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, Convolution 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 convolutions. 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, Convolutions 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, convolutions 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 Convolutions Measurement Procedure

To measure the size of protrusions, indentations and conductor shield convolutions 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 convolutions 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

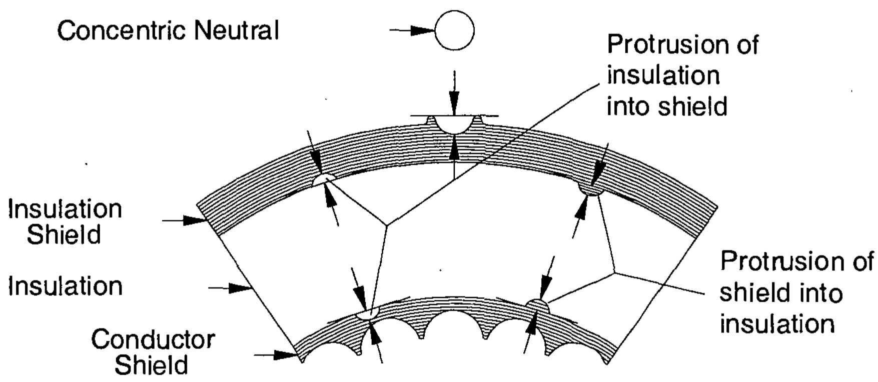
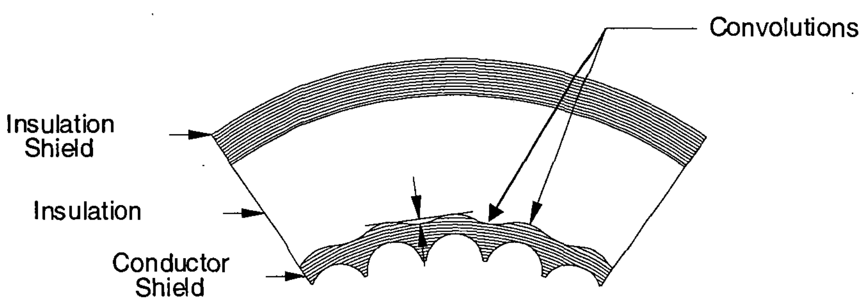


Figure 9-2
Procedure to Measure Convolutions



9.4.14 Internal Irregularity Test Procedure for Crosslinked Polyethylene Insulation (XLPE or TRXLPE) Only

9.4.14.1 Sample Preparation

This test is conducted on a 24-inch (610-mm) long sample cut into convenient lengths for the test apparatus. The insulation shield shall be removed. 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 conductor shield smoothness 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.

Care shall be used in making the insulation transparent to prevent overheating which may deform the cable 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.

9.4.14.2 Detection of Irregularities

Contaminants in the insulation and protrusions or deformations at the conductor shield shall be marked on the insulation surface. Wafers containing these irregularities shall be cut from the sample and viewed according to 9.4.13. To calculate the number of contaminants per in^3 (cm^3), the volume of insulation contained in the 24-inch (610-mm) sample is used. The irregularities shall not exceed the specified limits. The results of this examination shall be recorded in the production test report.

9.4.14.3 Resampling for Internal Irregularity Test

If the irregularity limits are exceeded, a second 24-inch (610-mm) long sample shall be taken from an adjacent length of cable in the same master length as the first sample. If this sample fails, the master length 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 one of the two samples from the shipping length fails, the shipping length shall be rejected.

9.4.15 Physical Tests for Semiconducting Material Intended for Extrusion

9.4.15.1 Test Sample

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

9.4.15.2 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.

9.4.15.3 Elongation

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

9.4.16 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

All metallic shielding wires or 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 round wires taken from the 6 inch specimen 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. The minimum measured individual wire diameter and the averaged measured total wire diameter shall be reported in the production test report.

All flat straps taken from the 6 inch specimen 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. The minimum measured individual strap width and thickness and the averaged measured total strap width and thickness shall be reported in the production test report.

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. Two silver-painted electrodes shall be applied to the conductor shield spaced at least 2 inches (50.8 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

Two silver-painted electrodes shall be applied to the insulation shield spaced at least 2 inches (50.8 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 layer in inches.
d = Diameter over the insulation 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 60 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

9.8.4.1 Two-electrode Method

Connect the electrodes to an ohmmeter.

9.8.4.2 Four-electrode Method

The four-electrode method may be used as a referee method.

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 (50.8 mm) apart. A current electrode shall be placed at least 1 inch (25.4 mm) beyond each potential electrode.

Insulation shield: Four annular-ring electrodes shall be applied to the surface of the insulation shield layer. The two potential electrodes (inner) 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.

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 60 Hz ac source can be used.

9.8.4.3 Measurement

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

9.8.5 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.

9.8.5.1 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.

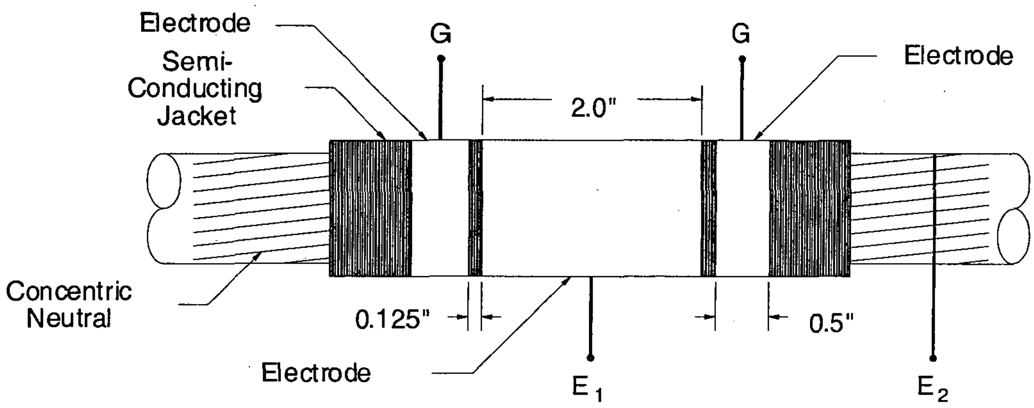


Figure 9-3
Sample Preparation for Radial Resistivity Measurement of Semi-conducting Jackets

Legend: E_1 - Measuring electrode, conducting paint on the surface of the jacket

E_2 - Measuring electrode, concentric neutral wires tied together

G - Guard electrode, conducting paint on the surface of the jacket

The sample shall be tested in air at room temperature.

9.8.5.2 Test Equipment Setup

The equipment needed to perform the test consists of two high input impedance (>1 megohm) voltmeters, an ammeter, an adjustable resistor and an adjustable voltage dc or 60 Hz ac power supply. The measuring circuit is connected as shown in Figure 9-4.

Adjustable resistor R_c is used to control the potential of the guard electrodes to the same value as E_1. This is done to prevent surface current from affecting the measurement. As it is adjusted, the measured voltage V_1 may go through a minimum point. The voltage V_2 and current measurements shall be made with R_c adjusted such that V_1 is as close to zero as possible.

Current density through the sample should be limited to 1mA/cm^2. Higher current density may cause inconsistency in the measurements due to heat generated in the semiconducting material.

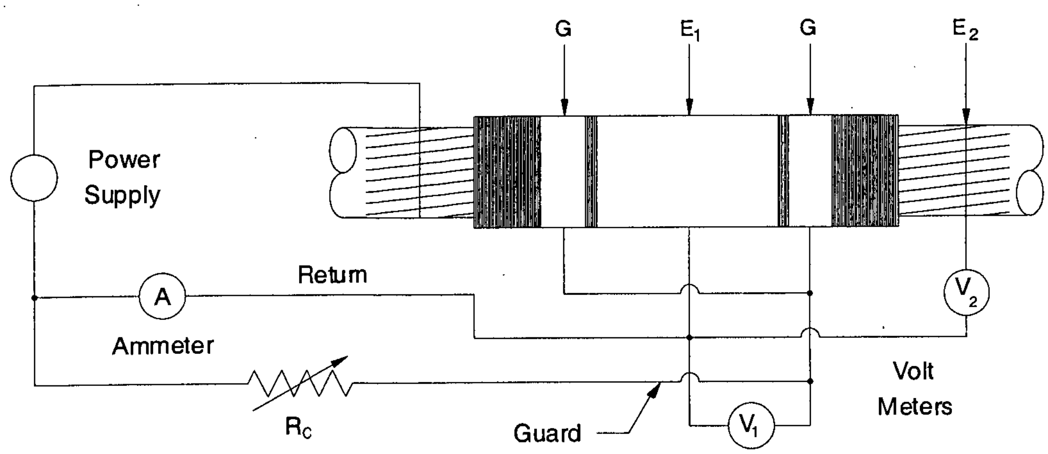


Figure 9-4
Circuit for Radial Resistivity Measurement of Semi-Conducting Jackets

Legend: E_1, E_2 and G are the same notations used in Figure 9-3.

9.8.5.3 Calculation

Calculate the resistance R of the cable jacket from the measurements of voltage (V_2) and current (I) obtained using the circuit in Figure 9-4 ($R = V_2/I$). Using the value R and the appropriate dimensions of the cable sample, calculate the apparent resistivity as follows:

$$\rho_v = \frac{R \; x \; 2\pi \; x \; L}{\ln\left(\frac{D}{d}\right)}$$

Where:

ρ_v = apparent resistivity in ohm-meters
R = calculated resistance in ohms
L = electrode length in meters
D = diameter over the semiconducting jacket in mm
d = pitch diameter* of the concentric wires in mm

* The pitch diameter d is measured from center to center of two concentric wires which are diametrically opposite from each other.

9.9 ADHESION (INSULATION SHIELD REMOVABILITY) TEST

Adhesion test shall be performed in accordance with ICEA T-27-581/NEMA WC-53 (Adhesion).

9.10 SHRINKBACK TEST PROCEDURE

9.10.1 Sample Preparation

Five samples, each 1.5 feet (0.45 m) are required for the test. A length of the specimen cable 17.5 feet (5.25 m) long is to be laid out and straightened. The sample is to 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 is to 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.

9.10.2 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 °C ±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 is to 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.

9.10.3 Pass/Fail Criteria and Procedure

The measured values shall be in accordance with Tables 4-5 or 4-6 of Part 4. Only consider the worst sample of the five using the total shrinkback of both ends.

9.11 RETESTS ON SAMPLES

Except for physical and aging properties and thickness tests	See 9.4.16
Except for Amber, Agglomerate, Gel, Contaminant, Protrusion, Indent, Irregularity and Void Test	See 9.4.13.3
Except for Internal Irregularity Test	See 9.4.14.3

If all of the samples pass the applicable tests described in 9.5 through 9.10 and 9.14, the lot of cable that they represent shall be considered as meeting the requirements of this Standard.

If any sample fails to pass these tests, 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.

9.12 AC VOLTAGE TEST

9.12.1 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.

9.12.2 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 25 and 60 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.

The duration of the ac voltage test shall be 5 minutes.

9.13 PARTIAL-DISCHARGE TEST PROCEDURE

Partial-discharge test shall be performed in accordance with ICEA Publication T-24-380. The manufacturer shall wait a minimum of 7 days after the insulation extrusion process before the tests are performed. The 7 day waiting period may be reduced by mutual agreement between the purchaser and manufacturer when effective de-gassing procedures are used. The cable shall not be subjected to any ac test (except for an in-process test not exceeding five seconds) for 7 days prior to performance of the partial discharge test.

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 ICEA T-27-581/NEMA WC-53.

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.