



**STANDARD FOR
NONSHIELDED CABLES RATED 2001-5000 V
FOR USE IN THE DISTRIBUTION OF
ELECTRICAL ENERGY**

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*Nonshielded Cables Rated 2001-5000 V
for Use in the Distribution of Electric Energy*

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Foreword

This standards publication, *Standard for Nonshielded Cables Rated 2001-5000 Volts for Use in the Distribution of Electric Energy*, was developed by the Insulated Cable Engineers Association, Inc. (ICEA) and approved by the National Electrical Manufacturers Association (NEMA).

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Contents

Foreword	i
Section 1 General	1
1.1 SCOPE	1
1.2 GENERAL INFORMATION	1
1.3 INFORMATION TO BE SUPPLIED BY PURCHASER	1
1.3.1 Characteristics of System on Which Cable Is to Be Used	1
1.3.2 Quantities and Descriptions of Cable	2
1.4 DEFINITIONS AND SYMBOLS	2
Section 2 Conductors	6
2.0 GENERAL	6
2.1 PHYSICAL AND ELECTRICAL PROPERTIES	6
2.1.1 Copper Conductors	6
2.1.2 Aluminum Conductors	6
2.2 OPTIONAL SEALANT FOR STRANDED CONDUCTORS	7
2.3 CONDUCTOR SIZE UNITS	7
2.4 CONDUCTOR DC RESISTANCE	7
2.4.1 Direct Measurement of DC Resistance	7
2.4.2 Calculation of DC Resistance	7
2.5 CONDUCTOR DIAMETER	8
Section 3 Stress Control Layer (Conductor Shield)	14
3.0 GENERAL	14
3.1 MATERIAL AND THICKNESS	14
3.2 PHYSICAL REQUIREMENTS	14
3.3 ELECTRICAL REQUIREMENTS	15
3.3.1 Extruded Semiconducting Material	15
3.3.2 Semiconducting Tape	15
3.3.3 Extruded Nonconducting Material (for EPR Insulation Only)	15
3.4 CROSSLINKED (THERMOSET) REQUIREMENTS	15
Section 4 Insulation	16
4.1 INSULATION MATERIALS	16
4.2 INSULATION LEVELS	16
4.3 INSULATION AND JACKET THICKNESSES	17
4.3.1 Three-Phase Systems With 100% or 133% Insulation Level	17
4.3.2 Delta Systems Where One Phase May Be Grounded for More Than One Hour	17
4.3.3 Single- and Two-Phase Systems With 100% And 133% Insulation Level	17
4.3.4 Direct-Current Systems	17
4.4 INSULATION REQUIREMENTS	18
4.4.1 Voltage Tests	18
4.4.2 Insulation Resistance	18
4.4.3 Other Requirements	18
Section 5 Coverings	21
5.1 JACKETS	21

5.1.1	Crosslinked and Thermoplastic Jackets.....	21
5.1.2	Neoprene, Heavy-duty Black (CR-HD).....	21
5.1.3	Neoprene, General Purpose (CR-GP)	21
5.1.4	Polyvinyl Chloride (PVC)	21
5.1.5	Low and Linear Low-density Polyethylene (LDPE & LLDPE)	21
5.1.6	Medium-density Polyethylene, Black (MDPE).....	21
5.1.7	High-density Polyethylene (HDPE).....	21
5.1.8	Nitrile-butadiene/Polyvinyl-chloride, Heavy-duty (NB/PVC-HD).....	21
5.1.9	Nitrile-butadiene/Polyvinyl-chloride, General-purpose-duty (NB/PVC-GP).....	21
5.1.10	Chlorosulfonated Polyethylene, Heavy-duty (CSPE-HD).....	22
5.1.11	Chlorinated Polyethylene, Thermoplastic (CPE-TP)	22
5.1.12	Chlorinated Polyethylene, Crosslinked, Heavy-duty (CPE-XL-HD)	22
5.1.13	Low-smoke, Halogen-free Jackets (LSHF)	22
5.1.14	Thermoplastic Elastomer (TPE)	22
5.1.15	Optional Requirements.....	22
5.1.16	Separator Under Jacket.....	22
5.1.17	Repairs	22
5.1.18	Jacket Thickness	26
5.2	METALLIC AND ASSOCIATED COVERINGS.....	27
5.2.1	General.....	27
5.2.2	Divisions	28
5.3	DIVISION I	28
5.3.1	Metallic Sheaths	28
5.3.2	Flat Steel Tape Armor	31
5.3.3	Interlocked Metal Tape Armor	32
5.3.4	Continuously Corrugated Metal Armor	33
5.3.5	Galvanized Steel Wire Armor for Submarine Cables	34
5.3.6	Bedding over Cable Cores to Be Metallic Armored.....	36
5.3.7	Outer Servings.....	37
5.3.8	Crosslinked Jackets over Metallic Sheaths and Armors	38
5.3.9	Thermoplastic Jackets over Metallic Sheaths or Armors	38
5.4	DIVISION II	39
5.4.1	Borehole Cable (Suspended at One End Only)	40
5.4.2	Dredge Cable.....	40
5.4.3	Shaft Cable	41
5.4.4	Vertical Riser Cable	41
5.5	DIVISION III	42
5.5.1	Buried Cables	42
Section 6	Assembly, Fillers, Grounding Conductors, and Identification	43
6.1	ASSEMBLY OF MULTIPLE-CONDUCTOR CABLES.....	43
6.1.1	Multiple-conductor Round Cables with an Overall Covering.....	43
6.1.2	Flat Twin Cables with Overall Covering	43
6.1.3	Multiple-conductor Cables Without an Overall Covering.....	44

6.2	FILLERS	44
6.3	GROUNDING CONDUCTORS.....	44
6.4	CONDUCTOR IDENTIFICATION.....	44
Section 7	Production Tests and Test Methods	45
7.1	TESTING AND SAMPLING FREQUENCY	45
7.2	TEST METHODS.....	45
7.3	NUMBER OF TEST SPECIMENS FROM SAMPLES	45
7.4	THICKNESS MEASUREMENTS.....	47
7.4.1	Beddings and Servings.....	47
7.4.2	Other Components	47
7.5	SAMPLES AND SPECIMENS FOR PHYSICAL AND AGING TESTS	47
7.5.1	General	47
7.5.2	Sampling.....	47
7.5.3	Size of Test Specimens.....	47
7.5.4	Specimens with Removable Jackets	48
7.5.5	Specimens with Non-removable Jackets	48
7.5.6	Specimen Surface Irregularities	48
7.5.7	Specimens for the Aging Tests.....	48
7.5.8	Calculation of Area of Test Specimens	49
7.6	TENSILE, ELONGATION AND SET TEST PROCEDURES.....	50
7.6.1	Test Specimens, Machine, and Temperature	50
7.6.2	Tensile Strength Test	50
7.6.3	Elongation Test.....	50
7.6.4	Tensile Stress Test.....	50
7.6.5	Set Test	50
7.7	AGING TESTS.....	50
7.7.1	Air Oven Aging Test	50
7.7.2	Oil Immersion Test	51
7.7.3	Hot Creep Test	51
7.8	VOLUME RESISTIVITY TEST (CONDUCTOR SHIELD)	51
7.9	COLD-BEND TEST.....	51
7.10	FLEXIBILITY TEST FOR CONTINUOUSLY CORRUGATED ARMOR	52
7.11	TIGHTNESS OF POLYETHYLENE JACKET TO SHEATH TEST.....	52
7.12	ELECTRICAL VOLTAGE TESTS ON COMPLETED CABLES.....	52
7.12.1	General	52
7.12.2	Cables Without Metallic Sheath or Metallic Armor	52
7.12.3	Cables with Metallic Sheath or Metallic Armor	53
7.13	WAFER BOIL TEST FOR CONDUCTOR SHIELDS.....	53
7.14	RETESTS	53
7.14.1	Physical and Aging Properties and Thickness	53
7.14.2	Other Tests	54
Section 8	Qualification Tests	55
8.0	GENERAL.....	55

8.1	ELECTRICAL ACCELERATED WATER ABSORPTION TEST (EM-60).....	55
8.2	INSULATION RESISTANCE TEST	55
8.3	U-BEND DISCHARGE RESISTANCE TESTS.....	55
8.3.1	Conditioning of Samples Prior to Testing	55
8.3.2	Bending Mandrel Diameters	56
8.3.3	Test Voltage and Time	56
8.4	HEAT SHOCK AND ENVIRONMENTAL TESTS	56
8.4.1	Heat Shock Test	56
8.4.2	Environmental Stress Cracking Test	56
8.4.3	Sunlight Resistance Test.....	56
8.5	TRAY CABLE FLAME TEST	57
8.6	HALOGEN CONTENT	57
8.7	SMOKE GENERATION	57
8.8	ACID GAS EQUIVALENT	57
Section 9	Constructions of Specific Types	58
9.1	PREASSEMBLED AERIAL CABLES	58
9.1.1	Scope.....	58
9.1.2	Construction.....	58
Section 10	Appendices	59
Appendix A (Normative)	.....	59
NEMA, ICEA, and ASTM Standards	.....	59
Appendix B (Normative)	.....	62
Definitions of Maximum Temperatures of Insulated Cable Conductors	.....	62
Appendix C (Informative)	.....	63
Emergency Overloads	.....	63
Appendix D (Informative)	.....	64
Abbreviations and Symbols	.....	64
Appendix E (Informative)	.....	65
Representative Tensile Strength and Elongation of Nonmagnetic Metals	.....	65
Appendix F (Informative)	.....	66
Recommended Bending Radii and Cable Installation Temperatures	.....	66
Appendix G (Informative)	.....	68
Additional Conductor Information	.....	68
Appendix H (Normative)	.....	71
Procedure for Determining Dimensional Requirements of Jackets and Associated Coverings	.....	71
Tables		
Table 2-1	Weight Increment Factors	8
Table 2-2	Schedule for Establishing Maximum Direct Current Resistance, Ω /1000 ft, of Cable Conductors Shown in Table 2-4.....	8
Table 2-3	Nominal Direct Current Resistance, R, Ω /1000 ft (Ohms per 1000 Ft) at 25°C of Solid and Stranded Conductors	9
Table 2-3	Nominal Direct Current Resistance, R, Ω /km (Ohms per Kilometer) at 25°C of Solid and Stranded Conductors (Metric)	10

Table 2-4	Nominal Diameters for Copper and Aluminum Conductors	11
Table 2-4	Nominal Diameters for Copper and Aluminum Conductors (Metric)	12
Table 2-5	Multiplier Factors for Calculating Nominal DC Resistance of Stranded Conductors, Ω/1000 ft at 25°C	13
Table 3-1	Extruded Conductor Shield Requirements	14
Table 4-1	Type Designation and Maximum Conductor Temperature	16
Table 4-2	Conductor Sizes, Insulation, and Jacket Thicknesses for Power Cables Rated 2001-5000 V, 100% and 133% Insulation Level.....	17
Table 4-2	Conductor Sizes, Insulation and Jacket Thicknesses for Power Cables Rated 2001-5000 V, 100% and 133% Insulation Level (Metric)	18
Table 4-3	Recommended Use and Limitation of Installation Locations of Nonshielded Cables Without Metallic Sheath or Armor.....	19
Table 4-4	Insulation Requirements	20
Table 5-1	Jacket Requirements	23
Table 5-1A	Halogen Free Jacket Requirements	25
Table 5-2	Thickness of Optional Jacket on Individual Conductors of Multiple-conductor Cables under a Common Jacket	26
Table 5-3	Thickness of Common Overall Jacket of Multiple-conductor Cable (for All Voltages and All Uses)	26
Table 5-4	Thickness of Lead Sheath on Unjacketed Cables.....	28
Table 5-5	Thickness of Lead Sheath for Cables Having a Crosslinked or Thermoplastic Jacket over Lead Sheath	29
Table 5-6	Thickness of Smooth Aluminum Sheath	29
Table 5-7	Width of Steel Tape for Flat Armor (Plain or Zinc-coated)	30
Table 5-8	Thickness of Steel Tape for Flat Armor (Plain or Zinc-coated)	31
Table 5-9	Width of Metal Tape for Interlocked Armor.....	31
Table 5-10	Thickness of Metal Tape for Interlocked Armor.....	32
Table 5-11	Minimum Thickness of Metal for Corrugated Armor.....	33
Table 5-12	Number of Twists (Torsion Test)	33
Table 5-13	Minimum Weights of Zinc Coating.....	34
Table 5-14	Mandrel Diameter for Adherence of Coating Tests	34
Table 5-15	Size of Galvanized Steel Armor for Submarine Cable	35
Table 5-16	Tolerances in Diameter	35
Table 5-17	Thickness of Bedding under Metallic Armor for Nonsheathed and Nonjacketed Cores	36
Table 5-18	Thickness of Servings over Metallic Sheath (Without Metallic Armor or Jacket)	37
Table 5-19	Thickness of Extruded Crosslinked Jackets and Extruded Thermoplastic Jackets over Metallic Sheaths and Armors	38
Table 5-20	Size of Galvanized Steel Armor Wire for Borehole Cable.....	39
Table 5-21	Pitch Ratio of Galvanized Wire Armor for Dredge Cable	39
Table 5-22	Size of Galvanized Steel Armor Wire for Dredge Cable	40
Table 5-23	Size of Galvanized Steel Armor Wire for Shaft Cable and Vertical Riser Cable	40
Table 5-24	Spacing and Length of Band Servings	40
Table 5-25	Thickness of Bedding and Size of Armor Wire.....	41
Table 6-1	Factors for Maximum Length of Lay of Conductors in Multiple Conductor Cables Having Overall Coverings.....	42
Table 6-2	Grounding Conductor Size	43
Table 7-1	Production Testing.....	45
Table 7-2	Mandrel Diameter for Cold Bend Test.....	50
Table 7-3	Water Soak Immersion Time	51
Table 8-1	Multipliers for Determining Maximum U-Bend Mandrel Diameter	55
Table 8-2	Mandrel Diameter for Heat Shock Test.....	55

Section 1 GENERAL

1.1 SCOPE

This standard applies to materials, constructions, and testing of 2001-5000 V nonshielded power cables having insulations of crosslinked polyethylene (includes both crosslinked and tree-retardant crosslinked polyethylene) or crosslinked rubber of the types shown in section 4. The insulation shall be covered with a discharge-resistant jacket or shall be a discharge-resistant material without a jacket. Discharge-resistant insulations and jackets shall comply with the applicable surface resistivity, U-Bend discharge, and track-resistance requirements of sections 4 and 5.

The nonshielded cables described in this standard are intended for use for the distribution of electrical energy in normal conditions of service in indoor, outdoor, aerial, underground, or subsea installations within the application limits shown in Table 4-3 and section 5.2.1. They are not intended for portable use applications.

1.2 GENERAL INFORMATION

This standard covers the requirements for conductors, insulations, jackets, and protective coverings, as well as general construction and dimensional details common to most standard nonshielded types of wires and cables rated 2001-5000 V. Insulation thicknesses are designated in terms of cable insulation levels defined in section 4. See sections 7 and 8 for test procedures not elsewhere referenced. Requirements of a referenced ASTM standard shall be determined in accordance with the procedure or method designated in the referenced ASTM standard unless otherwise specified in this standard.

See Appendix A in section 10 for complete titles and dates of ICEA publications, NEMA publications, and ASTM standards to which reference is made in this publication.

In classifying jackets and sheaths in this standard, the term “jacket” refers to a continuous nonmetallic covering and “sheath” to a continuous metallic covering.

U.S. customary units, except for temperature, are specified throughout this standard. Approximate International System of Units (SI) equivalents are included for information only.

1.3 INFORMATION TO BE SUPPLIED BY PURCHASER

When requesting proposals from cable manufacturers, the prospective purchaser should furnish the following information:

1.3.1 Characteristics of System on Which Cable Is to Be Used

- 1) Load current, alternating or direct
- 2) Frequency, Hertz
- 3) Normal operating voltage between phases or, for direct current systems, between conductors
- 4) Number of phases and conductors
- 5) Cable insulation level (see 4.2)
- 6) Minimum temperature at which cable will be installed

- 7) Description of installation
 - a. Indoor or outdoor
 - (1) In air, no enclosure
 - (2) In air, enclosed in conduit
 - (3) In cable trays, cable-bus, or other support racks
 - b. Underground
 - (1) Cables directly buried (must be sheathed or armored)
 - (2) Cables in directly buried ducts or conduits
 - (3) Cables in concrete-enclosed ducts or conduits (duct bank)
 - (4) Cables in precast open-trench assemblies
 - c. Aerial
 - (1) On messenger in metal rings
 - (2) Factory preassembled on messenger
 - (3) Field spun to messenger
 - d. SubSea
 - e. Descriptions other than the foregoing
- 8) Conditions of installation
 - a. Ambient temperature
 - b. Number and spacing of:
 - (1) Multiple loaded ducts in duct bank
 - (2) Multiple loaded conduits
 - (3) Multiple cables in tray, bus, trench, etc.
 - c. Number of cables per duct or conduit
 - d. Type of duct or conduit (metallic or nonmetallic)
 - e. Depth of burial of duct bank or conduits
 - f. Load factor
 - g. Thermal resistivity of earth, concrete, or other surrounding media
 - h. Wet or dry location

1.3.2 Quantities and Descriptions of Cable

- 1) Total number of feet, including test lengths, and lengths if specific lengths are required
- 2) Type of cable. Describe as single conductor, two-conductor flat or round, multiplexed singles, multiple conductor with overall covering, etc.
- 3) Rated circuit voltage, phase to phase
- 4) Type of conductor: copper or aluminum
- 5) Size of conductor: AWG or kcmil. If conditions require other than standard stranding, a complete description should be given.
- 6) Insulation type
- 7) Thickness of insulation, mils
- 8) Type of outer covering
- 9) Maximum allowable overall diameter in inches. When duct space or other enclosure dimensions are not limited, it is desirable not to restrict the overall diameter
- 10) Method of conductor identification

1.4 DEFINITIONS AND SYMBOLS

AWG	American Wire Gauge
BIL	Basic Impulse Insulation Level
BWG	Birmingham Wire Gauge
Cable Core	The portion of a cable that includes the conductor, the conductor shield, and the insulation

Cable Core Extruder Run	A continuous run of cable core with one conductor size, one conductor shield compound, and one insulation compound and thickness
Certified Test Report	A report containing the results of production tests or qualification tests that declares the cable shipped to a customer meets the applicable requirements of this standard
Completed Cable	A length of cable that has finished all manufacturing processes but might not have been fully tested
Dielectric Constant	The ratio of the capacitance of a given configuration of electrodes with the material as a dielectric to the capacitance of the same electrode configuration with a vacuum (or air, for most practical purposes) as the dielectric
Discharge-free Cable Design	A cable meeting the maximum partial discharge magnitude requirement of this standard, when measured in the manner described herein, at the specified partial discharge test voltage
Discharge-resistant Cable Design	A cable design capable of withstanding electrical discharge
Dissipation Factor	The cotangent of the dielectric phase angle of a dielectric material or the tangent of the dielectric loss angle. It is often called $\tan \delta$.
EPR Insulating Compound	A mixture of ethylene propylene base resin and selected ingredients
Filled Crosslinked Polyethylene Insulation	XLPE insulation containing 10% or more of mineral fillers by weight
High Dielectric Constant Compound	An extruded compound used for the conductor shield that has a dielectric constant typically between 8 and 200
Jacket	An extruded overall nonmetallic covering
Jacket Extruder Run	A cable with a jacket that was applied in one continuous run with one jacket compound and one jacket thickness
kcmil	Thousands of circular mils (formerly MCM)
Lay Direction	The lateral direction in which the components of a cable run over the top of the cable as they recede from an observer looking along the axis of the cable. Right-hand lay is a clockwise twist away from the observer; left-hand lay is a counterclockwise twist away from the observer.
Lay Length	The lay of any helical element of a cable is the axial length of one turn of a helix of that element
Lot (cable)	The quantity of cable requiring one test
Lot (material)	A quantity of material used in cable construction that is produced at the same location under the same manufacturing conditions during the same time period
Master Length	A continuous length of cable collected on a reel at the end of an extrusion line

**Maximum Rated
Conductor Temperatures:**

Normal Operating	The highest conductor temperature permissible for any part of the cable line under normal operating current load
Emergency Overload	The highest conductor temperature permissible for any part of the cable line during emergency overload of specified time, magnitude, and frequency of application
Short Circuit	The highest conductor temperature permissible for any part of the cable line during a circuit fault of specified time and magnitude
Nominal Value	The value by which a quantity is designated and often used in tables (taking into account specified tolerances) but does not require testing or measurement for verification
Pitch Diameter	The core diameter plus half the buildup of the layer being considered. The pitch diameter of a single layer of armor wires, for example, is equal to the diameter under the wires plus twice one half the diameter of one wire.
Power Frequency	A voltage frequency between 49 and 61 Hz
Production Tests	Tests defined in Part 7 of this standard with specific test frequency
Qualification Tests	Tests defined in Part 8 of this standard with specific test frequency
Room Temperature (RT)	25° ± 5°C air temperature
Sheath	A continuous metallic covering
Shipping Length	A completed length of cable that has passed all test requirements. It might or might not be cut into shorter lengths before it is supplied to the end-use customer.
Shipping Reel	A completed reel of cable shipped to the end use customer
Thermoplastic	A polymeric material that repeatedly can be softened by heating and hardened by cooling through a temperature range characteristic of the material and which, in softened state, can be shaped through the application of force
Thermoset	A polymeric material that, when crosslinked, will not flow on subsequent heating. Crosslinking is accomplished chemically or by irradiation.
Tree-retardant XLPE Insulation	A tree--retardant crosslinked polyethylene (TRXLPE) insulation compound based on XLPE, containing an additive, a polymer modification, or filler that retards the development and growth of water trees in the insulation compound
Unfilled Crosslinked Polyethylene	XLPE insulation containing less than 10% mineral filler by weight
V	phase-to-phase voltage

V_g	phase-to-ground voltage
Water Blocking Component	A nonmetallic material incorporated in a cable construction intended as an impediment to water penetration. A water-blocking component can be a pumpable or extrudable conductor filler compound; a water-swellable tape, yarn, or powder; or a combination thereof.
XLPE Insulation	Crosslinked polyethylene insulation

Section 2 CONDUCTORS

2.0 GENERAL

Conductors shall meet the requirements of the appropriate ASTM standards referenced in 2.1, except that compliance with cross-sectional area is not required. Resistance will be determined in accordance with 2.4, and diameters will be in accordance with 2.5.

The following technical information on typical conductors can be found in Appendix G:

- a) Approximate diameters of individual wires in stranded conductors.
- b) Approximate conductor weights.

2.1 PHYSICAL AND ELECTRICAL PROPERTIES

The conductors used in the cable shall be copper, in accordance with 2.1.1, or aluminum, in accordance with 2.1.2, as applicable, except as noted in 2.0. Conductors shall be solid or stranded. The outer layer of an uncoated stranded copper conductor may be tin-coated to obtain free stripping of an adjacent polymeric layer. Other stranding available by agreement between purchaser and manufacturer.

2.1.1 Copper Conductors

- a) ASTM B 3 for Soft or Annealed Uncoated Copper
- b) ASTM B 5 for Electrical Grade Copper
- c) ASTM B 8 for Class A, B, C, or D Stranded Copper Conductors
- d) ASTM B 33 for Soft or Annealed Tin-coated Copper Wire
- e) ASTM B 496 for Compact Round Stranded Copper Conductors
- f) ASTM B 784 for Modified Concentric-lay Stranded Copper Conductors
- g) ASTM B 787 for 19 Wire Combination Unilay-stranded Copper Conductors
- h) ASTM B 835 for Compact Round Stranded Copper Conductors Using Single-input Wire Constructions
- i) ASTM B 902 for Compressed Round Stranded Copper Conductors, Hard, Medium-Hard, or Soft Using Single-input Wire Constructions

2.1.2 Aluminum Conductors

- a) ASTM B 230 for Electrical Grade Aluminum 1350-H19
- b) ASTM B 231 for Class A, B, C, or D Stranded Aluminum 1350 Conductors
- c) ASTM B 233 for Electrical Grade Aluminum 1350 Drawing Stock
- d) ASTM B 400 for Compact Round Stranded Aluminum 1350 Conductors
- e) ASTM B 609 for Electrical Grade Aluminum 1350 Annealed and Intermediate Tempers
- f) ASTM B 786 for 19 Wire Combination Unilay-stranded Aluminum 1350 Conductors
- g) ASTM B 800 for 8000 Series Aluminum Alloy Annealed and Intermediate Tempers
- h) ASTM B 801 for 8000 Series Aluminum Alloy Wires, Compact Round, Compressed, and Concentric-lay Class A, B, C, and D Stranded Conductors
- i) ASTM B 836 for Compact Round Stranded Aluminum Conductors Using Single-input Wire Constructions
- j) ASTM B 901 for Compressed Round Stranded Aluminum Conductors Using Single-input Wire Construction

2.2 OPTIONAL SEALANT FOR STRANDED CONDUCTORS

With the approval of the purchaser, a sealant designed as an impediment to longitudinal water penetration may be incorporated in the interstices of the stranded conductor. Compatibility with the conductor shield shall be determined in accordance with ICEA T-32-645.

Longitudinal water penetration resistance shall be determined in accordance with ICEA Publication T-31-610 and shall meet a minimum requirement of 5 psig (34.5 kPa).

2.3 CONDUCTOR SIZE UNITS

Conductor size shall be expressed by cross-sectional area in units of one-thousand circular mils (kcmil). The AWG equivalents for small conductor sizes are found in Table 2-4. The metric equivalents for all sizes are found in Table 2-4 (Metric).

2.4 CONDUCTOR DC RESISTANCE

The DC resistance of each conductor in a production or shipping length of completed cable shall not exceed the value determined from the schedule of maximum DC resistances specified in Table 2-2, when using the appropriate nominal value specified in Table 2-3 or Table 2-3 (Metric). The DC resistance shall be determined in accordance with 2.4.1. Nominal DC resistance is calculated in accordance with 2.4.2. Table 2-3 shows nominal resistance for standard conductor sizes.

Where the outer layer of an otherwise uncoated stranded copper conductor is tin-coated, the direct current resistance of the resulting conductor shall not exceed the value specified for an uncoated copper conductor of the same size.

When a sample is taken from a multiple-conductor cable, the resistance shall comply with the appropriate maximum resistance value specified for a single-conductor cable.

2.4.1 Direct Measurement of DC Resistance

The DC resistance shall be determined by resistance measurements made in accordance with ICEA Publication T-27-581/NEMA WC 53 to an accuracy of or better than 2%. When measurements are made at a temperature other than 25°C, the measured value shall be converted to a resistance at 25°C by using the methods specified in ICEA T-27-581/NEMA WC 53.

If verification is required for the direct-current resistance measurement made on an entire length of completed cable, a sample at least 1 ft (0.305 m) in length shall be cut from that reel length, and the DC resistance of each conductor shall be measured using a Kelvin-type bridge or a potentiometer. This verification test does not constitute a retest and cannot be the basis to pass the entire length of cable.

2.4.2 Calculation of DC Resistance

The DC resistance, $\Omega/1000$ ft at 25°C, shall be calculated using the following formula:

$$R = k \frac{\rho}{A}$$

Where:

R = Conductor resistance, $\Omega/1000$ ft

k = Weight increment factor as given in Table 2-1 or as calculated in accordance with the applicable ASTM standard

ρ = Volume resistivity, $\Omega\text{-cmil/ft}$, determined in accordance with ASTM B 193 using round wires

A = Cross-sectional area of conductor, kcmil, determined in accordance with ICEA Publication T-27-581/NEMA WC 53

When the volume resistivity is expressed in $n\Omega \cdot m$ (nanohm•meter) and area is expressed in mm^2 (square millimeters) the resistance can be expressed in either Ω/km (ohm per kilometer) or $m\Omega/m$ (milliohm per meter).

2.5 CONDUCTOR DIAMETER

The conductor diameter shall be measured in accordance with ICEA Publication T-27-581/NEMA WC 53. The diameter shall not differ from the nominal values shown in Table 2-4 and Table 2-4 (Metric) by more than $\pm 2\%$.

Table 2-1
Weight Increment Factors*

Conductor Type and Size	Weight Factor (k)
Solid, all sizes	1
Stranded Classes B, C, and D 2000 kcmil or Less	1.02
Larger than 2000 kcmil	1.03

* Based on the method specified in ASTM B 8, ASTM B 231, ASTM B 400, ASTM B 496, ASTM B 786, ASTM B 787, ASTM B 801, B 901, or B 902, as applicable

Table 2-2
**Schedule for Establishing Maximum Direct Current Resistance, $\Omega/1000$ ft,
of Cable Conductors Shown in Table 2-4**

Cable Type	R_{max} (Maximum DC Resistance), $\Omega/1000$ ft
Single-conductor Cables and Flat Parallel Cables	Table 2-3* Nominal Value of R plus 2% $R_{max} = R \times 1.02$
Multiple-conductor Cables and Twisted Assemblies of Single-conductor Cables	Table 2-3* Nominal Value of R plus 2% plus an Additional 2% for a Single Layer of Conductors $R_{max} = R \times 1.02 \times 1.02$

* For conductor strandings or sizes not listed in Table 2-3, the nominal direct current resistance, $\Omega/1000$ ft, of a completed single-conductor cable shall be calculated using the following formula:

$$R = \frac{f}{A} \times 10^{-3}$$

Where:

R = Conductor resistance, $\Omega/1000$ ft

f = Multiplier factor from Table 2-5

A = Cross-sectional area of conductor, kcmil, determined in accordance with
ICEA Publication T-27-581/NEMA WC 53

Table 2-3
Nominal Direct Current Resistance, R, Ω /1000 ft (Ohms per 1000 Ft) at 25°C
of Solid and Stranded Conductors

Conductor Size AWG or kcmil	Solid			Concentric-lay Stranded*				
	Aluminum	Copper		Aluminum	Copper			
		Uncoated	Coated		Uncoated	Coated		
				Classes A,B,C,D	Classes B,C,D	Class B	Class C	Class D
8	1.05	0.640	0.659	1.07	0.652	0.678	0.678	0.680
7	0.833	0.508	0.522	0.851	0.519	0.538	0.538	0.538
6	0.661	0.403	0.414	0.675	0.411	0.427	0.427	0.427
5	0.524	0.319	0.329	0.534	0.352	0.338	0.339	0.339
4	0.415	0.253	0.261	0.424	0.258	0.269	0.269	0.269
3	0.329	0.201	0.207	0.336	0.205	0.213	0.213	0.213
2	0.261	0.159	0.164	0.266	0.162	0.169	0.169	0.169
1	0.207	0.126	0.130	0.211	0.129	0.134	0.134	0.134
1/0	0.164	0.100	0.102	0.168	0.102	0.106	0.106	0.106
2/0	0.130	0.0794	0.0813	0.133	0.0810	0.0842	0.0842	0.0842
3/0	0.103	0.0630	0.0645	0.105	0.0642	0.0667	0.0669	0.0669
4/0	0.0819	0.0500	0.0511	0.0836	0.0510	0.0524	0.0530	0.0530
250	0.0694	...	...	0.0707	0.0431	0.0448	0.0448	0.0448
300	0.0578	...	...	0.0590	0.0360	0.0374	0.0374	0.0374
350	0.0495	...	...	0.0505	0.0308	0.0320	0.0320	0.0320
400	0.0433	...	...	0.0442	0.0269	0.0277	0.0280	0.0280
450	0.0385	...	...	0.0393	0.0240	0.0246	0.0249	0.0249
500	0.0347	...	...	0.0354	0.0216	0.0222	0.0224	0.0224
550	...	...	...	0.0321	0.0196	0.0204	0.0204	0.0204
600	...	...	...	0.0295	0.0180	0.0187	0.0187	0.0187
650	...	...	...	0.0272	0.0166	0.0171	0.0172	0.0173
700	...	...	...	0.0253	0.0154	0.0159	0.0160	0.0160
750	...	...	...	0.0236	0.0144	0.0148	0.0149	0.0150
800	...	...	...	0.0221	0.0135	0.0139	0.0140	0.0140
900	...	...	...	0.0196	0.0120	0.0123	0.0126	0.0126
1000	...	...	...	0.0177	0.0108	0.0111	0.0111	0.0112
1100	...	...	...	0.0161	0.00981	0.0101	0.0102	0.0102
1200	...	...	...	0.0147	0.00899	0.00925	0.00934	0.00934
1250	...	...	...	0.0141	0.00863	0.00888	0.00897	0.00897
1300	...	...	...	0.0136	0.00830	0.00854	0.00861	0.00862
1400	...	...	...	0.0126	0.00771	0.00793	0.00793	0.00801
1500	...	...	...	0.0118	0.00719	0.00740	0.00740	0.00747
1600	...	...	...	0.0111	0.00674	0.00694	0.00700	0.00700
1700	...	...	...	0.0104	0.00634	0.00653	0.00659	0.00659
1750	...	...	...	0.0101	0.00616	0.00634	0.00640	0.00640
1800	...	...	...	0.00982	0.00599	0.00616	0.00616	0.00622
1900	...	...	...	0.00931	0.00568	0.00584	0.00584	0.00589
2000	...	...	...	0.00885	0.00539	0.00555	0.00555	0.00560

* Concentric-lay stranded includes compressed and compact conductors.

Table 2-3 (Metric)
Nominal Direct Current Resistance, R, Ω /km (Ohms per Kilometer) at 25°C
of Solid and Stranded Conductors

Conductor Size		Solid			Concentric-lay Stranded *				
		Aluminum	Copper		Aluminum	Copper			
AWG or kcmil	mm ²		Uncoated	Coated	Classes B,C,D	Uncoated	Coated		
						Classes B,C,D	Class B	Class C	Class D
8	8.37	3.44	2.10	2.16	3.51	2.14	2.22	2.22	2.23
7	10.6	2.73	1.67	1.71	2.79	1.70	1.76	1.76	1.76
6	13.3	2.17	1.32	1.36	2.21	1.35	1.40	1.40	1.40
5	16.8	1.72	1.05	1.08	1.75	1.07	1.11	1.11	1.11
4	21.1	1.36	0.830	0.856	1.39	0.846	0.882	0.882	0.882
3	26.7	1.08	0.659	0.679	1.10	0.672	0.699	0.699	0.699
2	33.6	0.856	0.522	0.538	0.872	0.531	0.554	0.554	0.554
1	42.4	0.679	0.413	0.426	0.692	0.423	0.440	0.440	0.440
1/0	53.5	0.538	0.328	0.335	0.551	0.335	0.348	0.348	0.348
2/0	67.4	0.426	0.260	0.267	0.436	0.266	0.276	0.276	0.276
3/0	85.0	0.338	0.207	0.212	0.344	0.211	0.219	0.219	0.219
4/0	107	0.269	0.164	0.168	0.274	0.167	0.172	0.172	0.172
250	127	0.228	...	...	0.232	0.141	0.147	0.147	0.147
300	152	0.190	...	...	0.194	0.118	0.123	0.123	0.123
350	177	0.162	...	...	0.166	0.101	0.105	0.105	0.105
400	203	0.142	...	...	0.145	0.0882	0.0909	0.0918	0.0918
450	228	0.126	...	...	0.129	0.0787	0.0807	0.0817	0.0817
500	253	0.114	...	...	0.116	0.0708	0.0728	0.0735	0.0735
550	279	...	...	...	0.105	0.0643	0.0669	0.0669	0.0669
600	304	...	...	...	0.0968	0.0590	0.0613	0.0613	0.0613
650	329	...	...	...	0.0892	0.0544	0.0561	0.0564	0.0567
700	355	...	...	...	0.0830	0.0505	0.0522	0.0525	0.0525
750	380	...	...	...	0.0774	0.0472	0.0485	0.0489	0.0492
800	405	...	...	...	0.0725	0.0443	0.0456	0.0459	0.0459
900	456	...	...	...	0.0643	0.0394	0.0403	0.0413	0.0413
1000	507	...	...	...	0.0581	0.0354	0.0364	0.0364	0.0367
1100	557	...	...	...	0.0528	0.0322	0.0331	0.0335	0.0335
1200	608	...	...	...	0.0482	0.0295	0.0303	0.0306	0.0306
1250	633	...	...	...	0.0462	0.0283	0.0291	0.0294	0.0294
1300	659	...	...	...	0.0446	0.0272	0.0280	0.0282	0.0283
1400	709	...	...	...	0.0413	0.0253	0.0260	0.0260	0.0263
1500	760	...	...	...	0.0387	0.0236	0.0243	0.0243	0.0245
1600	811	...	...	...	0.0364	0.0221	0.0228	0.0230	0.0230
1700	861	...	...	...	0.0341	0.0208	0.0214	0.0216	0.0216
1750	887	...	...	...	0.0331	0.0202	0.0208	0.0210	0.0210
1800	912	...	...	...	0.0322	0.0196	0.0202	0.0202	0.0204
1900	963	...	...	...	0.0305	0.0186	0.0192	0.0192	0.0193
2000	1013	...	...	...	0.0290	0.0177	0.0182	0.0182	0.0184

* Concentric-lay stranded includes compressed and compact conductors.

Table 2-4
Nominal Diameters for Copper and Aluminum Conductors

Conductor Size		Nominal Diameters (inches)							
		Solid	Concentric-lay Stranded						
AWG	kcmil		Com- pact*	Com- pressed	Class B**	Class C	Class D	Combi- nation Unilay	Unilay Com- pressed*
8	16.51	0.1285	0.134	0.141	0.146	0.148	0.148	0.143	...
7	20.82	0.1443	...	0.158	0.164	0.166	0.166	0.160	...
6	26.24	0.1620	0.169	0.178	0.184	0.186	0.186	0.179	...
5	33.09	0.1819	...	0.200	0.206	0.208	0.208	0.202	...
4	41.74	0.2043	0.213	0.225	0.232	0.234	0.235	0.226	...
3	52.62	0.2294	0.238	0.252	0.260	0.263	0.264	0.254	...
2	66.36	0.2576	0.268	0.283	0.292	0.296	0.297	0.286	...
1	83.69	0.2893	0.299	0.322	0.332	0.333	0.333	0.321	0.313
1/0	105.6	0.3249	0.336	0.362	0.373	0.374	0.374	0.360	0.352
2/0	133.1	0.3648	0.376	0.406	0.419	0.420	0.420	0.404	0.395
3/0	167.8	0.4096	0.423	0.456	0.470	0.471	0.472	0.454	0.443
4/0	211.6	0.4600	0.475	0.512	0.528	0.529	0.530	0.510	0.498
	250	0.5000	0.520	0.558	0.575	0.576	0.576	0.554	0.542
	300	0.5477	0.570	0.611	0.630	0.631	0.631	0.607	0.594
	350	0.5916	0.616	0.661	0.681	0.681	0.682	0.656	0.641
	400	0.6325	0.659	0.706	0.728	0.729	0.729	0.701	0.685
	450	0.6708	0.700	0.749	0.772	0.773	0.773	0.744	0.727
	500	0.7071	0.736	0.789	0.813	0.814	0.815	0.784	0.766
	550	...	0.775	0.829	0.855	0.855	0.855	...	0.804
	600	...	0.813	0.866	0.893	0.893	0.893	...	0.840
	650	...	0.845	0.901	0.929	0.930	0.930	...	0.874
	700	...	0.877	0.935	0.964	0.965	0.965	...	0.907
	750	...	0.908	0.968	0.998	0.999	0.998	...	0.939
	800	...	0.938	1.000	1.031	1.032	1.032	...	0.969
	900	...	0.999	1.061	1.094	1.093	1.095	...	1.028
	1000	...	1.060	1.117	1.152	1.153	1.153	...	1.084
	1100	...	...	1.173	1.209	1.210	1.211	...	1.137
	1200	...	...	1.225	1.263	1.264	1.264	...	1.187
	1250	...	...	1.251	1.289	1.290	1.290	...	1.212
	1300	...	...	1.276	1.315	1.316	1.316	...	1.236
	1400	...	...	1.323	1.364	1.365	1.365	...	1.282
	1500	...	...	1.370	1.412	1.413	1.413	...	1.327
	1600	...	...	1.415	1.459	1.460	1.460	...	1.371
	1700	...	...	1.459	1.504	1.504	1.504	...	1.413
	1750	...	...	1.480	1.526	1.527	1.527	...	1.434
	1800	...	...	1.502	1.548	1.548	1.549	...	1.454
	1900	...	...	1.542	1.590	1.590	1.591	...	1.494
	2000	...	...	1.583	1.632	1.632	1.632	...	1.533

* Diameters shown are for compact round, compact modified concentric, compact single-input wire, and Unilay compressed.

** Diameters shown are for concentric round and modified concentric.

Table 2-4 (Metric)
Nominal Diameters for Copper and Aluminum Conductors

Conductor Size		Nominal Diameters (mm)							
AWG or kcmil	mm ²	Solid	Concentric-lay Stranded						
			Com-pact*	Com-pressed	Class B**	Class C	Class D	Combi-nation Unilay	Unilay Com-pressed*
8	8.37	3.26	3.40	3.58	3.71	3.76	3.76	3.63	...
7	10.6	3.67	...	4.01	4.17	4.22	4.22	4.06	...
6	13.3	4.11	4.29	4.52	4.67	4.72	4.72	4.55	...
5	16.8	4.62	...	5.08	5.23	5.28	5.31	5.13	...
4	21.1	5.19	5.41	5.72	5.89	5.94	5.97	5.74	...
3	26.7	5.83	6.05	6.40	6.60	6.68	6.71	6.45	...
2	33.6	6.54	6.81	7.19	7.42	7.52	7.54	7.26	...
1	42.4	7.35	7.59	8.18	8.43	8.46	8.46	8.15	7.95
1/0	53.5	8.25	8.53	9.19	9.47	9.50	9.50	9.14	8.94
2/0	67.4	9.27	9.55	10.3	10.6	10.7	10.7	10.3	10.0
3/0	85.0	10.4	10.7	11.6	11.9	12.0	12.0	11.5	11.3
4/0	107	11.7	12.1	13.0	13.4	13.4	13.5	13.0	12.6
250	127	12.7	13.2	14.2	14.6	14.6	14.6	14.1	13.8
300	152	13.9	14.5	15.5	16.0	16.0	16.0	15.4	15.1
350	177	15.0	15.6	16.8	17.3	17.3	17.3	16.7	16.3
400	203	16.1	16.7	17.9	18.5	18.5	18.5	17.8	17.4
450	228	17.0	17.8	19.0	19.6	19.6	19.6	18.9	18.5
500	253	18.0	18.7	20.0	20.7	20.7	20.7	19.9	19.5
550	279	...	19.7	21.1	21.7	21.7	21.7	...	20.4
600	304	...	20.7	22.0	22.7	22.7	22.7	...	21.3
650	329	...	21.5	22.9	23.6	23.6	23.6	...	22.2
700	355	...	22.3	23.7	24.5	24.5	24.5	...	23.0
750	380	...	23.1	24.6	25.3	25.4	25.3	...	23.9
800	405	...	23.8	25.4	26.2	26.2	26.2	...	24.6
900	456	...	25.4	26.9	27.8	27.8	27.8	...	26.1
1000	507	...	26.9	28.4	29.3	29.3	29.3	...	27.5
1100	557	...	...	29.8	30.7	30.7	30.8	...	28.9
1200	608	...	...	31.1	32.1	32.1	32.1	...	30.1
1250	633	...	...	31.8	32.7	32.8	32.8	...	30.8
1300	659	...	...	32.4	33.4	33.4	33.4	...	31.4
1400	709	...	...	33.6	34.6	34.7	34.7	...	32.6
1500	760	...	...	34.8	35.9	35.8	35.9	...	33.7
1600	811	...	...	35.9	37.1	37.1	37.1	...	34.8
1700	861	...	...	37.1	38.2	38.2	38.2	...	35.9
1750	887	...	...	37.6	38.8	38.8	38.8	...	36.4
1800	912	...	...	38.2	39.3	39.3	39.3	...	36.9
1900	963	...	...	39.2	40.4	40.4	40.4	...	37.9
2000	1013	...	...	40.2	41.5	41.5	41.5	...	38.9

* Diameters shown are for compact round, compact modified concentric, compact single-input wire, and Unilay compressed.

** Diameters shown are for concentric round and modified concentric.

Table 2-5
Multiplier Factors* for Calculating Nominal DC Resistance
of Stranded Conductors, $\Omega/1000$ ft at 25°C

Size of the Stranded Conductor	Diameter of Individual Wires Used in Stranded Conductor (inches)						
	Aluminum	Uncoated Copper	Tin-coated Copper				
	All Wire Sizes	All Wire Sizes	From 0.460 to 0.290 Inclusive	Under 0.290 to 0.103 Inclusive	Under 0.103 to 0.0201 Inclusive	Under 0.0201 to 0.0111 Inclusive	Under 0.0111 to 0.001 Inclusive
	Multiplier Factor, f^{**}						
8 AWG-2000 kcmil (8.37-1013 mm ²)	17692	10786	11045	11102	11217	11456	11580
>2000-3000 kcmil (>1013-1520mm ²)	17865	10892	11153	11211	11327	11568	11694
Conductivity Used in Factors	61%	100%	97.66%	97.16%	96.16%	94.16%	93.15%

* The multiplier factors in this table are based on the following:

- a) Resistivity
 1. A volume resistivity of 10.575 Ω -cmil/ft (100% conductivity) at 25°C for uncoated (bare) copper.
 2. A 25°C volume resistivity converted from the 20°C values specified in ASTM B 33 for tin-coated copper
 3. A volume resistivity of 17.345 Ω -cmil/ft (61.0% conductivity) at 25°C for aluminum
- b) Increase in Resistance Due to Stranding
 1. The value of k (weight increment factor) given in Table 2-1

** See footnote under Table 2-2 for proper use of Multiplier Factors.

For conversion to metric values:

$$\begin{aligned}\Omega\text{-cmil/ft} \times 1.662 \times 10^{-3} &= \Omega\text{-m}^2/\text{m} = \Omega\text{-m} \\ \text{kcmil} \times 0.5067 &= \text{mm}^2 \\ \text{kilofoot} \times 0.3048 &= \text{kilometer}\end{aligned}$$

Section 3

STRESS CONTROL LAYER (CONDUCTOR SHIELD)

3.0 GENERAL

Conductors shall be covered with a separate stress controlling material compatible with the conductor and the insulation. The material shall have allowable operating temperature at least equal to that given for the insulation under which it will be used.

3.1 MATERIAL AND THICKNESS

The conductor shall be covered with an extruded shield material. A semiconducting tape may be used between the conductor and the extruded shield. The tape, if utilized, shall not be considered as part of the extruded shield thickness.

The extruded material shall be either semiconducting or nonconducting for ethylene propylene rubber (EPR) type insulation and semiconducting only for crosslinked polyethylene (XLPE or TRXLPE) type insulations. The extruded shield shall be compatible with all cable component materials with which it is in contact. The allowable operating temperatures of the conductor shield shall be equal to or greater than that of the insulation. The conductor shield shall be easily removable from the conductor, and the outer surface shall be firmly bonded to the overlying insulation.

The extruded layer shall have a minimum thickness of 6 mils (0.15 mm), and the minimum tape thickness shall be 2.5 mils (0.06 mm).

3.2 PHYSICAL REQUIREMENTS

Extrudable material, prior to application to the conductor, when tested according to section 7 shall meet the following requirements:

Table 3-1
Extruded Conductor Shield Requirements

Physical Properties of Stress Control Material	Used with Insulation Type*
	X-1, X-2, E-1, E-2, E-4
After Air Oven Exposure at 121°C for 168 hours duration: Elongation, minimum percent:	100
Brittleness Temperature, not warmer than °C:	-25

* See section 4, Table 4-1, for Designated Insulation Types and Temperature Ratings.

3.3 ELECTRICAL REQUIREMENTS

3.3.1 Extruded Semiconducting Material

The volume resistivity of an extruded semiconducting material, when measured according to section 7.8, shall not exceed 1000 $\Omega\cdot\text{m}$ at room temperature and at the maximum normal operating temperature of the cable.

3.3.2 Semiconducting Tape

The resistivity of a semiconducting tape, when measured in accordance with ASTM D4496 at room temperature, shall not exceed 10 k Ω (per square).

3.3.3 Extruded Nonconducting Material (for EPR Insulation Only)

An extruded nonconducting* stress-controlling material, when measured according to ICEA T-27-581, section 2.7, shall meet the following requirements at room temperature and at the maximum normal operating temperature of the cable:

Dielectric Constant, range 8 through 200

60 Hz AC voltage minimum withstand stress, S

$$S \geq \frac{60}{\text{dielectric constant}} \text{ kV/mm}$$

* Limited to use with Types E-1, E-2, E-4 insulations only (see Table 4-1).

The presence of the extruded nonconducting stress-control layer on each cable shall be verified according to the procedure of 2.5 of ICEA T-27-581 using a 2000 V minimum DC spark test potential applied to the layer prior to covering with insulation.

3.4 CROSSLINKED (THERMOSET) REQUIREMENTS

Crosslinked extruded conductor shields shall be effectively crosslinked as determined by the wafer boil test per paragraph 7.13.

Section 4 INSULATION

4.1 INSULATION MATERIALS

The insulation material shall be either a crosslinked polyethylene or a crosslinked rubber compound of the types designated in Table 4-1. The insulation material shall meet the dimensional, electrical, and physical requirements specified in this section. The insulation shall be applied directly to the surface of the conductor stress-control layer.

A crosslinked polyethylene insulation shall be either unfilled or filled. An unfilled crosslinked polyethylene insulation is one in which the combined mass fraction of carbon black and/or mineral fillers is less than 10%. A filled crosslinked polyethylene insulation is one in which the combined mass fraction of carbon black and/or mineral fillers is 10% or greater. In either material, unfilled or filled, the mass fraction of the carbon black contained therein shall not exceed 3.0%.

The designations, material types, and temperature ratings of the insulations are given in Table 4-1.

Table 4-1
Type Designation and Maximum Conductor Temperature

Designated Identity	Type of Insulation Material	Temperature Rating, °C*
X-1	Crosslinked Polyethylene, Unfilled	90
X-2	Crosslinked Polyethylene, Filled	90
E-1	Ethylene Propylene Rubber, Type I	90
E-2	Ethylene Propylene Rubber, Type II	90
E-4	Ethylene Propylene Rubber, Type IV	90

* For continuous operation.

See Appendix B for definitions of temperature ratings.

See Appendix C for emergency overload ratings.

4.2 INSULATION LEVELS

The cable insulation level is defined based on the phase-to-phase voltage and the system fault-clearing category for a particular installation as follows:

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

133% Level. This insulation level corresponds to that formerly designated for ungrounded systems. Cables in this category may be applied in situations where the clearing time requirements of the 100% Level category cannot be met and there is adequate assurance that the faulted section will be de-energized in a time not exceeding one hour.

173% Level. Cables in this category should be applied on systems where the time required to de-energize a grounded section is indefinite. Their use is also recommended for resonant grounded systems. For these applications, a shielded cable design is recommended, per ICEA Standard S-93-639, *Shielded Power Cables Rated 5kV through 46kV*.