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Standard for Control Cables





National Electrical Manufacturers Association ■ 2101 L Street, N.W., Suite 300, Washington, DC 20037
Insulated Cable Engineers Association ■ P.O. Box 440, South Yarmouth, MA 02664

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NEMA WC 57–1990
ICEA S–73–532

WC 57

STANDARD FOR CONTROL CABLES

Approved as an American National Standard on January 17, 1991

Prepared and Sponsored by:
Insulated Cable Engineers Association, Inc.
P.O. Box 440
South Yarmouth, MA 02664

Approved and Published by:
National Electrical Manufacturers Association
2101 L Street, N.W., Suite 300
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Foreword

The *Standard for Control Cables,* ICEA S–73–532, NEMA WC 57–1990, was developed by the Insulated Cable Engineers Association, Inc. (ICEA) and approved by the National Electrical Manufacturers Association (NEMA). Unless otherwise noted as Authorized Engineering Information, this Standards Publication has been approved by NEMA as NEMA Standard.

ICEA/NEMA Standards are adopted in the public interest and are designed to eliminate misunderstanding between the manufacturer and the user and to assist users in selecting and obtaining the proper product for their particular needs. Existence of an ICEA/NEMA Standard does not in any respect preclude the manufacture or use of products not conforming to the standard. The user of this standard is cautioned to observe any health or safety regulations and rules relative to the manufacture and use of cable made in conformity with this standard.

This standard does not specify any specific frequencies for sampling for test purposes, cable products, or components. One program of sampling frequencies is given in Publication ICEA T–26–465/NEMA WC 54–1990.

Requests for interpretation of this standard must be submitted in writing to the Insulated Cable Engineers Association, Inc., P.O. Box 440, South Yarmouth, MA 02664. An official written interpretation will be provided, once approved by ICEA and NEMA. Suggestions for improvements gained in the use of this publication will be welcomed by the Association.

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Scope

This standard applies to materials, construction, and testing of multiconductor control cables. Control cables are multiconductor cables that convey electrical signals used for monitoring or controlling electrical power systems and their associated processes. Control cables convey signals between devices interfaced directly with the electrical power system, such as current transformers, potential transformers, relays, switches, and meters.

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STANDARD FOR CONTROL CABLES

Part 1
GENERAL

1.1 GENERAL INFORMATION

This publication is so arranged that cables can be designated and selected in numerous constructions for a broad range of installation and service conditions. Parts 2 through 4 cover the major components of the cables:

Part 2—Conductors
Part 3—Insulations
Part 4—Shieldings and Coverings

Each of these parts designates the materials, material characteristics, dimensions, and tests applicable to the particular component.

Part 5 covers assembly, cabling, and identification of the individual insulated conductors, with or without associated shields.

Part 6 describes some, but not all, of the test methods applicable for the component materials and completed cables. Other test methods are found in ICEA T–27–581/NEMA WC 53.

Part 7 is reserved for future use.

Part 8 contains appendices with reference data such as abbreviations, definitions, material characteristics, application, and installation information. Particular attention is called to Appendix A, which gives the title and date of industry standards and other publications referenced herein.

In classifying components in this standard, the following definitions apply:

Metal Tape—A relatively thin and narrow metal strip that includes straps and ribbons.

Jacket—A polymeric (nonmetallic) protective covering applied over the insulation, core, sheath or armor of a cable, e.g. a PVC jacket. A jacket is not impervious to water or other liquids.

Sheath—A metallic covering, impervious to water and other liquids, applied over the insulation, core, or jacket of a cable, e.g. a lead sheath.

Conductor sizes are expressed by American Wire Gage (AWG). Steel armor wire sizes are expressed by Birmingham Wire Gage (BWG).

Temperatures are expressed in degrees Celsius. The Fahrenheit equivalents of degrees Celsius can be calculated by the equation °F = (1.8×°C) + 32. Room temperature is defined as a temperature from 20°C to 28°C inclusive.

Mass is expressed in grams. The ounce equivalents to grams can be calculated by dividing the number of grams by 28.35. Other values are expressed in non-metric units commonly used in North America.

To convert values in non-metric units to the approximate values in appropriate metric units, multipliers given in the following table should be used:

From	To	Multiplier
inches (in)	millimeters (mm)	25.4
ohms per 1000 ft (Ω/1000 ft)	milliohms per meter (mΩ/m)	3.28
square inch (in^2)	square millimeter (mm^2)	645
circular mil (cmil)	square millimeter (mm^2)	5.07×10^{-4}
pounds per square inch (psi)	megapascals (MPa)	6.89×10^{-3}
gigaohms-1000 ft (GΩ-1000 ft)	gigaohms-meter (GΩ-m)	305

1.2 INFORMATION TO BE SUPPLIED BY PURCHASER*

When requesting proposals from manufacturers, the prospective purchaser should describe the cable by reference to pertinent parts of this standard. To help avoid misunderstandings and possible misapplication of cable, he or she should also provide pertinent information concerning the intended application.

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Part 2
CONDUCTORS

2.1 GENERAL

Conductor requirements shall be determined in accordance with the procedures or methods designated by the referenced ASTM standards (see Appendix A) unless otherwise specified in this standard.

The following technical information on typical conductors may be found in Appendix B:

a. Approximate diameters of stranded copper conductors.
b. Approximate weights of copper conductors.

2.2 WIRES, PHYSICAL AND ELECTRIC PROPERTIES

The wires used in conductors shall be copper in accordance with 2.3.

2.3 COPPER CONDUCTORS

2.3.1 Wires

Copper wires shall meet the chemical requirements of ASTM B 5 and either 2.3.1.1 or 2.3.1.2.

2.3.1.1 Soft or annealed copper wires intended for a stranded conductor shall meet the elongation, finish, and coating continuity requirements of one of the following:

1. ASTM B 3 for uncoated wires,
2. ASTM B 33 for tin coated wires, or
3. ASTM B 189 for lead or lead alloy coated wires.

2.3.1.2 Copper wires, if removed from a concentric lay stranded conductor, annealed after stranding, shall meet the elongation requirements of ASTM B 8, Sections 7.4, 7.5, and 7.6.

2.3.2 Solid Conductors

A solid copper conductor shall consist of a single round wire meeting the requirements given in 2.3.1.1.

2.3.3 Stranded Conductors

Stranded conductors shall consist of seven wires or 19 wires individually meeting the appropriate requirements of 2.3.1.

Diameters of individual wires in stranded conductors are not specified. The requirements for lay and joints shall be in accordance with ASTM B 8 for concentric lay Class B or Class C stranded copper conductors.

2.3.4 Conductor dc Resistance per Unit Length

The dc resistance per unit length 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 2-1 when using the appropriate nominal value from Table 2-2. The dc resistance shall be determined in accordance with 2.3.4.1 or 2.3.4.2.

When the resistance is measured on a single conductor sample taken from a multiple conductor cable or when the resistance is calculated, the appropriate maximum resistance value specified for the single conductor shall apply.

2.3.4.1 DIRECT MEASUREMENT OF DC RESISTANCE PER UNIT LENGTH

The dc resistance per unit length shall be determined by dc resistance measurements made in accordance with ICEA T–27–581/NEMA WC 53 to an accuracy of 2 percent or better.

If measurements are made at a temperature other than 25°C, the measured value shall be converted to resistance at 25°C by using the methods specified in ICEA T–27–581/NEMA WC 53.

If verification is required for the dc resistance measurement made on an entire length of completed cable, a sample at least 1 foot long 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.

2.3.4.2 CALCULATION OF DC RESISTANCE PER UNIT LENGTH

The dc resistance per unit length at 25°C shall be calculated using the following formula:

$$R = 10^3 K\rho/A$$

Where:

R = Conductor resistance in Ω/1000 ft
K = Weight and resistance increment factor
ρ = Volume resistivity in Ω cmil/ft
A = Cross-sectional area of conductor in cmil

a. Volume resistivity (ρ) of the conductor material shall be determined in accordance with ASTM B 193 using round wires.
b. Cross-sectional area (A) of solid- and concentric-lay stranded conductors shall be determined in accordance with ICEA T–27–581/NEMA WC 53.
c. Weight and resistance increment factor (K) shall be taken as 1.02, or it shall be calculated in accordance with ASTM B 8.

2.3.5 Conductor Diameter

The diameter of a solid conductor shall be measured in accordance with ICEA T–27–581/NEMA WC 53. The diameter of a solid conductor shall not differ from the

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nominal values shown in Table 2-3 by more than ±5 percent.* No diameter requirements apply to stranded conductors.

*The 5-percent diameter tolerance for solid conductors is provided to enable a designer of connectors to determine the range of conductor sizes that will fit a particular connector; however, a conductor meeting the minimum diameter requirement does not necessarily meet the requirement for maximum dc resistance specified in 2.3.4. (This paragraph has been approved by NEMA as Authorized Engineering Information.)

Table 2-1
SCHEDULE FOR ESTABLISHING MAXIMUM DC RESISTANCE PER UNIT LENGTH OF COMPLETED CABLE

Cable Type	Maximum dc Resistance
Single Conductor*	Table 2-2 Value Plus 2% (R max = R×1.02)
Multiple Conductor Cables	Table 2-2 Value Plus 2% plus one of the following: 2%—One layer of Conductors (R max = R×1.02×1.02) 3%—More than one layer of conductors (R max = R×1.02×1.03) 4%—Pairs or other precabled units (R max = R×1.02×1.04) 5%—More than one layer of pairs or other precabled units. (R max = R×1.02×1.05)

*Applied to a sample only, see 2.3.4.

Table 2-3
NOMINAL DIAMETERS FOR SOLID COPPER CONDUCTORS

Conductor Size, AWG	Solid Diameters, Inch
22	0.0253
20	0.0320
19	0.0359
18	0.0403
17	0.0453
16	0.0508
14	0.0641
13	0.0720
12	0.0808
11	0.0907
10	0.1019
9	0.1144

Table 2-2
NOMINAL DC RESISTANCE IN OHMS PER 1000 FEET AT 25°C OF SOLID AND CONCENTRIC LAY STRANDED COPPER CONDUCTORS

Conductor Size, AWG	Solid Copper		Stranded Copper		
			Uncoated	Coated	
	Uncoated	Coated	Class B and C	Class B	Class C
22	16.5	17.2	16.7	17.9	18.1
20	10.3	10.7	10.5	11.1	11.3
19	8.20	8.52	8.33	8.83	8.96
18	6.51	6.76	6.67	7.07	7.14
17	5.15	5.35	5.21	5.52	5.64
16	4.10	4.26	4.18	4.43	4.44
14	2.57	2.67	2.63	2.73	2.79
13	2.04	2.12	2.08	2.16	2.21
12	1.62	1.68	1.66	1.72	1.75
11	1.29	1.34	1.31	1.36	1.36
10	1.02	1.06	1.04	1.08	1.08
9	0.808	0.831	0.825	0.856	0.856

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Part 3
INSULATION

3.0 GENERAL

The following insulations for control cable shall be an extruded dielectric material meeting the dimensional, electrical, and physical requirements specified in the following paragraphs. It shall be suitable for use in the locations and at the temperatures specified in 3.3. The insulation shall be applied directly to the surface of the conductor or conductor separator if used and shall fit tightly to that surface.

3.1 MATERIALS

The insulation shall consist of one of the materials shown below:

- Crosslinked Polyethylene (XLPE), Type I
- Crosslinked Polyethylene (XLPE), Type II
- Ethylene Propylene Rubber (EP), Type I
- Ethylene Propylene Rubber (EP), Type II
- Silicone Rubber (SR)
- Chlorosulfonated Polyethylene (CSPE)*
- Polyvinyl Chloride (PVC)
- Polyethylene (PE)
- Composite EP/CSPE or EP/Neoprene (CR)
- Synthetic Rubber (SBR)
- Thermoplastic Elastomer (TPE), Type I
- Thermoplastic Elastomer (TPE), Type II

*Also known as Chlorosulfonyl Polyethylene (CSM)

3.2 THICKNESS

The minimum average thickness shall not be less than as specified in Table 3-1. The minimum thickness at any one point shall not be less than 90 percent of the specified value.

3.2.1 SR

0.005 inch of the specified average SR insulation thickness may be replaced by not less than 0.005 inch of a closely woven and impregnated glass braid. (This paragraph has been approved by NEMA as Authorized Engineering Information.)

3.2.2 PE

For cables rated 600 volts, 0.010 inch of the specified average PE insulation thickness may be replaced by not less than 0.010 inch of PVC. For cables rated 1000 volts, 0.015 inch of the specified average PE insulation may be replaced with not less than 0.015 inch of PVC. The PVC shall comply with the physical and aging requirements of Table 3-2. For all voltages given in Table 3-1, 0.004 inch of the average PE insulation thickness may be replaced by not less than 0.004 inch of nylon except that in no case shall the thickness of the PE be less than 0.015 inch. (This paragraph has been approved by NEMA as Authorized Engineering Information.)

3.2.3 PVC

For all voltages given in Table 3-1, 0.004 inch of the specified average PVC insulation thickness may be replaced by not less than 0.004 inch of nylon. (This paragraph has been approved by NEMA as Authorized Engineering Information.)

Table 3-1
INSULATION THICKNESS, INCHES

Conductor Size, AWG	XLPE Types I and II	EP Types I and II	SR	SBR and CSPE	PVC	PE	TPE Types I and II	Composite EP/CSPE or EP/CR
				300 Volts				
22–19	0.020	0.020	0.025	0.025	0.020	0.015	0.020	0.020/0.010
18	0.020	0.020	0.025	0.025	0.025	0.020	0.020	0.020/0.010
16	0.020	0.020	0.025	0.025	0.025	0.020	0.020	0.020/0.010
14– 9	0.025	0.025	0.030	0.030	0.025	0.020	0.020	0.020/0.010
				600 Volts				
20–19	0.025	0.025	0.030	0.030	0.025	0.025	0.025	0.020/0.010
18–16	0.025	0.025	0.030	0.030	0.030	0.025	0.025	0.020/0.010
14– 9	0.030	0.030	0.045	0.045	0.045	0.030	0.030	0.020/0.010
				1000 Volts				
16	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.030/0.015
14– 9	0.045	0.045	0.060	0.060	0.060	0.045	0.045	0.030/0.015

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3.3 REQUIREMENTS

When tested in accordance with appropriate methods specified in Part 6, the insulation shall meet the applicable requirements specified in Table 3-2.

3.3.1 Crosslinked Polyethylene (XLPE) Insulation, Type I and Type II

This insulation shall be suitable for use in wet or dry locations at a temperature not exceeding 90°C.

3.3.2 Ethylene Propylene Rubber (EP) Insulation, Type I and Type II

This insulation shall be suitable for use in wet or dry locations at a temperature not exceeding 90°C.

3.3.3 Ozone Resisting Silicone Rubber (SR) Insulation

This insulation shall be suitable for use in dry locations at a temperature not exceeding 125°C.

3.3.4 Chlorosulfonated Polyethylene (CSPE) Insulation

This insulation shall be suitable for use in wet or dry locations at a temperature not exceeding 90°C.

3.3.5 Polyvinyl-Chloride (PVC) Insulation

This insulation shall be suitable for use in wet or dry locations at a temperature not exceeding 75°C. When tested in accordance with 6.22, the insulation shall have a dielectric strength retention of not less than 60 percent of the original value. Conductors having a nylon covering shall not show any cracks when subjected to the wrap test given in Part 6 (6.9.8). Wrinkles in the covering shall not constitute failure of this requirement.

3.3.6 Polyethylene (PE) Insulation

This insulation shall be suitable for use in wet or dry locations at a temperature not exceeding 75°C. The polyethylene material, prior to application to the conductor, shall comply with the requirements of ASTM D 1248 for Type I, Classes A, B, or C, Category 4 or 5, Grade E4 or E5. These requirements do not apply to insulation removed from the conductor. Conductors having a nylon covering shall not show any cracks when subjected to the wrap test given in Part 6. Wrinkles in the covering shall not constitute failure of this requirement.

3.3.7 Composite Insulation

This insulation shall be suitable for use in wet or dry locations at a temperature not exceeding 90°C. The composite insulation shall consist of an inner layer of Type I or Type II EP with an outer layer of insulating chlorosulfonated polyethylene (CSPE) or neoprene (CR). When the inner and outer insulating layers can be separated without injury to either layer, they shall be tested separately for compliance with the physical and aging requirements given in Table 3-2. When the layers cannot be separated, they shall be tested as a unit for compliance with the physical and aging requirements given in Table 3-2. The composite insulation, whether strippable or non-strippable, shall be tested as a unit to determine compliance with the electrical and moisture absorption requirements given in Table 3-2.

3.3.8 Synthetic Rubber (SBR) Insulation

This insulation is suitable for use at conductor temperatures not exceeding 75°C in dry locations and 60°C in wet locations.

3.3.9 Thermoplastic Elastomer (TPE) Insulation, Type I and Type II

This insulation shall be suitable for use in wet or dry locations at a temperature not exceeding 75°C or in dry locations only at a temperature not exceeding 90°C.

3.3.10 Jacket over Insulation

Jackets shall not be required over the individual conductors. However, if a jacket is used, it shall meet the minimum requirements of minimum average thickness of not less than 0.015 inch. The minimum thickness at any one point shall not be less than 80 percent of this value.

3.3.11 Repairs

When repairs in the insulation are required, they shall be made such that the repaired part meets the dielectric withstand requirements specified in 3.4 and the insulation resistance requirements specified in 3.5. The thickness of the repaired part shall conform to the thickness requirements given in 3.2.

3.4 VOLTAGE TESTS

Each production or shipping length of completed cable, when tested in accordance with ICEA T–27–581/NEMA WC 53 without immersion in water, shall withstand for five minutes either the ac test voltage given in Table 3-3, or a dc test voltage of three times the ac test voltage. The test voltage of the cable shall be based on the rated voltage of the cable and the conductor size and not on apparent thickness of the insulation.

3.5 INSULATION RESISTANCE

Each insulated conductor in the completed cable, when tested in accordance with ICEA T–27–581/NEMA WC 53, shall have an insulation resistance of not less than that corresponding to the applicable insulation resistance constant (K) specified in Table 3-2. The insulation resistance in gigaohms-1000 feet at a temperature of 15.6°C (60°F) shall not be less than the value of R calculated as follows:

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Table 3-2
INSULATION REQUIREMENTS

Properties	XLPE		EP Rubber		SR Rubber	CSPE Rubber	PVC	PE	Composite Insulation(d)						
									Separable Layers					Non-separable Layers	
									TPE		EP		CSPE or CR	Composite EP/CSPE or EP/CR	SBR
	Type I	Type II	Type I	Type II					Type I	Type II	Type I	Type II			
Initial Tensile Strength, minimum psi	1800	1800	700	1200	800	1500	2000	1400	1500	1500	700	1200	1500	1000	700
Initial Elongation at Rupture, minimum %	250	150	250	150	250	300	150	350	300	300	250	150	300	250	300
Tensile Stress,															
At ___ Percent Elongation,	...	...	...	100	...	...	...	...	...	...	...	100	...	...	...
Minimum, psi	...	...	...	500	...	...	...	...	...	...	...	500	...	...	...
Retention, minimum % of															
Tensile Strength	75	85	75	75	500(a)	85	80	75	75	75	75	75	85	75	80
Elongation	75	60	75	75	125(a)	50	75	75	75	75	75	75	40	50	60
After Air Oven Exposure at															
°C±1°C	121	121	121	121	200	121	121	100	121	121	121	121	121	121	100
For ___ Hours (indicated hours)	168	168	168	168	168	168	168	48	168	168	168	168	168	168	168
Retention, Minimum % of															
Tensile Strength	...	...	...	...	...	60	85	...	...	...	...	...	...	...	...
Elongation	...	...	...	...	...	60	85	...	...	...	...	...	...	...	...
After Oil Immersion															
°C±1°C	...	...	...	...	...	121	70	...	...	...	...	...	...	...	...
For ___ Hours (indicated hours)	...	...	...	...	...	18	4	...	...	...	...	...	...	...	...
Heat Distortion,															
Maximum %	30	30	...	...	...	...	25	...	25	25	...	...	...	...	...
at °C±1°C	121	121	...	...	...	...	121	...	121	121	...	...	...	...	...
Hot Creep @ 150°C±2°C	(e)	(e)	(e)	(e)	...	(e)	...	...	...	...	(e)	(e)	(e)	(e)	(e)
Ozone Resistance After 3 Hours Exposure	...	...	...	...	Pass	...	...	...	...	...	...	...	...	...	...
Heat Shock @ 121°C±1°C	...	...	...	...	...	...	No Cracks	...	...	...	...	...	...	...	...
Type A Flame Test	...	Pass	...	...	...	...	...	...	...	...	...	...	...	...	...
Type B Flame Test	...	...	...	...	...	Pass	Pass	...	...	Pass	...	...	...	...	...
Cold Bend After 1 Hour															
At °C±2°C	...	...	...	...	...	–25	–30	...	...	...	...	...	...	...	...
Minimum Requirement	...	...	...	...	...	No Cracks	No Cracks	...	...	...	...	...	...	...	...
Environmental Stress Cracking	...	...	...	...	...	...	...	No Cracks	...	...	...	...	...	...	...
Electrical Properties after Immersion in 75°C±1°C Water, Permittivity (SIC) after 24 Hours, Maximum	6.0	6.0	4.0	6.0	...	10.0	10.0	...	3.0	4.0	4.0	6.0	...	4.5	6.0

(Continued on next Page.)

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Table 3-2
INSULATION REQUIREMENTS

Properties	XLPE		EP Rubber		SR Rubber	CSPE Rubber	PVC	PE	Composite Insulation(d)						SBR
									Separable Layers					Non-separable Layers	
									TPE		EP		CSPE or CR	Composite EP/CSPE or EP/CR	
	Type I	Type II	Type I	Type II					Type I	Type II	Type I	Type II			
Increase in Capacitance, maximum %															
1–14 Days	3.0	4.0	3.5	5.0	10.0	6.0	4.0	...	3.0	4.0	3.5	5.0	...	3.5	10.0
7–14 Days	1.5	2.0	1.5	3.0	3.0	2.0	2.0	...	1.5	2.0	1.5	3.0	...	2.0	4.0
Stability Factor After 14 Days, maximum*	1.0	1.0	1.0	1.0	...	1.0	...	...	1.0	1.0	1.0	1.0	...	1.0	1.0
Alternate to Stability Factor, Maximum* Difference, 1–14 Days	0.5	0.5	0.5	...	...	0.5	...	...	0.5	0.5	0.5	...	...	...	0.5
Insulation Resistance Constant k @ 15.6°C, Minimum gigaohms-1000 ft(c)	10	10	20	10	4	1	2	50(b)	40	40	20	10	...	12	4
Mechanical Water Absorption Maximum Milligrams per Square Inch after 168 hours 70°C±1°C	...	...	...	...	...	...	...	...	...	...	...	...	35	35	20
Specific Surface Resistance, minimum gigaohms(c)	...	...	...	...	...	...	...	...	...	...	...	...	200	200	...

NOTES—

a. Values are minimum tensile strength (psi) and elongation (%) after exposure, not retained percentages.
b. Value shall be not less than 30, based on the sum of the thickness of the two layers, if a layer of PVC is applied over the PE.
c. It may be more convenient at times to express this value in megohms (1 gigaohm = 10^3 megohms).
d. See 3.3.7
e. For Engineering Information only.
f. A dash under any insulation indicates that a particular value for the applicable property is not required.

*Only one of these requirements needs to be satisfied, not both.

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Table 3-3
TEST VOLTAGES

Conductor Size, AWG	Kilovolts (ac-rms)							
	XLPE Types I & II	EP Types I & II	SR	SBR and CSPE	PVC	PE	TPE Types I & II	Composite EP/CSPE or EP/CR
				300 Volts				
22–19	2.0	2.5	1.0	1.0	1.0	1.5	1.5	2.5
18	2.0	2.5	1.0	1.0	1.0	2.0	2.0	2.5
16	2.0	2.5	1.0	1.0	1.0	2.0	2.0	2.5
14– 9	2.5	3.0	1.0	1.0	1.0	2.0	2.0	3.0
				600 Volts				
20–16	2.5	2.5	1.0	1.0	1.5	2.5	2.5	2.5
14– 9	3.0	3.0	4.5	4.5	3.0	3.0	3.0	3.0
				1000 Volts				
16	4.5	4.5	4.5	4.5	3.0	4.5	4.5	4.5
14– 9	4.5	4.5	6.0	6.0	3.5	4.5	4.5	4.5

$$R = K \log_{10} (D/d)$$

Where—
R = Insulation resistance in gigaohms-1000 feet
K = Constant for insulation in gigaohms-1000 feet
D = Diameter over insulation
d = Diameter under insulation

3.5.1 Resistance measurements taken at temperatures other than 15.6°C shall be converted to readings at 15.6°C by use of an appropriate factor according to ICEA T–27–581/NEMA WC 53.

3.5.2 When a nonconducting separator is applied between the conductor and the insulation or when an insulated conductor is individually covered with a non-metallic jacket, the insulation resistance shall not be less than 60 percent of that required for the insulation based on the thickness of the insulation.

3.5.3 Exception: The 60 percent reduction does not apply to composite insulations (see 3.3.7).

3.6 TYPE A FLAME TEST

When tested in accordance with 6.16.1, a single conductor specimen of a multiple conductor cable shall not burn longer than 1 minute after any flame application. Not more than 25 percent of the extended portion of the indicator shall be burned. The cotton under the specimen shall not be ignited by flaming particles or drippings from the specimen. Flameless charring of the cotton shall be disregarded.

3.7 TYPE B FLAME TEST

When tested in accordance with 6.16.2, a single conductor specimen of a multiple conductor cable shall not burn longer than 1 minute after the last flame application. Not more than 25 percent of the extended portion of the indicator shall be burned.

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Part 4
SHIELDINGS AND COVERINGS

4.1 SHIELDING—GENERAL

Shielding of control cables is for the purpose of reducing or eliminating (1) electrostatic interference between conductors or groups of conductors within the cable or (2) outside interference induced on cable conductors or groups of conductors. Electrostatic shields are non-magnetic metal tapes or braids or a concentric serve or wrap applied over one or more of the cable conductors. A shield, when used, shall meet the requirements of one of the shield types described in 4.1.3 or 4.1.4 or 4.1.5. This standard does not cover methods for reducing electromagnetic interference. (Consult the manufacturer for recommendations.)

4.1.1 Shield Continuity

Each shield shall be electrically continuous throughout the cable length (see 6.20).

4.1.2 Shield Isolation

When necessary to allow for single point grounding, shields shall be electrically insulated or isolated from other metallic cable components such as other shields and grounding conductors. Such isolation may be achieved by covering the shield with a coating, tape, or jacket. (This sentence has been approved by NEMA as Authorized Engineering Information.)

When shield isolation is necessary, the insulation resistance between shields shall not be less than 1 megohm based on 1000 cable feet or a 600-volt dc voltage shall be applied between shields without failure (see 6.21).

4.1.3 Metal Tape Shields

Metal tape shields shall be smooth or corrugated and provide 100 percent coverage of the enclosed conductors. They shall be applied either helically or longitudinally with an overlap of sufficient width to prevent opening during normal bending during installation, but not less than $\frac{3}{16}$ inch or $12\frac{1}{2}$ percent of the tape width, whichever is greater. Metal tapes shall be a non-magnetic material such as copper, copper alloy, or aluminum. Metal tapes may be coated or uncoated, all metal or laminated to a non-metallic backing or reinforcement. Drain wires (see 4.1.3.1) shall be used in conjunction with tapes in which the thickness of the metal is less than or equal to 0.001 inch.

4.1.3.1 Drain Wires

Drain wires shall be copper or coated copper in accordance with Part 2 and not smaller than #22 AWG. Coated wires shall be used in conjunction with aluminum tape shields to protect against electrolytic corrosion. Drain wires shall be positioned adjacent to the metal tape so as to maintain effective grounding contact and shall be considered an integral part of the shield.

4.1.4 Metal Braid Shields

When shielding is applied in the form of a braid, the coverage shall be determined by the following formula:

$$\text{Percent Coverage} = 100\,(2F - F^2)$$

Where:

$$F = NP \times \frac{d}{\sin \alpha}$$

α = Angle of braid wires with longitudinal axis of enclosed core = $\tan^{-1}\,[2\pi\,(D + 2d)\,P/C]$, degrees

D = Diameter of core under shield, inches

d = Diameter of individual braid wires, inches

C = Number of carriers

F = Fill or space factor

N = Number of braid wires per carrier

P = Picks per inch

4.1.5 Metal Wire Shields

When shielding is applied in the form of a serving or wrap, the coverage shall be determined by the following formula:

$$\text{Percent Coverage} = Nd/W \times 100$$

Where:

N = Number of parallel wires

d = Diameter of individual wires in inches

$W = \pi D \cos \alpha$

D = Diameter under shield in inches

α = Angle between serve wires and axis of cable

$\text{Tan}\ \alpha = \pi D/C$

C = Pitch or lay of serving in inches

4.2 JACKETS

Jackets shall be either thermoplastic or crosslinked and shall be one of the materials shown below:

1. Polyvinyl Chloride (PVC),
2. Black Polyethylene (PE),
3. Styrene-Butadiene Rubber (SBR),
4. Chloroprene (Neoprene) Rubber (CR),
5. Nitrile-Butadiene/Polyvinyl Chloride (NBR/PVC),
6. Chlorosulfonated Polyethylene (CSPE),
7. Chlorinated Polyethylene (CPE) (Thermoplastic),
8. Chlorinated Polyethylene (CPE) (Crosslinked),
9. Natural Rubber (NR), or
10. Thermoplastic Elastomer (TPE).

Because of different maximum temperature ratings of the insulations given in Part 3, not all of the materials given

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above are necessarily suitable for all insulations or all applications. Consult the manufacturer for further information. (This paragraph approved by NEMA as Authorized Engineering Information.)

4.2.1 Thickness

The minimum average thickness shall not be less than as specified in Table 4-1. The minimum thickness at any one point shall not be less than 80 percent of the specified value.

Table 4-1
JACKET THICKNESS, INCHES

Calculated Diameter of Cable under Jacket*	Thickness
0–0.425	0.045
0.426–0.700	0.060
0.701–1.500	0.080
1.501–2.500	0.110
2.501 and larger	0.140

*For flat twin cable, use the calculated major core dimension under the jacket to determine the jacket thickness.

4.2.2 Requirements

The jacket shall meet the applicable requirements specified in Table 4-2 according to the test methods given in Part 6.

4.2.3 Binder

A separator or binder tape may be used under the overall jacket. (This sentence has been approved by NEMA as Authorized Engineering Information.)

4.3 METALLIC AND ASSOCIATED COVERINGS

This section covers requirements for optional metallic and associated coverings recommended for use where normal conditions of installation and service for control cables exist. Where unusual conditions exist, modifications may be necessary. These conditions shall be defined before the cable design is completed. When tested according to the appropriate methods in ICEA T–27–581/NEMA WC 53, metallic coverings shall meet the applicable requirements given herein.

4.3.1 Types of Metallic Coverings

The following types of metallic coverings apply:

1. Interlocked metal tape armor (see 4.3.3).
2. Galvanized steel wire armor (see 4.3.4).
3. Flat metal tape armor (see 4.3.5).
4. Continuously corrugated metal armor (see 4.3.6).

4.3.2 Core Covering for Nonshielded and Nonjacketed Cable with Metallic Armor

A covering of tape, braid, or jute or other material, or combinations thereof, shall be applied over the core of nonsheathed and nonjacketed cable to act as a protective bedding. If multiple layers are used, they shall be laid in opposite directions.

4.3.3 Interlocked Metal Tape Armor

This section covers flat metal strip used to form interlocked armor. All tests shall be made prior to the application of the strip to the cable.

4.3.3.1 TAPE MATERIAL

The flat metal strip shall be one of the following:

1. Plain and zinc-coated flat steel strip-in coils for use as flat armor for electrical cables. The zinc coating shall be applied by either hot-dip or the electro-galvanizing process such that all surfaces of the finished tape width are coated, including edges. The strip shall meet the requirements given in 4.3.3.4.
2. Non-magnetic metal tapes, e.g., aluminum, brass, bronze, zinc, Ambrac*, Monel*, and stainless steel. Representative values of tensile strength and elongation are given in Appendix C for information only.

*Trade Names—The listing of these materials implies no endorsement by this standard.

4.3.3.2 WIDTH

The width of a metal tape shall be permitted to be less than, but not greater than the value specified in Table 4-3. For any width of metal tape used, the tolerance in width shall not be more than plus 0.010 inch and minus 0.005 inch, except for aluminum that shall not be more than ±0.010 inch.

Table 4-3
WIDTH OF METAL TAPE
FOR INTERLOCKED ARMOR, INCHES

Calculated Diameter of Cable Under Armor*	Maximum Width of Metal Tape Armor
0.500 or less	0.500
0.501–1.000	0.750
1.001–2.000	0.875
2.001 and larger	1.000

*For flat twin cable the maximum width shall be based on the calculated major core dimension.

4.3.3.3 THICKNESS

The average thickness of a metal tape shall be as specified in Table 4-4. For any thickness of metal tape used, the tolerance in thickness of an individual tape shall not be more than ±0.003 inch. The thickness of a zinc-coated tape

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Table 4-2
JACKET REQUIREMENTS

Properties	Thermoplastic Jackets					Crosslinked Jackets								
				TPE		General Purpose						Heavy Duty		
	PVC	PE	CPE	General Purpose	Heavy Duty	NR	SBR	CR	NBR/PVC	CPE	CR	NBR/PVC	CSPE	CPE
Initial Tensile Strength, minimum psi	1500	1400	1400	1500	1800	3500	1800	1500	1500	1500	1800	1800	1800	1800
Initial Elongation at Rupture, Minimum %	100	350	150	350	350	500	300	250	250	300	300	300	300	300
Tensile Stress at 200% Elongation, Minimum psi	...	...	1000•	...	400	500	...	...	...	...	500	500	500	500
Set, Maximum %	...	...	...	...	...	15	20	20	20	35	20	30	30	30
Retention, Minimum% of														
Tensile Strength	85	75	85	75	75	2500•	1600•	50	50	55	50	50	85	85
Elongation	60	75	50	75	75	400•	300•	50	50	55	50	50	65	55
After Air Oven Exposure at														
°C±1°C	100	100	121	121	121	70	70	100	100	100	100	100	100	100
For ___ Hours (indicated hours)	120	48	168	168	168	96	168	168	168	168	168	168	168	168
Retention, Minimum % of														
Tensile Strength	80	...	60	75	75	...	...	60	60	60	60	60	60	60
Elongation	60	...	60	75	75	...	...	60	60	60	60	60	60	60
After Oil Immersion														
at °C±1°C	70	...	100	70	70	...	...	121	121	121	121	121	121	121
For ___ Hours (indicated hours)	4	...	18	4	4	...	...	18	18	18	18	18	18	18
Heat Distortion,														
Maximum %	50	...	25	25	25	...	...	...	...	...	...	...	...	...
At °C±1°C	121	...	121	121	121	...	...	...	...	...	...	...	...	...
Heat Shock 121°C±1°C	No Cracks	...	...	...	...	...	...	...	...	...	...	...	...	...
Cold Bend after 1 hour														
at °C±2°C	–35	...	–35	...	...	...	...	...	...	...	...	...	...	...
Requirement	No Cracks	...	No Cracks	...	...	...	...	...	...	...	...	...	...	...
Environmental Stress Cracking	...	No Cracks	...	...	...	...	...	...	...	...	...	...	...	...
Absorption Coefficient, Minimum Milli (Absorbance/Meter)	...	320*	...	...	...	...	...	...	...	...	...	...	...	...

*In lieu of testing finished cable jackets, a certification by the manufacturer of the polyethylene compound that his requirement has been completed shall suffice.
•Values are minimum tensile strength (psi) and elongation (%) after exposure, not retained percentages.
•Elongation shall be 100 percent.

shall not be more than 20 percent greater than the thickness of the tape stripped of its coating. The thickness tolerance of bare metal tape shall apply to the stripped tape.

Table 4-4
THICKNESS OF METAL TAPE FOR INTERLOCKED ARMOR, INCHES

Calculated Diameter of Cable Under Armor*	Ambrac•, Brass, Stainless Steel, Bronze, and Monel•	Aluminum and Zinc	Plain Steel and Galvanized Steel
1.000 or less	0.020	0.025	0.020
1.001–1.500	0.020	0.025	0.020
1.501 and larger	0.025	0.030	0.025

* For flat twin cable, the thickness shall be based on the calculated major core dimension.

•Trade Names—The listing of these materials implies no endorsement; rather, it shows them as being typical of materials commercially available at the time of printing.

4.3.3.4 PLAIN AND ZINC-COATED STEEL TAPE REQUIREMENTS

4.3.3.4.1 TENSILE STRENGTH AND ELONGATION

The plain and zinc-coated strip shall have a tensile strength of not less than 40,000 psi nor more than 70,000 psi. The tensile strength shall be determined on longitudinal specimens consisting of the full width of the strip when practical or on a straight specimen slit from the center of the strip. The strip shall have an elongation of not less than 10 percent in 10 inches. The elongation shall be the permanent increase in length of a marked section of the strip originally 10 inches in length, and shall be determined after the specimen has fractured. All tests shall be made prior to application of the strip to the cable.

4.3.3.4.2 GALVANIZING TESTS

a. Weight of Zinc Coating
The weight of zinc coating shall be determined before application of the strip to the cable. The strip shall have a minimum weight of coating of 0.35 ounce per square foot (106.8 grams/meter^2) of exposed surface. The weight of coating specified is the total amount on both surfaces and edges and shall be determined in accordance with the method described in ASTM A 90.

b. Adherence of Coating
The zinc coating shall remain adherent without flaking or spalling when the strip is subjected to a 180-degree bend over a mandrel ⅛ inch in diameter. The zinc coating shall be considered as meeting this requirement if, when the strip is bent around the specified mandrel, the coating does not flake and none of it can be removed from the strip by rubbing with the fingers.

Loosening or detachment during the adherence test of superficial, small particles of zinc formed by mechanical polishing of the surface of the zinc-coated strip shall not constitute failure.

4.3.4 Galvanized Steel Wire Armor

This section covers zinc-coated low-carbon steel wire for use as a served wire armor. The steel wire shall meet the requirements of ASTM A 411 prior to armoring. The weight of zinc coating shall be in accordance with Table 4-5.

Table 4-5
MINIMUM WEIGHTS OF ZINC COATING FOR WIRE ARMOR

Nominal Diameter of Coated Wire, Inch	Nominal Wire Size, BWG	Ounces per Square Foot of Exposed Wire Surface
0.022	24	0.30
0.028	22	0.30
0.035	20	0.40
0.049	18	0.40
0.065	16	0.50
0.083	14	0.60

4.3.4.1 SIZE OF ARMOR

The nominal size of the served armor wires shall be as given in Table 4-6.

Table 4-6
SIZE OF GALVANIZED STEEL WIRE ARMOR

Calculated Diameter of Cable under Armor or Bedding, Inch*	Nominal Wire Size	
	BWG	Inch
0.250 or Less	24	0.022
0.251–0.350	22	0.028
0.351–0.500	20	0.035
0.501–0.670	18	0.049
0.671–0.900	16	0.065
0.901–1.200	14	0.083
1.201 and Larger	(Consult Manufacturer)	

*For flat twin cable, the wire size shall be based on the calculated major core dimension.

4.3.4.1.1 The tolerances of the diameters of the galvanized wire shall be as given in Table 4-7.

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Table 4-7
GALVANIZED STEEL WIRE DIAMETER TOLERANCES, INCHES

Wire Diameter	Tolerance
0.020–0.064	±0.002
0.065 and larger	±0.003

4.3.4.1.2 The number of wires used in a serve over any given core shall be adjusted to yield a coverage of not less than 85 percent (see 4.1.5).

4.3.4.2 Length of Armor Wire Lay

The length of lay of the armor wires shall not be less than seven nor more than 12 times their pitch diameter.

"Lay" is defined as follows: "The lay of any helical element of a cable is the axial length of a turn of the helix of that element."

"Pitch Diameter" is defined as the core diameter plus the diameter of one armor wire. If the armor is applied over a bedding (see 4.3.2), the armor and bedding shall be laid in opposite directions.

4.3.5 Flat Metal Tape Armor

This section covers flat metal strip for use as flat armor. All tests shall be made prior to the application of the strip to the cable.

4.3.5.1 Tape Material

See 4.3.3.1.

4.3.5.2 Width

The nominal width of metal tape may be less than, but not greater than, the values given in Table 4-8. For nominal widths of 1.000 inch or less, the tolerance in width for an individual tape shall be ±0.030 inch. For nominal widths greater than 1.000 inch, the tolerance in width for an individual tape shall be ±0.045 inch.

Table 4-8
WIDTH OF METAL TAPE FOR FLAT ARMOR, INCHES

Calculated Diameter of Cable Under Bedding*	Maximum Width of Metal Tape
0.450 or less	0.750
0.451–1.000	1.000
1.001–1.400	1.250
1.401–2.000	1.500
2.001–3.500	2.000
3.501 and larger	3.000

*For flat twin cable, the maximum width shall be based on the calculated major core dimension.

4.3.5.3 Thickness

The thickness of metal tape, for metals other than steel, is not specified and shall be as agreed upon between the user and manufacturer. The thickness of steel tape shall be as given in Table 4-9.

Table 4-9
NOMINAL THICKNESS OF STEEL TAPE (PLAIN OR ZINC COATED), INCHES

Calculated Diameter under Armor	Nominal Thickness of Tape
1.000 or less	0.020
1.001 and larger	0.030

4.3.5.4 Application, Lay, and Spacing

One or two tapes shall be applied helically over the bedding (see 4.3.2). When two tapes are used and the total cross-sectional area of the conductors is 50,000 circular mils or greater, the two tapes shall be applied in the same direction.

When the outer tape is applied in the same direction as the inner tape, the outer tape shall be approximately centered over the (butt) spaces between the convolutions of the inner tape. The maximum (butt) space between the turns shall not exceed 20 percent of the width of the tape or 0.20 inch, whichever is greater.

When required, a corrosion-inhibiting compound shall be applied to plain metal tapes.

4.3.6 Continuously Corrugated Metal Armor

This section covers continuously corrugated metal armor. The metal armor is formed from a flat metal tape that is longitudinally folded around the cable core, seam welded, and corrugated or by applying over the cable core a seamless sheath or tube that is then corrugated.

4.3.6.1 Type of Metal

When metal armor is formed from a flat metal tape, the tape used shall be aluminum, copper, steel, or alloys thereof.

When metal armor is formed by applying a seamless sheath or tube, the metal shall be aluminum or an aluminum alloy.

4.3.6.2 Thickness

The minimum thickness of the tape or of the sheath or tube before corrugation shall be as shown in Table 4-10.

4.3.6.3 Flexibility

The armored cable shall be capable of being bent around a mandrel having a diameter of 14 times the cable diameter. The armor shall show no evidence of fracture visible to the unaided eye. The test shall be conducted in accordance with the procedure given in Part 6.

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4.3.6.4 Corrosion Protection

When required, a corrosion-protective covering shall be applied over the armor.

The cable manufacturer should be consulted for recommendations for corrosion protection. (This sentence has been approved by NEMA as Authorized Engineering Information.)

Table 4-10
MINIMUM THICKNESS OF METAL FOR CORRUGATED ARMOR, INCHES

Calculated Diameter of Cable under Armor	Aluminum	Copper	Steel
2.180 or less	0.022	...	...
2.181–3.190	0.029	...	...
3.190–4.200	0.034	...	...
2.365 or less	...	0.017	...
2.366–3.545	...	0.021	...
3.546–4.200	...	0.025	...
1.905 or less	...	...	0.016
1.906–3.050	...	...	0.020
3.051–4.200	...	...	0.024

4.3.7 Thermoplastic or Crosslinked Coverings over Metallic Armor

Thermoplastic or crosslinked coverings, when used, shall be extruded either directly over the metallic armor or over an optional separator or binder tape located between the armor component and overall jacket. The overall covering and tape shall conform to the core. The coverings shall be one of the types given in 4.2 and shall meet the requirements of 4.2 except that the thickness shall be in accordance with 4.3.7.1.

4.3.7.1 Thickness

The average thickness of the covering shall not be less than as specified in Table 4-11. The minimum thickness at any point shall not be less than 70 percent of the specified value. The minimum and maximum thickness of the coverings shall be determined per the method described in 6.11.

Table 4-11
THICKNESS OF COVERING OVER METALLIC ARMOR, INCHES

Calculated Diameter of Cable over Armor	Thickness	
	Interlocked or Corrugated Armor	All Other Armor
0.425 or less	0.040	0.050
0.426–1.500	0.050	0.065
1.501–2.250	0.060	0.080
2.251–3.000	0.075	0.095
3.001 and larger	0.085	0.110

4.3.7.2 Irregularity Inspection

Jackets shall not have irregularities as determined by the jacket irregularity inspection procedure of 3.8 of ICEA T–27–581/NEMA WC 53. The methods to be used are:

Method A	Method B	Method C
Chloroprene (Neoprene) Rubber (CR)	Natural Rubber (NR)	Polyvinyl Chloride (PVC)
Thermoplastic Elastomer (TPE)	Styrene-Butadiene Rubber (SBR)	Polyethylene (PE)
	Chlorinated Polyethylene (CPE) Thermoplastic	Chlorinated Polyethylene (CPE), Crosslinked
	Nitrile-butadiene/ Polyvinyl Chloride (NBR/PVC)	
	Chlorosulfonated Polyethylene Rubber (CSPE)	

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Part 5
ASSEMBLY, FILLERS, AND CONDUCTOR IDENTIFICATION

5.1 ASSEMBLY OF MULTIPLE CONDUCTOR CABLES

5.1.1 Round Cables

When cables consist of one layer of conductors, the layer shall have a left-hand lay; when there is more than one layer, the outer layer shall have a left-hand lay. A left-hand lay is defined as a counterclockwise twist away from the observer.

The length of lay of the individual conductors or subassemblies in the outer layer of cables shall not exceed the value calculated from the factors given in Table 5-1. Where there is more than one layer of conductors or subassemblies, the inner layers shall have a length of lay not greater than those in the outer layer unless the inner layer consists of a single conductor or subassembly.

5.1.2 Flat Twin Cables

Flat twin cables shall consist of two insulated conductors laid parallel.

5.2 FILLERS

Fillers shall be used in the interstices of round cables where necessary to give the completed cable a substantially circular cross-section.

5.3 BINDERS

A separator or binder tape may be used under the overall jacket.

5.4 CONDUCTOR IDENTIFICATION

When required, conductors shall be identified by any suitable means.

See Appendix E for recommendation. (This sentence approved by NEMA as Authorized Engineering Information.)

Table 5-1
FACTORS FOR MAXIMUM LAY LENGTH

Number of Conductors or Subassemblies in Cable	Multiplying Factors Based on Calculated Diameter
2	30 times largest conductor or subassembly diameter
3	35 times largest conductor or subassembly diameter
4	40 times largest conductor or subassembly diameter
5 or more	15 times assembled cable diameter

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Part 6
TESTING AND TEST METHODS

6.1 TESTING—GENERAL

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

6.2 CONDUCTOR TEST METHODS

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

6.3 THICKNESS MEASUREMENTS FOR INSULATIONS AND NONMETALLIC JACKETS

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

6.4 PHYSICAL AND AGING TESTS FOR INSULATIONS AND JACKETS

6.4.1 Size and Preparation of Specimens

The test specimens shall be of suitable length, shall have no surface incisions, and shall be as free as possible from other imperfections.

For insulated wire, the test specimen shall be taken prior to the application of any additional coverings and shall be the entire cross-section of the insulation. See 3.3.7 for composite insulations. The specimens shall not be cut longitudinally.

Exception: If it is not possible to obtain a specimen of insulation prior to the application of a covering, the specimen shall be taken after the application of a covering, provided such covering can be removed without injury to the insulation.

Specimens for tests on jacket compounds shall be taken from the completed wire or cable and cut parallel to the axis of the wire or cable. The test specimen shall be a suitable cut segment or a shaped specimen cut out with a die, and shall have a cross-sectional area not greater than 0.025 square inch after irregularities, corrugations, and reinforcing cords or wires have been removed.

6.4.2 Calculation of Test Specimen Area

6.4.2.1 When the total cross-section of the insulation is used, the area shall be taken as the difference between the area of the circle whose diameter is the average outside diameter of the insulation and the area of the conductor. The area of a stranded conductor shall be calculated from its maximum diameter.

6.4.2.2 Where a slice cut from the insulation by a knife held tangent to the wire is used and when the cross-section of the slice is the cross-section of a segment of a circle, the area shall be calculated as that of the segment of a circle with a diameter that is that of the insulation. The height of the segment is the wall of insulation on the side from which the slice is taken. (The values may be obtained from a table giving the areas of segments of a unit circle for the ratio of the height of the segment to the diameter of the circle.*)

*This sentence is approved by NEMA as Authorized Engineering Information.

When the cross-section of the slice is not a segment of a circle, the area shall be calculated from a direct measurement of the volume or from the specific gravity and the weight of a known length of the specimen having a uniform cross-section.

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

6.4.3 Physical Test Procedures

Physical tests on both the unaged and aged test specimen shall be made approximately at the same time.

6.4.3.1 TEST TEMPERATURE

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

6.4.3.2 TYPE OF TESTING MACHINE

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

6.5 TENSILE STRENGTH TEST

The tensile strength test shall be made on specimens prepared in accordance with 6.4.2 and 6.4.3. The length of all the specimens for the test shall be equal. Specimens shall have a length of 4.5 or 6 inches. ASTM D 412 Die C or D shall be used with specimens at least 4.5 inches in length with the gauge marks placed 1 inch apart. ASTM D 412 Die B or E shall be used with specimens at least 6 inches in length with the gauge marks placed 2 inches apart except that 1-inch gauge marks shall be used for polyethylene regardless of specimen length.

Cross-sectional area between gauge marks shall be determined in accordance with 6.4.2. The jaws of the testing machine for 6-inch long specimens shall be 4 inches apart. The jaws of the testing machine for 4.5 inch long specimens shall be 2.5 inches apart. Each specimen shall be stretched at the rate of 20±2 inches per minute (jaw speed)

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until it breaks. The tensile and elongation determinations for polyethylene compounds for which the compound manufacturer certifies that the base resin content is more than 50 percent by weight of high density polyethylene (having a density of 0.926 mg/m^3 or greater), shall be permitted to be tested at a jaw separation rate of 2 inches per minute as an alternate to 20 inches per minute. The tensile strength shall be calculated in accordance with ASTM D 412. Specimens shall break between the gauge marks and the tensile strength shall be calculated on the area of the unstretched specimen. Specimen length, gauge mark distance, and jaw speed shall be recorded with the results.

6.6 TENSILE STRESS TEST

The tensile stress test shall be made in conjunction with the tensile strength test by recording the load when the gauge marks indicate that the specimen is at its prescribed elongation. The tensile stress shall be calculated in accordance with ASTM D 412.

6.7 ELONGATION TEST

Elongation at rupture shall be determined simultaneously with the test for tensile strength and on the same specimen. The elongation shall be taken as the distance between gauge marks at rupture less the original gauge length of the test specimen. The percentage of elongation at rupture is the elongation divided by the original gauge length and multiplied by 100.

6.8 SET TEST

The set test shall be made on 6-inch long test specimens that have been prepared, marked with 2-inch gauge marks and stretched in accordance with 6.6 until the gauge marks are 6 inches apart. The test specimen shall be held in the stretched position for 5 seconds and then released. The distance between gauge marks shall be determined 1 minute after the release of tension. The set is the difference between this distance and the original 2-inch gauge length, expressed as a percentage of the original gauge length.

6.9 AGING TESTS

6.9.1 Test Specimens

Test specimens of similar size and shape shall be prepared in accordance with 6.4.1. When the entire cross-section of insulation is used, the insulation shall be subjected to the aging condition with the conductor removed. Simultaneous aging of different compounds should be avoided. (This sentence is approved by NEMA as Authorized Engineering Information.)

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

The aged specimens shall have a rest period at room temperature of not less than 16 hours nor more than 96 hours between the completion of the aging tests and the determination of tensile strength and elongation.

6.9.2 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 within ±1°C and recorded continuously.

6.9.3 Oil Immersion Test

The test specimens shall be immersed in ASTM Oil No. 2 (described in Table I of ASTM D 471) for the specified time and at the specified temperature. At the end of this period, the specimen shall be removed from the oil, blotted lightly, and allowed to rest at room temperature for 4±½ hours before being tested for tensile strength and elongation. The calculations for tensile strength shall be based on the cross-sectional area of the specimen obtained before immersion in oil. The elongation shall be based on gauge marks applied to the specimen before immersion in oil.

6.9.4 Hot Creep Test

See ICEA T-28-562.

6.9.5 Heat Distortion for Insulated Conductors

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

6.9.6 Heat Distortion for Thermoplastic Jackets

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

6.9.7 Heat Shock for Thermoplastic Jackets

A sample of jacketed cable shall be wound tightly around a mandrel having a diameter in accordance with Table 6-1. The specimen shall be held firmly in place and shall be subjected to a temperature of 121°C±1°C for 1 hour. At the end of the test period, the specimen shall be examined for cracking of the jacket.

6.9.8 Nylon Wrap Test

The specimen with the nylon-covered insulated conductor shall be taken from the completed cable and wrapped four turns around a smooth metal mandrel having a diameter not more than six times that of the specimen. The ends of the specimen shall be secured to the mandrel so that four completed turns of the specimen will be exposed to the air between the secured ends. The specimen and mandrel shall be suspended for 24 hours in a full-draft circulating air oven at a temperature of 95°C±2°C after which the specimen and mandrel shall be removed from the oven and cooled for 1 hour in a silica-gel desiccator or the equivalent at room temperature. The specimen shall be straightened

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immediately upon removal from the desiccator and inspected for surface cracks.

Table 6-1
MANDREL DIAMETER
FOR HEAT SHOCK OF JACKET

Outside Diameter of Cable (Inch)	Number of Adjacent Turns	Diameter of Mandrel as a Multiple of Outside Cable Diameter, Inch
0.750 or less	6	3
0.751–1.500	180 degree bend	8
1.501 and larger	180 degree bend	12

6.10 OZONE RESISTANCE TEST

The test shall be made in accordance with ASTM D 470. The ozone concentration shall be 0.025 to 0.030 percent by volume.

6.11 THICKNESS OF COVERINGS

See ICEA T–27–581/NEMA WC 53.

6.12 ENVIRONMENTAL CRACKING

The test shall be made in accordance with ASTM D 1693, Condition I.

6.13 ABSORPTION COEFFICIENT

The absorption coefficient of jacket compounds shall be determined in accordance with ASTM D 3349.

6.14 ACCELERATED WATER ABSORPTION

6.14.1 General

The test shall be performed on one of the insulated conductors taken from the completed cable with all coverings over the insulation removed. Composite insulations shall be tested with both insulation layers in place over the conductor (see 3.3.7).

Insulated conductors having a nonconducting separator between the insulation and conductor or having a covering that cannot be removed without damage to the insulation shall not be tested. In that case, a representative 22–16 AWG conductor having the same insulation and an insulation thickness applicable to the voltage rating shall be tested.

The length of each sample required by the electrical method shall be 15 feet and by the gravimetric method 11 inches.

6.14.2 Electrical Method (EM-60)

See ICEA T–27–581/NEMA WC 53. Crosslinked insulation shall be tested 48 hours or more after crosslinking. Thermoplastic insulations shall be tested any time after extrusion.

Capacitance See ICEA T–27–581/NEMA WC 53

Stability Factor See ICEA T–27–581/NEMA WC 53

Permittivity (SIC) The permittivity of the insulation at 60 Hz shall be calculated as follows:
Permittivity = 13600 C $\log_{10}$ D/d
Where:
C = Capacitance in microfarads of the 10-foot section
D = Diameter over the insulation
d = Diameter under the insulation

6.14.3 Gravimetric Method

See ICEA T–27–581/NEMA WC 53.

6.15 COLD BEND

See ICEA T–27–581/NEMA WC 53. The mandrel shall have a diameter in accordance with Table 6-2.

Table 6-2
MANDREL DIAMETER FOR COLD BEND OF WIRE OR CABLE, INCHES

Outside Diameter of Wire or Cable	Diameter of Mandrel as a Multiple of Outside Wire or Cable Diameter
0.800 or less	8
0.801 and larger	10

6.16 FLAME TESTING

6.16.1 Type A

6.16.1.1 APPARATUS

The test apparatus shall consist of the following:

a. Test chamber of sheet metal 12 inches wide, 14 inches deep, and 24 inches high, that is open at the top and that is provided with means for clamping the test specimen at the upper end and supporting it in a vertical position.
b. Means for adjusting the position of the test specimen.
c. A suitable means to keep the specimen taut.
d. Tirrill Burner with an attached pilot light and mounted on a 20-degree angle block. The burner shall have a nominal bore of $\frac{3}{8}$ inch and a length of approximately 4 inches above the primary air inlets.
e. An adjustable steel angle (jig) attached to the bottom of the chamber to insure the correct location of the burner with relation to the test specimen.

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f. Gas (a supply of ordinary illuminating gas at normal pressure).
g. Watch or clock with a hand that makes one complete revolution per minute.
h. Flame indicators consisting of strips of gummed kraft paper having a nominal thickness of 5 mils and a width of ½ inch.*
i. Untreated surgical cotton.

*The paper used for the indicators is known to the trade as 60-pound stock and is material substantially the same as that described in federal specification UU-T-111 covering tape, paper, gummed (kraft). (This paragraph is approved by NEMA as Authorized Engineering Information.)

6.16.1.2 PREPARATION

The test shall be made in a room that is generally free from drafts of air, although a ventilated hood may be used if air currents do not affect the flame. One end of the test specimen, approximately 22 inches in length, shall be clamped tautly in a vertical position. A paper indicator shall be applied to the specimen so that the lower edge is 10 inches above the point at which the inner blue cone of the test flame is to be applied. The indicator shall be wrapped once around the specimen, with the gummed side toward the conductor. The ends shall be pasted evenly together and shall project ¾ inch from the specimen on the opposite side of the specimen to that which the flame is to be applied. The paper tab shall be moistened only to the extent necessary to permit proper adhesion. The height of the flame with the burner vertical shall be adjusted to 5 inches, with an inner blue cone 1½ inches high.

The temperature at the top of the inner blue cone shall be not less than 836°C.

A flat horizontal layer of untreated surgical cotton shall be placed on the floor of the chamber and centered directly under the specimen. The upper surface of the cotton shall be no more than 9½ inches from the point at which the inner blue cone touches the cable surface.

6.16.1.3 PROCEDURE

The burner, with only the pilot lighted, shall be placed in front of the sample so that the vertical plane through the stem of the burner includes the axis of the wire or cable. The angle block shall rest against the jig, that shall be adjusted so that there is a distance of 1½ inches along the axis of the burner stem between the top of the stem and the surface of the specimen. The valve supplying the gas to the burner proper shall then be opened and the flame automatically applied to the sample. This valve shall be held open for 15 seconds and then closed for no less than 15 seconds, then reopened for 15 seconds, closed for no less than 15 seconds, and such, for a total of five 15-second flame applications. The flame shall not be reapplied until flaming of the specimen ceases of its own accord. During each application of flame, the position of the burner or specimen shall be adjusted, as necessary, so that the tip of the inner blue cone just touches the surface of the specimen.

6.16.2 Type B

6.16.2.1 APPARATUS

See 6.16.1.1, except delete item (i).

6.16.2.2 PREPARATION

See 6.16.1.2, except delete cotton layer.

6.16.2.3 PROCEDURE

See 6.16.1.3, except the gas valve shall be closed for 15±0 seconds after each application, then reopened and the flame reapplied to the specimen regardless if the specimen is flaming or not.

6.17 VOLTAGE TESTS

See ICEA T-27-581/NEMA WC 53. The voltage shall be applied between each insulated conductor with all other conductors and any metallic sheath, metallic shield, or metallic armor connected to ground.

6.17.1 AC Voltage Test

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

6.17.2 DC Voltage Test

See ICEA T-27-581/NEMA WC 53. This test shall be made after the insulation resistance test.

6.17.3 AC Spark Test

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

6.18 INSULATION RESISTANCE

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

6.18.1 Determination of Temperature Conversion Factors for Insulation Resistance

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

6.19 SPECIFIC SURFACE RESISTIVITY

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

6.20 SHIELD CONTINUITY

Shield continuity shall be determined using any method. For example, a low voltage buzzer or light circuit or dc resistance method may be used.

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6.21 SHIELD ISOLATION

Shield isolation shall be determined using either of the methods below:

a. Insulation Resistance Method—Using the apparatus specified in ICEA T–27–581/NEMA WC 53, the insulation resistance shall be measured between each shield with all other shields and any bare conductor connected to ground potential.

b. Dielectric Method—Using the apparatus specified in ICEA T–27–581/NEMA WC 53, the appropriate voltage shall be applied for 1 minute between each shield with all other shields and any bare conductor connected to ground potential.

6.22 DIELECTRIC STRENGTH RETENTION

Twenty samples, each at least 5 feet long, shall be cut from a reel or coil.

Ten identified samples shall be immersed, except for the ends, for 14 days in water at the specified temperature. Immediately thereafter, all 20 samples shall be immersed, except for the ends, in water at 20°C to 30°C for one hour. At least 3 feet of each sample shall be immersed.

After the 20 samples have been immersed, an ac test voltage, starting at zero, shall be applied across the insulation and increased at the rate of 500 volts per second until breakdown occurs.

The dielectric strength retention shall be calculated as follows:

$$\text{Dielectric strength retention, percent} = \frac{B}{A} \times 100$$

Where:

B = Average breakdown voltage of the 10 samples immersed for 14 days at the specified temperature.

A = Average breakdown voltage of the 10 samples not immersed for 14 days at the specified temperature.

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Part 7
SPECIAL CONSTRUCTIONS

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Part 8
APPENDICES

Appendix A
INDUSTRY STANDARD REFERENCES

(Appendix A is classified by NEMA as Authorized Engineering Information.)

Copies of the above documents may be obtained from the appropriate source as follows:

American National Standards Institute (ANSI)
1430 Broadway
New York, NY 10018

ANSI/NFPA 70–1990	*National Electrical Code*

American Society for Testing and Materials (ASTM)
1916 Race Street
Philadelphia, PA 19103

ASTM A 90–81	*Weight of Coating on Zinc-Coated (Galvanized) Iron or Steel Articles*
ASTM A 411–86	*Zinc Coated (Galvanized) Low Carbon Steel Armor Wire*
ASTM A 459–88	*Zinc Coated Flat Steel Armoring Tape*
ASTM B 3–74 (1985)	*Soft or Annealed Copper Wire*
ASTM B 5–89	*Electrolytic Tough-pitch Copper Refinery Shapes*
ASTM B 8–86	*Concentric-Lay-Stranded Copper Conductors, Hard, Medium-Hard, or Soft*
ASTM B 33–81 (1985)	*Tinned Soft or Annealed Copper Wire for Electrical Purposes*
ASTM B 189–81 (1985)	*Lead-Coated and Lead-Alloy-Coated Soft Copper Wire for Electrical Purposes*
ASTM B 193–87	*Resistivity of Electrical Conductor Materials*
ASTM B 263–89	*Cross-Sectional Area of Stranded Conductors*
ASTM D 257–78 (1983)	*DC Resistance of Plastics and Electrical Insulating Materials*
ASTM D 412–87	*Rubber Properties in Tension*
ASTM D 470–82	*Testing of Thermosetting Insulations and Jackets for Wire and Cable*
ASTM D 471–79	*Rubber Property—Effect of Liquids*
ASTM D 1248–84	*Polyethylene Plastics Molding and Extrusion Materials*
ASTM D 1693–70 (1988)	*Environmental Stress-Cracking of Ethylene Plastics*

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NEMA WC*57 90 ■ 6470247 0020662 4 ■

ASTM D 2765–84 — *Degree of Crosslinking in Crosslinked Ethylene Plastics as Determined by Solvent Extraction*

ASTM D 3349–86 — *Absorption Coefficient of Carbon Black Pigmented Ethylene Film*

National Electrical Manufacturers Association
2101 L Street, NW
Washington, DC 20037

Insulated Cable Engineers Association Inc.
(ICEA, formerly IPCEA)
Box 440
South Yarmouth, MA 02664

ICEA T–26–465/NEMA WC 54–1990 — *Guide for Frequency of Sampling Extruded Dielectric Power, Control, Instrumentation, and Portable Cables for Tests*

ICEA T–27–581/NEMA WC 53–1990 — *Standard Test Methods for Extruded Dielectric Power, Control, Instrumentation and Portable Cables*

ICEA T–28–562 (1983) — *Test Methods for Measurement of Hot Creep of Polymeric Insulations*

ICEA T–30–520 (1986) — *Procedure for Conducting Vertical Cable Tray Flame Tests with a Theoretical Heat Input Rate of 70,000 B.T.U./Hour*

National Institute of Standards and Technology
(formerly the National Bureau of Standards (NBS))
The NBS Handbook 100 is sold by the National Technical Information Service
Port Royal Road
Springfield, VA 22161

NBS Handbook 100 (2/21/66) — *Copper Wire Tables*

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APPENDIX B
ADDITIONAL CONDUCTOR INFORMATION

(Appendix B is classified by NEMA as Authorized Engineering Information.)

Table B-1
APPROXIMATE DIAMETERS OF STRANDED CLASS B AND C COPPER CONDUCTORS

Conductor Size, AWG	Diameter, Inch
22	0.029
20	0.036
19	0.041
18	0.046
17	0.052
16	0.058
14	0.073
13	0.082
12	0.092
11	0.103
10	0.116
9	0.130

Table B-2
APPROXIMATE WEIGHTS OF COPPER CONDUCTORS IN LBS/1000 FEET

Conductor Size, AWG	Conductor Weight	
	Solid	Stranded
22	1.94	1.98
20	3.10	3.15
19	3.90	3.97
18	4.92	5.02
17	6.21	6.32
16	7.81	7.97
14	12.4	12.6
13	15.7	16.0
12	19.8	20.2
11	24.9	25.4
10	31.4	32.0
9	39.6	40.4

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Appendix C
REPRESENTATIVE VALUES OF TENSILE STRENGTH AND ELONGATION FOR NON-MAGNETIC ARMOR MATERIALS

(Appendix C is classified by NEMA as Authorized Engineering Information.)

Table C-1
NON-MAGNETIC ARMOR MATERIALS

Metal	Tensile Strength, psi	Elongation 2-Inch Length, percent
Aluminum	13,000–45,000	15–45
Ambrac*	50,000–70,000	20–40
Brass	40,000–50,000	40–50
Bronze	35,000–42,000	40
Monel*	75,000	45
Stainless Steel	82,000–90,000	50
Zinc	20,000	60

*Trade names—The listing of these materials implies no endorsement; rather, it shows them as being typical of materials commercially available at the time of printing.

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Appendix D
FLAME TESTING FINISHED CABLE

D.1 SCOPE

When mutually agreed upon between the user and manufacturer, the following flame test may be conducted to determine relative resistance to flame propagation under specified test conditions for a given cable construction.

D.2 PROCEDURE

The test shall be conducted as described in ICEA T–30–520 with the following exceptions:

1. The representative sample to be tested shall be a 7 or 9 conductor #12 AWG, rated 600 volts.
2. Individual conductors in the completed cable shall comply with the requirements of Flame Test B in 6.16.2.

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Appendix E
CONDUCTOR IDENTIFICATION FOR CONTROL CABLES

E.1 SCOPE

This appendix contains recommendations for conductor and circuit identification of control cables when such identification is used.

E.2 NATIONAL ELECTRICAL CODE APPLICATIONS

The *National Electrical Code* specifies that conductors colored white be used only as grounded conductors and that conductors colored green or green/yellow be used only as grounding conductors and that neither white nor green be used in any manner on ungrounded conductors. Tables E-2 and E-4 provide color sequences that do not include white or green conductors. If grounded or grounding conductors, or both, are used in the cable, they shall be colored white or green, respectively, and inserted as the second or third, or both, designated conductor in the first sequence of circuit identification only. Where these conductors are required, they shall be specified.

E.3 METHODS OF CIRCUIT IDENTIFICATION

E.3.1 Method 1—Colored Compounds with Tracers

This method uses base colors with tracers in accordance with Table E-1 or E-2. These color combinations shall be repeated in regular sequence as necessary.

Base and tracer colors shall be recognizably the color combinations given in the tables and should approximately match the color shades given in Table E-6.

Base colors may be obtained by suitable color coatings applied to the insulation or jacket surface or by colored insulation or jacket compound.

Tracers shall be colored stripes or bands marked on the surface of the insulation or jacket in such a manner as to afford distinctive circuit coding throughout the length of each wire. Tracers may be continuous or broken lines, such as series of dots or dashes, and shall be applied longitudinally, annularly, spirally, or in other distinctive patterns.

E.3.2 Method 2—Neutral Colored Compounds with Tracers

This method uses a neutral background or base color, such as tan, on all conductors, with tracers as defined in Method 1 and in accordance with Table E-3 or E-4. These color combinations shall be repeated in regular sequence as necessary.

E.3.3 Method 3—Neutral or Single-Color Compounds with Surface Printing of Numbers and Color Designations

This method uses a single-color insulation or covering on all conductors with printed conductor numbers and color designations in accordance with Table E-1 or E-2. These color combinations shall be repeated in regular sequence as necessary.

For example, using Table E-2 for conductors 1 to 3, inclusive:

1—Black	1—Black	1—Black, and such
2—Red	2—Red	2—Red, and such
3—Blue	3—Blue	3—Blue, and such

E.3.4 Method 4—Neutral or Single-Color Compounds with Surface Printing of Numbers

This method uses a single color insulation or covering on all conductors with each conductor numbered in sequence by surface printing, beginning with the number 1.

E.3.5 Method 5—Individual Color Coding with Braids

This method uses colored braids over the insulated conductors in accordance with Table E-2 or E-5. The shades of the colors should approximately match those identified by the number given in Table E-6. (This paragraph has been approved by NEMA as Authorized Engineering Information.)

Color sequence shall begin with black on the inside. When more than one color is required, the first color named in the tables shall be the background color.

The tracers shall consist of three carriers with each carrier composed of a minimum of two ends. Where two tracers are used, they shall be crossed.

E.3.6 Method 6—Layer Identification

This method uses a distinctively identified conductor in each layer for control cables having braidless or jacketed individual conductors requiring layer-tracer identification. One conductor in each layer of the cable shall be covered by a braid or tape, or shall be provided with a raised ridge or ridges to function as a tracer, or be otherwise distinctively marked or colored.

E.3.7 Method 7—Paired Conductors

For cables with other than silicone-rubber insulation, one conductor of each pair shall be coded "white" or "black," and the other conductors shall be coded in accord-

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ance with the sequence given in Table E-2 or E-5, omitting white or black, respectively. This color sequence shall be repeated as necessary.

E.3.8 Method 8—Silicone Rubber Insulated Cables

When circuit identification is required for silicone rubber insulated cables (including pairs), it shall be by means of colored braids. The color sequence shall be in accordance with Table E-7. For cables composed of more than 16 conductors, these 16 color combinations shall be repeated in regular sequence to the extent necessary to provide such identification of all conductors.

When more than one color is required, the first color named in the table shall be the background color. The shades of the colors shall approximately match those identified by the numbers given in Table E-6.

The tracers shall consist of three carriers with each carrier composed of a minimum of two ends. When two tracers are used, they shall be crossed.

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Table E-1
COLOR SEQUENCE, INCLUDING WHITE AND GREEN

Conductor Number	Background or Base Color	First Tracer Color	Second Tracer Color	Conductor Number	Background or Base Color	First Tracer Color	Second Tracer Color	Conductor Number	Background or Base Color	First Tracer Color	Second Tracer Color
1*	Black	...	...	44	White	White	Blue	86	Blue	Green	...
2	White	...	...	45	White	Black	Blue	87	Black	Orange	...
3	Red	...	...	46	Red	White	Blue	88	White	Orange	...
4	Green	...	...	47	Green	Orange	Red	89	Red	Orange	...
5	Orange	...	...	48	Orange	Red	Blue	90	Green	Orange	...
6	Blue	...	...	49	Blue	Red	Orange	91	Blue	Orange	...
7	White	Black	...	50	Black	Orange	Red	92	Black	Blue	...
8	Red	Black	...	51	White	Black	Orange	93	White	Blue	...
9	Green	Black	...	52	Red	Orange	Black	94	Red	Blue	...
10	Orange	Black	...	53	Green	Red	Blue	95	Green	Blue	...
11	Blue	Black	...	54	Orange	Black	Blue	96	Orange	Blue	...
12	Black	White	...	55	Blue	Black	Orange	97	Yellow	...	...
13	Red	White	...	56	Black	Orange	Green	98	Yellow	Black	...
14	Green	White	...	57	White	Orange	Green	99	Yellow	White	...
15	Blue	White	...	58	Red	Orange	Green	100	Yellow	Red	...
16	Black	Red	...	59	Green	Black	Blue	101	Yellow	Green	...
17	White	Red	...	60	Orange	Green	Blue	102	Yellow	Orange	...
18	Orange	Red	...	61	Blue	Green	Orange	103	Yellow	Blue	...
19	Blue	Red	...	62	Black	Red	Blue	104	Black	Yellow	...
20	Red	Green	...	63	White	Orange	Blue	105	White	Yellow	...
21	Orange	Green	...	64	Red	Black	Blue	106	Red	Yellow	...
22	Black	White	Red	65	Green	Orange	Blue	107	Green	Yellow	...
23	White	Black	Red	66	Orange	White	Red	108	Orange	Yellow	...
24	Red	Black	White	67	Blue	White	Red	109	Blue	Yellow	...
25	Green	Black	White	68	Black	Green	Blue	110	Black	Yellow	Red
26	Orange	Black	White	69	White	Green	Blue	111	White	Yellow	Red
27	Blue	Black	White	70	Red	Green	Blue	112	Green	Yellow	Red
28	Black	Red	Green	71	Green	White	Red	113	Orange	Yellow	Red
29	White	Red	Green	72	Orange	Red	Black	114	Blue	Yellow	Red
30	Red	Black	Green	73	Blue	Red	Black	115	Black	Yellow	White
31	Green	Black	Orange	74	Black	Orange	Blue	116	Red	Yellow	White
32	Orange	Black	Green	75	Red	Orange	Blue	117	Green	Yellow	White
33	Blue	White	Orange	76	Green	Red	Black	118	Black	Yellow	White
34	Black	White	Orange	77	Orange	White	Green	119	Blue	Yellow	White
35	White	Red	Orange	78	Blue	White	Green	120	Black	Yellow	Green
36	Orange	White	Blue	79	Red	White	Orange	121	White	Yellow	Green
37	White	Red	Blue	80	Green	White	Orange	122	Red	Yellow	Green
38	Black	White	Green	81	Blue	Black	Green	123	Orange	Yellow	Green
39	White	Black	Green	82	Orange	White	...	124	Blue	Yellow	Green
40	Red	White	Green	83	Green	Red	...	125	Black	Yellow	Blue
41	Green	White	Blue	84	Black	Green	...	126	White	Yellow	Blue
42	Orange	Red	Green	85	White	Green	...	127	Red	Yellow	Blue
43	Blue	Red	Green								

*This conductor is on the inside of the assembly.

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Table E-2
COLOR SEQUENCE WITHOUT WHITE AND GREEN

Conductor Number	Background or Base Color	Tracer Color	Conductor Number	Background or Base Color	Tracer Color
1*	Black	...	19	Orange	Blue
2	Red	...	20	Yellow	Blue
3	Blue	...	21	Brown	Blue
4	Orange	...	22	Black	Orange
5	Yellow	...	23	Red	Orange
6	Brown	...	24	Blue	Orange
7	Red	Black	25	Yellow	Orange
8	Blue	Black	26	Brown	Orange
9	Orange	Black	27	Black	Yellow
10	Yellow	Black	28	Red	Yellow
11	Brown	Black	29	Blue	Yellow
12	Black	Red	30	Orange	Yellow
13	Blue	Red	31	Brown	Yellow
14	Orange	Red	32	Black	Brown
15	Yellow	Red	33	Red	Brown
16	Brown	Red	34	Blue	Brown
17	Black	Blue	35	Orange	Brown
18	Red	Blue	36	Yellow	Brown

*This conductor is on the inside of the assembly.

NOTE: See E.2 for *National Electrical Code* applications.

Table E-3
COLOR SEQUENCE INCLUDING WHITE AND GREEN

Conductor Number	First Tracer Color (e.g., Wide Tracer)	Second Tracer Color (e.g., Narrow Tracer)	Conductor Number	First Tracer Color (e.g., Wide Tracer)	Second Tracer Color (e.g., Narrow Tracer)
1*	Black	...	12	Black	White
2	White	...	13	Red	White
3	Red	...	14	Green	White
4	Green	...	15	Blue	White
5	Orange	...	16	Black	Red
6	Blue	...	17	White	Red
7	White	Black	18	Orange	Red
8	Red	Black	19	Blue	Red
9	Green	Black	20	Red	Green
10	Orange	Black	21	Orange	Green
11	Blue	Black			

*This conductor is on the inside of the assembly.

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Table E-4
COLOR SEQUENCE WITHOUT WHITE AND GREEN

Conductor Number	First Tracer Color (e.g., Wide Tracer)	Second Tracer Color (e.g., Narrow Tracer)	Conductor Number	First Tracer Color (e.g., Wide Tracer)	Second Tracer Color (e.g., Narrow Tracer)
1*	Black	...	19	Orange	Blue
2	Red	...	20	Yellow	Blue
3	Blue	...	21	Brown	Blue
4	Orange	...	22	Black	Orange
5	Yellow	...	23	Red	Orange
6	Brown	...	24	Blue	Orange
7	Red	Black	25	Yellow	Orange
8	Blue	Black	26	Brown	Orange
9	Orange	Black	27	Black	Yellow
10	Yellow	Black	28	Red	Yellow
11	Brown	Black	29	Blue	Yellow
12	Black	Red	30	Orange	Yellow
13	Blue	Red	31	Brown	Yellow
14	Orange	Red	32	Black	Brown
15	Yellow	Red	33	Red	Brown
16	Brown	Red	34	Blue	Brown
17	Black	Blue	35	Orange	Brown
18	Red	Blue	36	Yellow	Brown

*This conductor is on the inside of the assembly.

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Table E-5
COLOR SEQUENCE FOR BRAIDS, INCLUDING WHITE AND GREEN

Conductor Number	Background or Base Color	First Tracer Color	Second Tracer Color
1*	Black	...	...
2	White	...	...
3	Red	...	...
4	Green	...	...
5	Orange	...	...
6	Blue	...	...
7	White	Black	...
8	Red	Black	...
9	Green	Black	...
10	Orange	Black	...
11	Blue	Black	...
12	Black	White	...
13	Red	White	...
14	Green	White	...
15	Blue	White	...
16	Black	Red	...
17	White	Red	...
18	Orange	Red	...
19	Blue	Red	...
20	Red	Green	...
21	Orange	Green	...
22	Black	White	Red
23	White	Black	Red
24	Red	Black	White
25	Green	Black	White
26	Orange	Black	White
27	Blue	Black	White
28	Black	Red	Green
29	White	Red	Green
30	Red	Black	Green
31	Green	Black	Orange
32	Orange	Black	Green
33	Blue	White	Orange
34	Black	White	Orange
35	White	Red	Orange
36	Orange	White	Blue
37	White	Red	Blue

*This conductor is on the inside of the assembly.

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Table E-6
SHADES OF COLOR

Color	Munsell Notation*	
Black	N2/	
White	N9/	
Red	2.5 R	4/12
Blue	2.5 PB	4/10
Green	2.5 G	5/12
Orange	2.5 YR	6/14
Yellow	5 Y	8.5/12
Brown	2.5 YR	3.5/6

*Munsell Color System published by:

Munsell Color—Macbeth Division
2441 North Calvert Street
Baltimore, MD 21218 USA

Table E-7
COLOR SEQUENCE FOR SILICONE RUBBER INSULATED CABLES

Conductor Number	Background or Base Color	First Tracer Color	Second Tracer Color
1*	White	...	...
2	White	Black	...
3	White	Red	...
4	White	Green	...
5	White	Orange	...
6	White	Blue	...
7	White	Red	Black
8	White	Green	Black
9	White	Orange	Black
10	White	Blue	Black
11	White	Orange	Red
12	White	Blue	Red
13	White	Red	Green
14	White	Orange	Green
15	White	Orange	Blue
16	White	Blue	Green

*This conductor is on the inside of the assembly.

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NEMA STANDARDIZATION

The purpose of NEMA Standards, their classification and status are set forth in certain clauses of the NEMA *Standardization Policies and Procedures* manual and are referenced below:

Purpose of Standards

National Electrical Manufacturers Association Standards are adopted in the public interest and are designed to eliminate misunderstandings between the manufacturer and the purchaser and to assist the purchaser in selecting and obtaining the proper product for their particular needs. Existence of a National Electrical Manufacturers Association Standard does not in any respect preclude any member or nonmember from manufacturing or selling products not conforming to the standard.

(Standardization Policies and Procedures, p. 1)

Definition of a Standard

A standard of the National Electrical Manufacturers Association defines a product, process or procedure with reference to one or more of the following: nomenclature, composition, construction, dimensions, tolerances, safety, operating characteristics, performance, rating, testing, and the service for which they are designed.

(Standardization Policies and Procedures, p. 2)

Dimensions

Where dimensions are given for interchangeability purposes, alternate dimensions satisfying the other provisions of the Standards Publication may be capable of otherwise equivalent performance.

(Standardization Policies and Procedures, p. 8)

Categories of Standards

National Electrical Manufacturers Association Standards are of three classes:

1. NEMA Standard, which relates to a product, process or procedure commercially standardized and subject to repetitive manufacture, which standard has been approved by at least 90 percent of the members of the Subdivision eligible to vote thereon;
2. Suggested Standard for Future Design, which may not have been regularly applied to a commercial product, but which suggests a sound engineering approach to future development, which standard has been approved by at least two-thirds of the members of the Subdivision eligible to vote thereon.
3. Adoptive Standard, which is adopted in whole or in part from the standards of another organization, either domestic, regional, or international.

(Standardization Policies and Procedures, pp 7 & 16)

Authorized Engineering Information

Authorized Engineering Information consists of explanatory data and other engineering information of an informative character not falling within the classification of NEMA Standard or Suggested Standard for Future Design, which standard has been approved by at least two-thirds of the members of the Subdivision eligible to vote on the standard.

(Standardization Policies and Procedures, pp. 7 & 16)

Official Standards Proposal

An Official Standards Proposal is an official draft of a proposed standard which is formally recommended to an outside organization(s) for consideration, comment and/or approval, and which has been approved by at least 90 percent of the members of the Subdivision eligible to vote thereon. *(Standardization Policies and Procedures, pp 7 & 16)*

Identification of Status

Standards in NEMA Standards Publications are identified in the foreword or following each standard as "NEMA Standard" or "Suggested Standard for Future Design." These indicate the status of the standard. These words are followed by a date which indicates when the standard was adopted in its present form by the Association.

The material identified as "Authorized Engineering Information" and "Official Standards Proposal" is designated similarly.

July 17, 1990

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