, the samples shall be wetted with an optical coupling fluid such as silicone oil to enhance the viewing procedure.

The samples shall then be viewed for semiconducting shield smoothness (conductor and insulation shield) and for contaminants. A flat glass surface or magnifying glass may be part of the viewing path. Curved glass surfaces such as the wall of a beaker are not recommended because they can impede the detection of irregularities. A magnification of 1 to 10-power is appropriate. A high-intensity light shall be directed at the cable end to enhance the detection of irregularities. Further enhancement may be accomplished with a dark background or a darkened room. Digital pictures shall be taken to document the inspection of these samples.

Care shall be used in making the insulation transparent to prevent overheating which may deform the cable core or create conditions, which did not already exist such as voids, protrusions, and cracks. This test method is not recommended for the detection of voids in the insulation.

9.4.13.2.2 Detection of Irregularities

Contaminants in the insulation and protrusions or deformations at the semiconducting shields shall be marked. Wafers containing these irregularities shall be cut from the sample and viewed according to 9.4.13.1. To calculate the number of contaminants per in^3 (cm^3), the volume of insulation contained in the 6-inch (152-mm) or 4-inch (102-mm) sample shall be used. The irregularities shall not exceed the specified limits. The results of this examination shall be recorded in the production test report. If voids are observed during the examination, the unheated 1-inch sample will be tested in accordance with 9.4.13.1 to determine if voids are actually present and the quantity and size of the voids.

9.4.13.2.3Resampling for Internal Irregularity Test

If the irregularity limits are exceeded in a sample from a shipping length, the shipping length shall be divided into shipping reels. One specimen shall be taken from the beginning and end of each shipping reel. For the shipping reel to pass, all samples shall meet the requirements of this section. If one of the four samples (or six samples) from the shipping reel fails, the shipping reel shall be rejected.

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

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.

9.4.16 Retests for Thickness

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

9.5.1 Tape Shield

Metallic shielding tape shall be removed from no less than 6 inches (152 mm) of the insulated conductor, except for corrugated tape shields where measurements shall be made on tape prior to corrugating and application to cable core. Measurements shall be made with a micrometer readable to at least 0.0001 inch (0.002 mm) having a presser foot 0.25 ± 0.01 inch (6.35 ± 0.25 mm) in diameter and exerting a total force of 3.0 ± 0.1 ounces (85 ± 3 grams), the load being applied by means of a weight. Five readings shall be taken at different points on the sample, and the average of these readings shall be taken as the thickness of the tape.

9.5.2 Wire Shield

All metallic shielding wires 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). The diameter of all wires taken from the 6-inch specimen shall be measured.

9.5.3 Sheath

The thickness of the sheath shall be determined by measurements made with a micrometer caliper having a rounded anvil or 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). The measurements shall be made directly on the sheath removed from the cable.

9.5.4 Flat Straps

Metallic shielding straps 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). All straps taken from 6-inch (152-mm) specimen shall be measured for 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).

If greater accuracy is desired, 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. All diameter measurements shall be made on cable samples that contain the conductor.

9.7 TESTS FOR JACKETS

9.7.1 Heat Shock (PVC only)

9.7.1.1 Preparation of Test Specimen

For jackets with a wall thickness not exceeding 200 mils (5.0 mm), each test specimen shall consist of a strip taken from the jacket, whose width shall be at least 1.5 times its thickness but not less than 160 mils (4.0 mm); the strip shall be cut in the direction of the axis of the cable.

For jackets with a wall thickness exceeding 200 mils (5.0 mm), each test specimen shall consist of a strip taken from the jacket, whose width shall be at least 1.5 times its thickness but not less than 160 mils (4.0 mm) and then ground or cut (avoiding heating) on the outer surface, to a thickness between 160 mils (4.0 mm) and 200 mils (5.0 mm). This thickness shall be measured on the thicker part of the strip, whose width shall be at least 1.5 times the thickness.

9.7.1.2 Winding of the Test Specimen on Mandrels

Each test specimen shall be tightly wound and fixed at ambient temperature on a mandrel to form a close helix. The diameter of the mandrel and the number of turns are given in Table 9-2.

Table 9-2
Bending Requirements for Heat Shock Test

Thickness of Test Specimen		Number of Adjacent Turns	Diameter of Mandrel Inches (mm)
Inches	mm		
0 - 0.039	0 - 1	6	0.079 (2)
0.040 - 0.079	1.01 - 2	6	0.157 (4)
0.080 - 0.118	2.03 - 3	6	0.236 (6)
0.119 - 0.157	3.02 - 4	4	0.315 (8)
0.158 – 0.200	4.01 - 5	2	0.394 (10)

9.7.1.3 Heating and Examination

Each test specimen, on its mandrel, shall be placed in an air oven pre-heated to a temperature of 121 ±1°C. The test specimen shall be maintained at the specified temperature for 1 hour. At the end of the test period, the sample shall be examined without magnification.

9.7.2 Heat Distortion

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

9.7.3 Cold Elongation (PVC and LSHF only)

9.7.3.1 Test Temperature

Physical tests shall be made at –35°C for PVC or –25°C for LSHF. Test samples shall be conditioned at the test temperature for 1 hour prior to performing the tensile pull.

9.7.3.2 Type of Testing Machine

The testing machine shall be in accordance with ASTM D412 and equipped with a cooling device or installed in a cooling chamber. The test area (grips, chamber, extensometer) shall be conditioned at the test temperature for a minimum of 3 hours to ensure stability of the test environment. As an alternate, the samples may be removed from a cold chamber and tested within 15 seconds on a testing machine at room temperature.

9.7.3.3 Elongation Test

The number of elongation specimens shall be in accordance with 9.4.3. The length of all of the specimens for the test shall be equal. The test specimens shall be prepared using an ASTM D412 Die D and the gauge marks shall be 1 inch (25 mm) apart. Specimens 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. The wall thickness of the specimen after irregularities, corrugations, and wires have been removed shall not exceed 80 mils (2.0 mm) and not less than 30 mils (0.76 mm). Specimens can be ground or cut to meet thickness requirements. Specimens shall be left at ambient temperature after cutting or grinding for at least 16 hours before die cutting.

Specimens shall be placed in the jaws of the testing machine with a maximum distance between jaws of 4 inches (101.6 mm). The specimen shall be stretched at the rate of 2 inches (51 mm) per minute jaw speed until it breaks.

Specimens shall break between the gauge marks to be a valid test. 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, elongation measurement system, and jaw speed shall be reported with results.

9.8 VOLUME RESISTIVITY

9.8.1 Conductor Shield

The samples shall be cut in half longitudinally and the conductor removed. Four silver-painted electrodes shall be applied to the conductor shield. The two potential electrodes (inner) shall be at least 2 inches (51 mm) apart. A current electrode shall be placed at least 1 inch (25 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 (51 mm) apart.

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 and Semiconducting Extruded Jacket Coating

Four annular-ring electrodes shall be applied to the surface of the insulation shield layer or extruded jacket coating. The two potential electrodes (inner) shall be at least 2 inches (51 mm) apart. A current electrode shall be placed at least 1 inch (25 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 (51 mm) apart.

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 or semiconducting extruded jacket coating layer in inches.
d = Diameter over the insulation or over the nonconducting jacket in inches.
L = Distance between potential electrodes in inches.

9.8.3 Test Equipment

A suitable instrument (e.g., Wheatstone, Kelvin Bridge or Ohmmeter) or instruments (e.g., voltmeter and ammeter) shall be utilized for determining resistance and provide a source of 49 - 61 Hz ac or dc voltage. The energy released in the conducting component shall not exceed 100 milli-watts.

A convection-type forced-draft, circulating air oven, shall be utilized capable of maintaining any constant (± 1°C) temperature up to 140°C, e.g., Hot Pack Model 1204-14, Blue M Model OV-490, or Precision Type A.

9.8.4 Test Procedure

For the four-electrode method, connect the two outer electrodes (current) in series with the current source and an ammeter or the current leads of a bridge. Connect the two inner electrodes (potential) to potentiometer leads of a bridge or to a voltmeter. A dc or 49 - 61 Hz ac source can be used.

For the two-electrode method, connect the electrodes to an ohmmeter.

The resistance of the conducting component between the electrodes shall be determined at the specified temperature.

9.9 SHRINKBACK TEST PROCEDURE

9.9.1 Sample Preparation

Five samples, each 1.5 feet (0.45 m) long are required for the test. A length of the specimen cable 17.5 feet (5.25 m) long shall be laid out and straightened. The sample shall be marked at a point 5.0 feet (1.5 m) from one end and then marked at 1.5-foot (0.45-m) intervals for a distance of 7.5 feet (2.25 m). The cable shall be cut using a fine tooth saw at the 1.5-foot (0.45-m) intervals marked on the sample. The two 5.0-foot (1.5-m) end pieces from the original cable length are to be discarded.

9.9.2 Test Procedure

The five 1.5-foot (0.45-m) long cable samples shall be placed in a forced air convection oven at a temperature of 50 ±1°C for a period of 2-hours. After the 2-hour period, the samples shall be removed from the oven and allowed to cool for 2 hours at room temperature. The heating and cooling cycle shall be performed three times, if required.

At the end of each cooling period, the samples shall be measured for shrinkback using a micrometer, or preferably an optical measuring device. The selected measuring device shall have a minimum resolution of 0.001 inch (0.025 mm).

One reading shall be made from each end of each sample between the end of the conductor and the edge of the conductor shield interface at the point of circumference of the conductor where shrinkback is maximum.

9.9.3 Pass/Fail Criteria and Procedure

The measured values shall be in accordance with Table 4-8 of Part 4. Only the sample with the most shrinkback of the five shall be considered using the total shrinkback of both ends.

9.10 RETESTS ON SAMPLES

If all of the samples pass the applicable tests described in 9.4 through 9.9 and 9.13, the lot of cable that they represent shall be considered as meeting the requirements of this standard. Retests already detailed in this standard are:

For dc resistance retests	See 9.3.1.1
For physical and aging properties retests	See 9.4.15
For thickness retests	See 9.4.16
For Amber, Agglomerate, Gel, Contaminant, Protrusion, Irregularity and Void Test	See 9.4.13.1.3

For Internal Irregularity retests See 9.4.13.2.3

For all other tests, if any sample fails to pass, the length of cable from which the sample was taken shall be considered as not meeting the requirements of this standard and another sample shall be taken from each of the two other lengths of the cable in the lot of cable under test. If either of the second samples fails to pass the test, the lot of cable shall be considered as not meeting the requirements of this standard. If both such second samples pass the test, the lot of cable (except the length represented by the first sample), shall be considered as meeting the requirements of this standard.

Failure of any sample shall not preclude resampling and retesting the length of cable from which the original sample was taken.

9.11 AC VOLTAGE TEST

9.11.1 General

These tests consist of voltage tests on each shipping length of cable. The voltage shall be applied between the conductor and the metallic shield with the metallic shield grounded. The rate of increase from the initially applied voltage to the specified test voltage shall be approximately uniform and shall be not more than 100 percent in 10 seconds nor less than 100 percent in 60 seconds.

9.11.2 AC Voltage Test

This test shall be made with an alternating potential from a transformer and generator of ample capacity but in no case less than 5 kVA. The frequency of the test voltage shall be nominally between 49 and 61 Hz and shall have a wave shape approximating a sine wave as closely as possible.

The initially applied ac test voltage shall be not greater than the rated ac voltage of the cable under test.

9.12 PARTIAL-DISCHARGE TEST PROCEDURE

Partial-discharge test shall be performed in accordance with ANSI/ICEA T-24-380 except that each length tested shall be calibrated prior to being tested. An effective de-gassing procedure shall be used such as temperature conditioning. The manufacturer shall specify the de-gassing conditions. See Appendix J for de-gassing guidelines.

9.13 DISSIPATION FACTOR AND CAPACITANCE MEASUREMENT

After completion of the partial discharge test, when required (see Table 9-3), the shipping length of cable shall have the dissipation factor and capacitance measured. The measurement will be performed at V_g and at ambient temperature. The dissipation factor shall meet the requirements of Part 4 and the capacitance will be recorded for engineering information.

9.14 METHOD FOR DETERMINING DIELECTRIC CONSTANT AND DIELECTRIC STRENGTH OF EXTRUDED NONCONDUCTING POLYMERIC STRESS CONTROL LAYERS

Determination of dielectric constant and dielectric strength shall be performed in accordance with ANSI/NEMA WC 53/ICEA T-27-581.

9.15 WATER CONTENT

Each end of each shipping length shall be examined for water under the jacket (if the cable is jacketed) and for water in the conductor (if cable does not have a sealant and is stranded).

9.15.1 Water Under the Jacket

If the cable is jacketed, 6 inches (152 mm) of the jacket shall be removed and the area under the jacket shall be visually examined for the presence of water. If water is present, or there is an indication that it was in contact with water, effective steps shall be taken to assure that the water is removed or that the length of cable containing water under the jacket is discarded.

9.15.2 Water in the Conductor

If the cable has an unsealed, stranded conductor, 6 inches (152 mm) of the conductor shall be exposed on each end. The strands shall be individually separated and visually examined. If water is present, the conductor shall be subjected to 9.15.4.

9.15.3 Water Expulsion Procedure

A suitable method of expelling water from the strands shall be used until the cable passes the Presence of Water Test. As soon as possible after the procedure, both ends of the cable shall be sealed to prevent the ingress of water during shipment and storage.

9.15.4 Presence of Water Test

To verify the presence of water in the conductor, the following steps shall be taken.

Each length of cable to be tested shall be sealed at one end over the insulation shield using a rubber cap filled with anhydrous calcium sulphate granules. The rubber cap shall be fitted with a valve.

Dry nitrogen gas or dry air shall be applied at the other end until the pressure is 15 psi (100 kPa) gauge. The valve on the rubber cap shall then be opened sufficiently to hear a flow of gas.

After 15 minutes, a check of the change of color of the granules in the rubber cap shall be made.

If the color has not completely changed to pink after 15 minutes, it is an indication that a tolerable amount of moisture is present in the strands. In the case of complete change in color of all granules, the water shall be expelled from the conductor per 9.15.3.

This procedure shall be repeated after placing new granules in the cap.

9.16 ADHESION TEST FOR METALLIC FOIL LAMINATES

9.16.1 Visual Inspection

The cable shall be dissected and visually examined. Examination of the samples with normal or corrected vision without magnification shall reveal no cracks or separation of the metallic foil laminate or damage to other parts of the cable.

9.16.2 Adhesion Strength of Metallic Foil Laminate

The test specimen shall be taken from the cable covering where the metallic foil laminate is adhered to the jacket. The length and width of the test specimen shall be 8 inches (203 mm) and between 0.375 inches (9.5 mm) to 1 inch (25 mm) respectively. One end of the test specimen shall be peeled nominally 1 inch and inserted in a tensile testing machine by clamping the free end of the jacket in one grip. The free end of the metallic foil laminate shall be turned back and clamped in the other grip as shown in Figure 9-3.

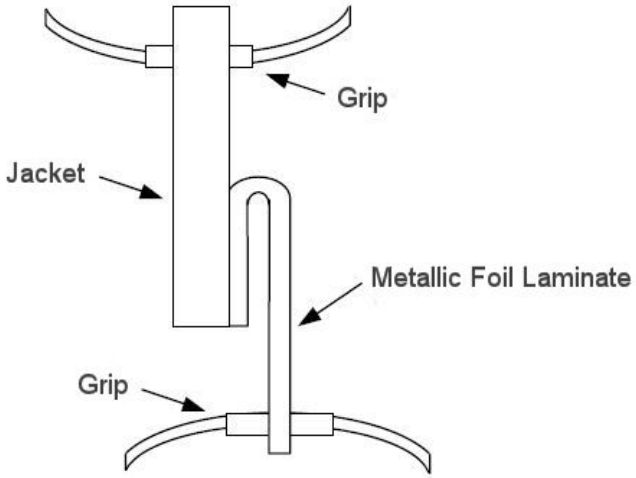

Figure 9-3
Adhesion of Metallic Foil Laminate
(Not to scale)

The specimen shall be maintained approximately vertical in the plane of the grips during the test by holding the specimen. After adjusting the continuous recording device, the separating member shall be stripped from the specimen at an angle of approximately 180° and the separation continued for a sufficient distance to indicate the adhesion strength value. At least one half of the remaining bonded area shall be peeled with a speed of approximately 2 inch/min (51 mm/min).

The adhesion strength shall then be calculated by dividing the peel force, in pounds, by the width of the specimen, in inches.

NOTE: When the adhesion strength is greater than the tensile strength of the metal foil so that the latter breaks before peeling, the test should be terminated and the break point recorded.

9.16.3 Adhesion Strength of Overlap of Metallic Foil Laminate

A sample specimen 8 inches (203 mm) in length shall be taken from the cable including the overlapped portion of the metal foil. The test specimen shall be prepared by cutting only the overlapped portion from this sample as shown in Figure 9-4.

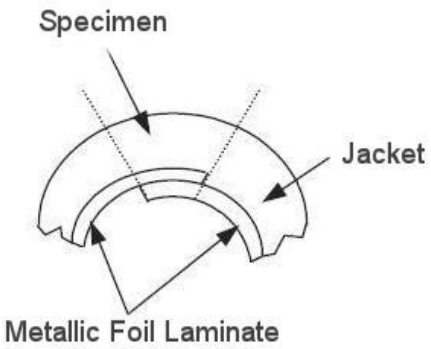

Figure 9-4
Example of overlapped metal foil
(Not to scale)

The test shall be conducted in the same manner as described in 9.16.2. The arrangement of the test specimen is shown in Figure 9-5.

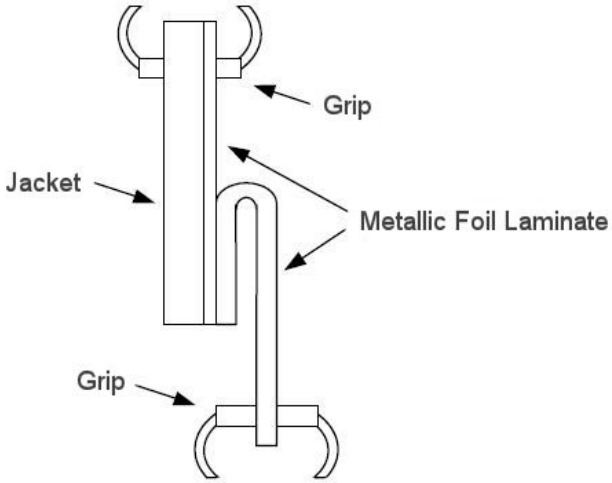

Figure 9-5
Peel strength of overlapped metal foil
(Not to scale)

9.17 PRODUCTION TEST SAMPLING PLANS

Table 9-3
Summary of Production Tests and Sampling Frequency Requirements

TEST	STANDARD REFERENCE	TEST METHOD REFERENCE	MINIMUM FREQUENCY
Conductor			
dc Resistance	Part 2	9.3.1 and ICEA T-27-581	100%
Diameter	Part 2	ICEA T-27-581	Plan A
Segmental Conductor Eccentricity	Part 2	2.1.3.1	Plan C
Temper	Part 2	ASTM	Manufacturer certification that required values are met
Non-Metallic Conductor Shield			
Elongation After Aging	Part 3	9.4.14	Plan H
Volume Resistivity	Part 3	9.8.1	Plan H
Thickness	Part 3	9.4.2	Plan E
Voids, Protrusions and Irregularities	Part 3	9.4.13	Plan A
Wafer Boil	Part 3	9.4.12	Plan B
Spark Test (Non-conducting Layer Only)	Part 3	ICEA T-27-581	100%
Insulation			
Unaged and Aged Tensile and Elongation	Part 4	9.4.8 and 9.4.9	Plan C
Hot Creep	Part 4	ICEA T-28-562	Plan B
Voids and Contaminants	Part 4	9.4.13	Plan A
Diameter	Appendix C	9.6	Plan A
Shrinkback Test (XLPE Only)	Part 4	9.9	Plan C
Thickness and Eccentricity	Part 4	9.4.2	Plan E
Non-Metallic Insulation Shield			
Elongation After Aging	Part 5	9.4.14	Plan H
Volume Resistivity	Part 5	9.8.2	Plan H
Thickness	Part 5	9.4.2	Plan E
Voids and Protrusions	Part 5	9.4.13	Plan A
Wafer Boil	Part 5	9.4.12	Plan B
Diameter	Appendix C	9.6	Plan A