STD.NEMA WC 8-ENGL 1988 ■ 6470247 0514010 337 ■

NEMA Standards Publication No. WC 8-1992
ICEA Publication No. S-68-516

ETHYLENE-PROPYLENE-RUBBER-INSULATED WIRE AND CABLE FOR THE TRANSMISSION AND DISTRIBUTION OF ELECTRICAL ENERGY

Revision No. 3, December, 1996

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
1300 North 17th Street
Rosslyn, VA 22209

© Copyright 1998 by the National Electrical Manufacturers Association and the Insulated Cable Engineers Association. All rights including translation into other languages, reserved under the Universal Copyright Convention, the Berne Convention for the Protection of Literary and Artistic Works, and the International and Pan American Copyright Conventions.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS

Not for Resale

NEMA STANDARDS PUBLICATION NO. WC 8-1988/ICEA S-68-516

ETHYLENE-PROPYLENE-RUBBER-INSULATED WIRE AND CABLE FOR THE TRANSMISSION AND DISTRIBUTION OF ELECTRICAL ENERGY

Revision No. 2 – July 1992

Published by:

National Electrical Manufacturers Association
2101 L Street, N.W., Suite 300
Washington, DC 20037

© 1993 National Electrical Manufacturers Association

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS

Not for Resale

6470247 0522399 693

ICEA Pub. No. S-68-516
NEMA WC 8-1988

WC 8

ETHYLENE-PROPYLENE-RUBBER-INSULATED WIRE AND CABLE FOR THE TRANSMISSION AND DISTRIBUTION OF ELECTRICAL ENERGY

Revision No. 1 – September 1991

Published by:

National Electrical Manufacturers Association
2101 L Street, N.W., Suite 300
Washington, DC 20037

© 1991 National Electrical Manufacturers Association

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

WC 8-88 6470247 0008327 7 A-33-01

NEMA STANDARDS PUBLICATION NO. WC 8
ICEA PUBLICATION NO. S-68-516

icea/nema

Ethylene-Propylene-Rubber-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION ■ 2101 L STREET, N.W., WASHINGTON, D.C. 20037
INSULATED CABLE ENGINEERS ASSOCIATION ■ PO BOX P, SOUTH YARMOUTH, MA 02664

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

WC 8-88 6470247 0008328 9

ICEA PUB. NO. S-68-516
NEMA WC 8-1988

WC 8

ETHYLENE-PROPYLENE-RUBBER-INSULATED WIRE AND CABLE FOR THE TRANSMISSION AND DISTRIBUTION OF ELECTRICAL ENERGY

Published by:

National Electrical Manufacturers Association
2101 L Street, N.W.
Washington, DC 20037

©1989 by National Electrical Manufacturers Association

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS

Not for Resale

Foreword

This Standards Publication for Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy was developed by the Insulated Cable Engineers Association and approved by the National Electrical Manufacturers Association.

ICEA/NEMA Standards are adopted in the public interest and are designed to eliminate misunderstanding between the manufacturer and the user and to assist the user in selecting and obtaining the proper product for his particular need. 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.

Requests for interpretation of this Standard must be submitted in writing to:

Insulated Cable Engineers Association
P.O. Box P
South Yarmouth, Massachusetts 02664

An official written interpretation will be provided. Suggestions for improvements gained in the use of this publication will be welcomed by the Association.

For the sake of uniformity, all appendices in NEMA WC 3 (ICEA S-19-81), NEMA WC 5 (ICEA S-61-402), NEMA WC 7 (ICEA S-66-524), and NEMA WC 8 (ICEA S-68-516) are lettered the same.

TABLE OF CONTENTS*

Part 1	General
Part 2	Conductors
Part 3	Insulation
Part 4	Shielding and Coverings
Part 5	Assembly, Fillers, and Conductor Identification
Part 6	Testing and Test Methods
Part 7	Construction of Specific Types
Part 8	Appendices

*A more detailed table of contents follows.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

TABLE OF CONTENTS

		Page
Part 1	GENERAL	
	Scope	1
	General Information	1
	Information to be Supplied by Purchaser	1
	Characteristics of Systems on which Cable is to be Used	1
	Quantities and Description of Cable	1
Part 2	CONDUCTORS	
	Wires, Physical, and Electrical Properties	3
	Copper Wires	3
	Aluminum Wires	3
	Solid Conductors	3
	Stranded Conductors	4
	Conductor Size Units	4
	Conductor DC Resistance per Unit Length	4
	Direct Measurement of DC Resistance per Unit Length	4
	Calculation of DC Resistance per Unit Length	4
	Conductor Diameter	5
	Stress Control Layer (Conductor Shield)	5
Part 3	INSULATION	
	Material	12
	Insulation Thicknesses	12
	For Three-phase Systems with 100 or 133 Percent Insulation Level	12
	For Delta Systems Rated 2001 Volts and Over Where One Leg May Be Grounded for Periods Over 1 Hour	12
	For Single- and Two-phase Systems with 100 Percent Insulation Level	12
	For Single- and Two-phase Systems with 133 Percent Insulation Level	12
	DC Systems	12
	Insulation Thickness for Submarine Power Cable	12
	Repairs	12
	Insulation Types and Requirements	12
	Insulation Types	12
	Voltage Tests	12
	Insulation Resistance Constants	12
	Type I Insulation	13
	Physical and Aging Requirements	13
	Electrical Requirements	13
	Voltage Tests	13
	Insulation Resistance Test	13
	Partial-discharge Extinction Level	13
	Additional Requirements	13
	Capacity and Power Factor	13
	Accelerated Water Absorption	13
	Type II Insulation	13
	Physical and Aging Requirements	13
	Electrical Requirements	17
	Additional Requirements	17
	Capacity and Power Factor	17
	Accelerated Water Absorption	17
Part 4	SHIELDING AND COVERINGS	
	Shielding of Insulated Cables	18
	Insulation Shield	18
	Nonmetallic Covering	18
	Metallic Component	18
	Multiple-conductor Cables	18

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

Conductor Identification 18
Shielding Limits for Power Cable for Fixed Locations 18
Jackets 20
General 20
Rubber or Thermoplastic Jackets 20
Natural Rubber 20
Synthetic Rubber 20
Neoprene, Heavy-duty Black 21
Neoprene, General Purpose 21
Polyvinyl Chloride 22
Polyethylene, Black 22
Chlorinated Polyethylene, Thermoplastic 22
Nitrile-butadiene/Polyvinyl-Chloride, Heavy-Duty 22
Nitrile-butadiene/Polyvinyl-Chloride, General-purpose Duty 23
Chlorosulfonated Polyethylene, Heavy Duty 23
Chlorinated Polyethylene, Heavy-Duty, Cross-Linked (Thermoset) 23
Jacket Thickness 25
Separator Under Jacket 25
Discharge-resisting Jacket 25
Irregularity Inspection of Jackets Over Metallic Shielded Power Cable 25
Metallic and Associated Coverings 28
Metallic and Associated Coverings 28
Scope 28
General 28
Unusual Conditions 28
Types of Metallic Coverings and Conditions of Installation 28
Division I—Coverings for Use Under Normal Conditions 28
Scope 28
Metallic Sheath 28
Lead Sheath 28
Type of Lead 28
Thickness of Lead 28
Measurement of Thickness of Lead 29
Reapplication of Lead Sheaths 29
Aluminum Sheath 29
Type of Aluminum 29
Thickness of Aluminum 29
Measurement of Thickness of Aluminum 29
Reapplication of Aluminum Sheaths 29
Jute Serving over Metallic Sheath without Metallic Armor 29
Jute Servings 29
Application 30
Flat Metal Tape Armor 30
Scope 30
Tensile Strength and Elongation 30
Galvanizing Test 30
Weight of Zinc Coating 30
Adherence of Coating 30
Width 30
Thickness 30
Application, Lay, and Spacing 31
Interlocked Metal Tape Armor 31
Scope 31
Steel Tape 31
Width 31
Thickness 31
Nonmagnetic Tape 32
Continuously Corrugated Metal Armor 32
Scope 32
Type of Metal 32
Flexibility 32

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

Corrosion Protection . . . 32
Galvanized Steel Wire Armor . . . 32
Scope . . . 32
Tensile Strength, Elongation, and Torsion . . . 32
Tensile Strength . . . 32
Elongation . . . 32
Torsion Test . . . 33
Galvanizing Tests . . . 33
Weight of Zinc Coating . . . 33
Adherence of Coating . . . 33
Size of Armor . . . 33
Lay . . . 33
Direction of Lay . . . 33
Jute Bedding for Armored Cable . . . 33
Application . . . 33
Direction of Lay . . . 33
Thickness . . . 33
Jute Serving Overall for Armored Cable . . . 33
Application . . . 33
Direction of Lay . . . 34
Jute for Interlocked Armored Cable . . . 34
Jute Bedding . . . 34
Jute Serving Overall . . . 34
Core Covering for Nonsheathed and Nonjacketed Cable with Metallic Armor . . . 34
Core Covering for Thermosetting and Thermoplastic Jacketed Cable Under Armor . . . 34
Flat Steel Tape Armor . . . 34
Interlocked Armor . . . 34
Round Wire Armor . . . 34
Thermosetting Coverings over Metallic Sheath . . . 34
Thermosetting Covering . . . 34
Thickness . . . 35
Thickness of Lead Sheath . . . 35
Thickness of Aluminum Sheath . . . 35
Thermoplastic Jacket over Metallic Sheath . . . 35
Thermoplastic Jacket . . . 35
Thickness . . . 35
Tightness of Polyethylene Jacket to Sheath . . . 35
Cold Bend . . . 36
Irregularity Inspection . . . 36
Jackets over Metallic Armor . . . 36
Thermoplastic Types . . . 36
Cross linked Types . . . 36
Thickness . . . 36
Irregularity Inspection . . . 36
Division II—Round Wire Armor for Borehole, Dredge, Shaft, and Vertical Riser Cable . . . 37
Scope . . . 37
General . . . 37
Borehole Cable (Suspended at One End Only) . . . 37
Armor . . . 37
Size of Armor Wires . . . 37
Lay . . . 37
Dredge Cable . . . 37
Armor . . . 37
Size of Armor Wires . . . 37
Pitch Ratio . . . 37
Shaft Cable . . . 37
Vertical Riser Cable (Suspended at One End Only) for Installation within Buildings . . . 38
Armor . . . 38
Size of Armor Wires for Nonsheathed Cable . . . 38
Size of Armor Wires for Sheathed Vertical Riser Cable . . . 38
Wire-band Serving . . . 38

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

Division III—Round Wire Armor for Buried Cable 38
Scope 38
General 38
Armor Wire and Jute Beddings and Servings (Sheathed and Nonsheathed Cables) . . . 38

Part 5 ASSEMBLY, FILLERS, AND CONDUCTOR IDENTIFICATION

Assembly of Multiple-conductor Cables 40
Multiple-conductor Round Cables 40
Flat Twin Cables 40
Fillers 40
Conductor Identification 40
Power Cables 40
Control Cables (Deleted) 40

Part 6 TESTING AND TEST METHODS

Testing 41
Selection of Samples 41
Conductor Test Methods 41
Method for DC Resistance Determination 41
Methods for Cross-sectional Area Determination 41
Cross-sectional Area by Diameter Measurement 41
Cross-sectional Area by Weight 42
Methods for Diameter Determination 42
Diameter by Micrometer Measurement 42
Diameter by Tape Measurement 42
Thickness Measurements for Insulations and Nonmetallic Jackets 42
Number of Thickness Measurements 42
Measurement of Thickness 42
Micrometer Measurements 42
Microscope Measurements 45
Thickness Conformance 45
Physical and Aging Tests for Insulations, Jackets, and Nonmetallic Conducting Materials 45
Sampling 45
Insulations 45
Jackets 45
Nonmetallic Conducting Materials 45
Number of Test Specimens 45
Size and Preparation of Specimens 45
Calculation of Area of Test Specimens 45
Physical Test Procedures 46
Test Temperature 46
Type of Testing Machine 46
Retests 46
Tensile Strength Test 46
Tensile Stress Test 46
Elongation Test 47
Set Test 47
Aging Tests 47
Test Specimens 47
Oxygen Pressure Test 47
Air Oven Test 47
Air Pressure Heat Test 47
Oil Immersion Test for Polyvinyl Chloride Jacket 47
Oil Immersion Test for Thermosetting Jacket 47
Physical Tests for Nonmetallic Conducting Materials Intended for Extrusion 48
Test Sample 48
Test Specimens 48
Elongation 48
Brittleness 48
Tear Test 48

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

Retests . . . 48
Thickness of Jute Beddings and Servings . . . 48
Thickness of Metallic Tapes . . . 48
Thickness of Metallic Sheaths . . . 48
Heat Shock . . . 49
Heat Distortion . . . 49
Test Specimen . . . 49
Test Procedures . . . 49
Cold Bend . . . 49
Environmental Cracking . . . 49
Test Specimens . . . 49
Test Procedure . . . 49
Absorption Coefficient . . . 49
Accelerated Water Absorption . . . 49
General . . . 49
Electrical Method (EM-60) . . . 50
Gravimetric Method (Deleted) . . . 50
Capacity and Power Factor . . . 50
Tests for Discharge Resistance . . . 50
Test Samples . . . 50
Specific Surface Resistivity . . . 50
U-Bend Discharge . . . 51
Volume Resistivity . . . 51
Test Samples . . . 51
Conductor Stress Control . . . 51
Insulation Shield . . . 51
Stripping Test . . . 51
Retests for Tests Covered by 6.13 through 6.25 and 6.30 and 6.31 . . . 52
Electrical Tests on Completed Cables . . . 52
Voltage Tests . . . 52
General . . . 52
Cables without Metallic Sheath, Metallic Shield, or Metallic Armor . . . 52
Cables with Metallic Sheath, Metallic Shield, or Metallic Armor . . . 52
AC Voltage Test . . . 52
DC VoltageTest . . . 52
AC Spark Test . . . 52
Application . . . 52
Test Apparatus . . . 53
Test Procedure . . . 53
Failure . . . 53
DC Spark Test . . . 53
Voltage Tests after Installation . . . 53
Insulation Resistance . . . 53
Test Apparatus . . . 53
Test Procedure . . . 54
Determination of Temperature Correction Factors for Insulation Resistance . . . 54
Partial-discharge Test Procedure . . . 54
Method for Flexibility Test for Continuously Corrugated Armor . . . 54
Method for Determining Permittivity (S.I.C.) and Dielectric Strength of Extruded Nonconducting Polymeric Stress Control Layers . . . 54
Hot Creep Test . . . 55

Part 7 CONSTRUCTIONS OF SPECIFIC TYPES

Mine Power Cables . . . 57
Scope . . . 57
Conductors . . . 57
Power Conductors . . . 57
Grounding Conductors . . . 57
Ground Check Conductor . . . 57
Insulation . . . 57

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

Insulation Shielding . . . 57
Identification . . . 57
Conductor Assembly . . . 57
Jacket . . . 58
Outside Diameters . . . 58
Tests . . . 58
Portable Single- and Multiple-conductor Power Cables . . . 58
Scope . . . 58
General Description of Completed Cable . . . 63
Single-conductor Cables, Nonshielded, 0–2000 Volts . . . 63
Type W and G Two-conductor Cables, 0–2000 Volts . . . 63
Two-conductor Flat Twin Cables . . . 63
Type W, Without Grounding Conductor . . . 63
Type G, With Grounding Conductor . . . 63
Two-conductor Round Cables . . . 63
Type W, Without Grounding Conductors . . . 63
Type G, With Grounding Conductors . . . 63
Type W, G, and G-GC Three- and Four-conductor Cables, 0–2000 Volts . . . 63
Type W, Round, Without Grounding Conductors . . . 63
Type G, Round, With Grounding Conductors . . . 63
Type G, Three-conductor Flat, With Grounding Conductors . . . 64
Type G-GC, Three-conductor Round, With Grounding Conductors and Ground Check Conductor . . . 64
Type G-GC, Three-conductor Flat, with Grounding Conductor and Ground Check Conductor . . . 64
Type W and G, Five- and Six-conductor, 0–2000 Volts . . . 64
Type W, Without Grounding Conductor . . . 64
Type G, With Grounding Conductor (Five-conductor Cables Only) . . . 64
Type PG, Two and Three Power Conductor with Single Grounding Conductor, 0–2000 Volts . . . 64
Type PCG, Two and Three Power Conductor with Control Conductors and Single Grounding Conductor, 0–2000 Volts . . . 64
Type G, Three-conductor Round with Grounding Conductors, 2001–5000 volts . . . 65
Type SH, SHC-GC, SHD, and SHD-GC, Shielded Cables, 0–25000 Volts at 100 Percent Insulation Level Only . . . 65
Type SH Single-conductor Cables, 2001–25000 Volts . . . 65
Type SHC-GC Three-conductor Cables, 0–2000 Volts . . . 65
Type SHD Three-conductor Cables, 0–25000 Volts . . . 65
Type SHD-GC Three-conductor Cables, 0–25000 Volts . . . 65
Power Conductors . . . 65
Control and Ground Check Conductors . . . 65
Grounding Conductors . . . 66
Insulation . . . 66
Tapes and Braids . . . 66
Conductor Identification . . . 66
Power Conductors . . . 66
Control and Ground Check Conductors . . . 67
Shielding . . . 67
Metal Braid Shields . . . 67
Metal Wire Shields . . . 67
Conductor Assembly . . . 67
Jackets . . . 67
General . . . 67
Extra-heavy-duty Neoprene Jacket . . . 67
Heavy-duty Neoprene Jacket . . . 68
Extra-heavy-duty Nitrile-butadiene/Polyvinyl-chloride Jacket . . . 68
Heavy-duty Nitrile-butadiene/Polyvinyl-chloride Jacket . . . 68
Heavy-duty Chlorosulfonated Polyethylene Jacket . . . 68
Extra-Heavy-Duty Chlorosulfonated Polyethylene . . . 69
Heavy-Duty Chlorinated Polyethylene, Cross-Linked . . . 69
Extra-Heavy-Duty Chlorinated Polyethylene, Cross-Linked . . . 69

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

Thickness of Jacket . . . 69
Completed Cable . . . 69
Outside Diameters . . . 69
Diameter Tolerances . . . 70
Marking . . . 70
Tests . . . 70
Preassembled Aerial Cables . . . 86
Scope . . . 86
Copper . . . 86
Aluminum . . . 86
Conductor Stress Control Layer . . . 86
Insulation . . . 86
Cable Types . . . 86
Type I—Nonshielded, Jacketed or Nonjacketed . . . 86
Type II—Shielded, Nonjacketed . . . 86
Type III—Shielded, Jacketed . . . 86
Jacket . . . 87
Identification . . . 87
Assembly . . . 87
Messenger Sizes . . . 87
Design Criteria . . . 88
Tests . . . 88
Single- and Multiple-conductor Flexible Cords . . . 88
Scope . . . 88
Conductors . . . 90
Sizes . . . 90
Stranding . . . 90
Separator . . . 90
Insulation . . . 90
Average Thickness . . . 90
Minimum Thickness . . . 90
Conductor Assembly . . . 91
Circuit Identification . . . 92
Length of Lay . . . 92
Fillers . . . 92
Binder . . . 92
Jackets . . . 92
Heavy-duty Jackets . . . 92
Medium-duty Jackets . . . 92
Oil Resistance . . . 94
Application . . . 94
Reinforcement . . . 94
Thickness . . . 94
Overall Diameters . . . 94
Strength of Completed Cord . . . 94
Tests . . . 94
Electrical Tests . . . 94
Control Cables . . . 95
Scope (Deleted) . . . 95
Conductors (Deleted) . . . 95
Insulation (Deleted) . . . 95
Jacket over Insulation (Deleted) . . . 95
Conductor Identification (Deleted) . . . 95
Assembly (Deleted) . . . 95
Overall Jacket (Deleted) . . . 95
Type D Cables (Deleted) . . . 95
Tests (Deleted) . . . 95
Optional Flame Test Requirements (Deleted) . . . 95
Concentric-neutral Underground Distribution Cables . . . 95
Scope . . . 95
Central Conductor . . . 95

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

Copper . . . 99
Aluminum . . . 99
Conductor (Stress Control Layer) . . . 99
Insulation . . . 99
Insulation Shielding and Protective Covering . . . 99
Concentric Conductor . . . 99
Optional Jackets Applied over a Concentric Conductor . . . 100
Extruded to Fill Type Jacket . . . 100
Overlaying Type Jacket . . . 100
Identification . . . 101
Spark Test for Nonconducting Jackets . . . 101
Tests . . . 101
Concentric-neutral Underground Distribution Cables . . . 101
Metal-clad Cables with Grounding Conductor . . . 102
Scope . . . 102
Conductors . . . 102
Cables Rated 2000 Volts or Less . . . 102
Cables Rated 2001 Volts and Above . . . 102
Conductor Stress Control Layer . . . 102
Insulation . . . 102
Insulation Shielding . . . 103
Covering . . . 103
Assembly . . . 103
Armor . . . 103
Tests . . . 103
Nonshielded Single-conductor Power Cable . . . 103
Scope . . . 103
Conductors . . . 103
Insulation . . . 103
Jacket . . . 103
Length of Lay . . . 103
Tests . . . 104
Electrical Requirements . . . 104
AC Voltage Test . . . 104
Insulation Resistance . . . 104
DC Voltage Test . . . 104
Tests for Discharge Resistance . . . 104
Surface Resistivity . . . 104
U-Bend Discharge . . . 104
Nonshielded Single-conductor Cables for Series-lighting Circuits . . . 104
Scope . . . 104
Conductors . . . 104
Insulation . . . 104
Nonjacketed Cable . . . 104
Jacketed Cable . . . 104
Jacket . . . 104
Tests . . . 104
Voltage Tests . . . 105
Insulation Resistance . . . 105
Tests for Discharge Resistance . . . 105
Surface Resistivity . . . 105
U-Bend Discharge . . . 105

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

Part 8 APPENDICES

Appendix A Abbreviations and Symbols 106

Appendix B Representative Tensile Strength and Elongation of Nonmagnetic Metals 107

Appendix C Definitions for Maximum Temperature of Conductors in Insulated Wire and Cable . . . 108
- Maximum Conductor Temperature—Operating 108
- Maximum Conductor Temperature—Emergency Overload 108
- Maximum Conductor Temperature—Short Circuit 108

Appendix D Emergency Overloads 109

Appendix E ICEA Publications and ASTM Standards 110
- ICEA Publications 110
- ASTM Standards 110

Appendix F Ampacities for Two-conductor Concentric-neutral Single-phase Primary Underground Residential Distribution Cables 112

Appendix F-1 Ampacities for Three-phase Underground Distribution Cables 112

Appendix G Shielding 113
- Definition of Shielding 113
- Functions of Shielding 113
- Use of Insulation Shielding 113
- Grounding of the Insulation Shield 113
- Shield Materials 113
- Splices and Terminations 114

Appendix H Recommended Bending Radii for Cables 115
- Scope 115
- Power Cables without Metallic Shielding or Armor 115
- Power Cables with Metallic Shielding or Armor 115
  - Interlocked Armored Cables 115
  - Flat Tape and Wire Armored Cables 115
  - Shielded Cables 115
    - Tape Shielded Cables 115
    - Wire Shielded Cables 115
- Portable Cables 115
- Drum Diameters of Reels 115

Appendix I Ampacities for Three-conductor Mine Power Cables 117

Appendix J Ampacities and Voltage Ratings of Portable Cables 118
- Ampacities (Current-carrying Capacity in Amperes) 118
- Voltage Ratings 118

Appendix K Deleted 120

Appendix L Additional Conductor Information 124

Appendix M Ampacities for Preassembled Aerial Cables 132

Appendix N Flexible Cords and Remote Control and Drill Cords 133
- Ampacities of Flexible Cords 133
- National Electrical Code Type Designations and Maximum Voltage Ratings of Multiple-conductor Flexible Cords 133
- Remote Control and Drill Cords 134

NOTE: Appendix K not included.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

Part 1
GENERAL

1.1 SCOPE

These standards apply to materials, constructions, and testing of ethylene-propylene-rubber-insulated wires and cables which are used for the transmission and distribution of electrical energy for normal conditions of installation and service, such as indoor and outdoor installations, above and below grade, and submarine.

1.2 GENERAL INFORMATION

This publication is so arranged that cables can be designed for a broad range of installation and service conditions. Parts 2 to 4 cover the three major components of cables:

Part 2—Conductors
Part 3—Insulation
Part 4—Shielding and Coverings

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

Specific attention is directed to 4.2 "Shielding Practice." A thorough understanding of these requirements is necessary to secure safe and reliable cable operation at voltages over 2 kV.

Part 5 deals with the assembly, cabling, and identification of two or more conductors.

Part 6 covers the test procedures applicable to cable component materials and to completed cables.

Part 7 covers cables for specific service and installation conditions and gives construction details and additional or modified tests applicable to these particular types. If there is a conflict between Parts 1 through 6 and Part 7, the provisions of Part 7 apply.

Part 8 contains reference data such as definitions, abbreviations, cross-references to other standards, and application and installation information.

In classifying jackets and sheaths in these standards, the term "jacket" refers to a continuous nonmetallic covering and "sheath" to a continuous metallic covering.

Units in these standards are expressed in the English system. For information only, their approximate metric equivalents are included.

1.3 INFORMATION TO BE SUPPLIED BY PURCHASER

When requesting proposals for cable manufacturers, the prospective purchaser should describe the cable desired by reference to pertinent provisions of these standards. To help avoid misunderstandings and possible misapplication of the cables, he should also furnish the following information: (This paragraph is approved by NEMA as Authorized Engineering Information.)

1.3.1 Characteristics of Systems on which Cable is to be Used

a. Current—alternating or direct.
b. Frequency—hertz.
c. Normal operating voltage between phases or, if direct current, between conductors.
d. Number of phases and conductors. If series lighting, give open-circuit voltage and state whether system is operated with or without protectors.
e. Cable insulation level (see 3.2).
f. Minimum temperature at which cable will be installed.
g. Description of installation.
    1. In buildings.
    2. In underground ducts.
    3. Aerial.
        a. On messenger in metal rings.
        b. On messenger with marlin ties.
        c. Preassembled.
        d. Field spun.
    4. Direct burial in ground.
    5. Submarine.
    6. Descriptions other than the foregoing.
h. Conditions of installations.
    1. Ambient temperature.
    2. Number of loaded cables in duct bank or conduit. If in conduit, give type of conduit (metallic or nonmetallic), number of loaded conduits, enclosed or exposed, and spacing between conduits.
    3. Load factor.
    4. Method of bonding and grounding of metallic coverings (including shields).
    5. Wet or dry location.
    6. Thermal resistivity (rho) of soil.

1.3.2 Quantities and Description of Cable

a. Total number of feet, including test lengths, and lengths if specific lengths are required.
b. Type of cable. Describe as single conductor, two-conductor flat, two-conductor round, and such.
c. Rated circuit voltage, phase-to-phase.
d. Type of conductor—copper or aluminum.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

e. Size of conductors – AWG or circular mils. If conditions require other than standard stranding, a complete description should be given.
f. Grade of insulation.
g. Thickness of insulation in mils.
h. Type of outer covering.
i. Maximum allowable overall diameter in inches. When duct space is not limited, it is desirable not to restrict the overall diameter.
j. Method of conductor identification.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS

Not for Resale

Part 2
CONDUCTORS

2.0 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 the standard.

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

a. Approximate diameters of individual wires in stranded conductors
b. Approximate diameters of conductors not listed in Table 2-7.
c. Approximate conductor weights

2.1 WIRES, PHYSICAL, AND ELECTRICAL PROPERTIES

The wires used in conductors shall be copper in accordance with 2.1.1 or aluminum in accordance with 2.1.2.

2.1.1 Copper Wires

Copper wires shall meet the requirements of 2.1.1.1 and either 2.1.1.2 or 2.1.1.3. The 2.1.1.3 option shall apply only to non-compressed and non-compact conductors.

2.1.1.1 Copper wires shall meet the chemical requirements of ASTM B 5.

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

a. ASTM B 3 for uncoated wires.
b. ASTM B 33 for tin-coated wires.
c. ASTM B 189 for lead or lead-alloy-coated wires.

2.1.1.3 Copper wires 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.

2.1.2 Aluminum Wires

Aluminum wires shall meet the requirements of 2.1.2.1 and either 2.1.2.2 or 2.1.2.3. The 2.1.2.3 option shall apply only to non-compressed and non-compact conductors. The requirements of 2.1.2.2 or 2.1.2.3 shall not apply, if the requirements of 2.3.1 or 2.3.2 are met.

2.1.2.1 Aluminum 1350 wires shall meet the chemical requirements of ASTM B 233. Aluminum alloy wires shall contain a minimum of 97 percent aluminum by weight.

2.1.2.2 Aluminum 1350 and aluminum alloy wires intended for a stranded conductor shall meet one of the following:

1. Hard-drawn wire shall meet the tensile, elongation, finish, and brittleness requirements of ASTM B 230.
2. Annealed or intermediate temper wire shall meet the tensile and finish requirements of ASTM B 609.

2.1.2.3 Aluminum 1350 and aluminum alloy wires removed from a concentric lay stranded conductor shall meet the tensile requirements and bending properties of ASTM B 231, Sections 8.5 and 8.6 or 9.2 and 9.4.

2.2 SOLID CONDUCTORS

Solid conductors shall meet the requirements of 2.2.1 or 2.2.2.

2.2.1 A solid copper conductor shall consist of a single round wire meeting the requirements given in 2.1.1.1 and 2.1.1.2.

2.2.2 A solid aluminum 1350 or aluminum alloy conductor shall consist of a single round wire meeting the requirements given in 2.1.2.1, 2.2.2.1, and Table 2-1 and the finish requirements of ASTM B 230. Tensile strength of aluminum 1350 and aluminum alloy conductors and elongation of aluminum alloy conductors shall be determined according to ASTM B 230.

2.2.2.1 Size 12 to 8 American Wire Gauge (AWG) solid aluminum conductors shall be an aluminum alloy with an elongation at rupture of not less than 10 percent in 10 inches.

Table 2-1
Solid Aluminum 1350 and Aluminum Alloy Conductors

Conductor Size	Tensile Strength			
	Aluminum 1350		Aluminum Alloy	
AWG	psi	MPa	psi	MPa
12–8	...	...	15,000–22,000	103–152
7–1	12,000–22,000	83–152	12,000–22,000	83–152
1/0 and larger	8,500–22,000	59–152	8,500–22,000	59–152

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

2.3 STRANDED CONDUCTORS

Stranded conductors shall consist of a number of wires individually meeting the appropriate requirements of 2.1. All wires in a stranded conductor shall be of the same material and temper. There shall be no water in the conductor as shipped.

Exception: Coated wires shall be permitted to be used in only the outer layer of an uncoated conductor in order to obtain free stripping of the adjacent polymeric layer. The dc resistance of the resulting conductor shall not exceed the value specified for an uncoated conductor of the same size.

The requirements for lay, joints, and number of wires shall be in accordance with one of the following:

a. ASTM B 8 for concentric-lay Class B, C, or D stranded copper conductors.
b. ASTM B 172 for rope-lay stranded copper conductors with bunch-stranded members.
c. ASTM B 173 for rope-lay stranded copper conductors with concentric-stranded members.
d. ASTM B 174 for bunch-stranded copper conductors.
e. ASTM B 496 for compact-round stranded copper conductors.
f. ASTM B 231 for concentric-lay Class B, C, or D stranded aluminum 1350 or aluminum alloy conductors.
g. ASTM B 400 for compact-round stranded aluminum 1350 or aluminum alloy conductors.

2.3.1 Concentric-lay-stranded aluminum conductors, including compressed strand, if tested as a unit as an alternative to 2.1.2.2 or 2.1.2.3 and before application of any coverings, shall meet the tensile requirements and bending properties of ASTM B 231, Sections 8.2 to 8.4 and 8.6 or Sections 9.3 and 9.4.

2.3.2 Compact stranded aluminum conductors, if tested as a unit as an alternative to 2.1.2.2 and before application of any coverings, shall meet the tensile requirements of ASTM B 400, Section 8.2 or Section 9.

2.4 CONDUCTOR SIZE UNITS

Conductor size shall be expressed by cross-sectional area in thousand circular mils (kcmil). The AWG equivalents for small sizes shall be found in Table 2-7.

2.5 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 2-3 when using the appropriate nominal value specified in Table 2-4, Table 2-5, and Table 2-6. The dc resistance shall be determined in accordance with 2.5.1 or 2.5.2.

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

2.5.1 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 6.3.1 to an accuracy of 2 percent or better. If measurements are made at a temperature other than 25°C (77°F), the measured value shall be converted to resistance at 25°C (77°F) by using either the following:

a. The appropriate multiplying factor from Table 6-1.
b. A multiplying factor calculated using the applicable formula in the footnote to Table 6-1.

If verification is required for the dc resistance measurement made on an entire length of completed cable, a sample at least 1 foot (30.5 cm) 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.

Where an uninsulated conductor is in contact with another metallic or conductive component of the cable, measurements shall be made on a sample taken from the completed cable.

2.5.2 Calculation of DC Resistance Per Unit Length

The dc resistance per unit length at 25°C (77°F) shall be calculated using the following formula:

$$R = K\rho/A$$

Where:

R = Conductor resistance in Ω / 1000 ft.
K = Weight increment factor, as given in Table 2-2.
ρ = Volume resistivity in Ω cmil/ft., determined in accordance with ASTM B 193 using round wires
A = Cross-sectional area of conductor in kcmil, determined in accordance with 6.3.2.1 or 6.3.2.2 for solid, concentric-lay, rope-lay, and bunch-stranded conductors or 6.3.2.2 for compressed or compact-stranded conductors.

When the volume resistivity is expressed in nana-ohm meter (nΩ • m) and area is expressed in square millimeters (mm^2), the resistance is expressed in milliohms per meter (mΩ/m).

2.6 CONDUCTOR DIAMETER

The diameter of a conductor having a diameter less than 0.750 inch (19 mm) shall be measured in accordance with 6.3.3.1. The diameter of a conductor having a diameter 0.750 inch (19 mm) or larger shall be measured in accordance with 6.3.3.1 or 6.3.3.2. The diameter shall not differ from the nominal values shown in Table 2-7 by more than plus or minus 5 percent.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

Table 2-2
Weight Increment Factors*, K

Solid Conductors	1
Concentric-lay Strand, Class B, C, and D	
up to 2,000 kcmil	1.02
>2,000–3,000 kcmil	1.03
>3,000–4,000 kcmil	1.04
>4,000–5,000 kcmil	1.05
Rope-lay Strand Having Concentric Stranded Members, Classes G and H	
49 wires	1.03
133 wires	1.04
259 wires	1.045
427 wires	1.05
Over 427 wires	1.06
Bunched Strand, single bunches	
All sizes	1.02
Rope-lay Strand Having Bunch-stranded Members, Classes I, K, and M	
7 bunch stranded members	1.04
19	1.05
37	1.05
61	1.05
7 × 7 bunch stranded members	1.06
19 × 7	1.07
37 × 7	1.07
61 × 7	1.07

*Based on the method specified in either ASTM B 8, ASTM B 496, ASTM B 400, ASTM B 231, ASTM B 172, ASTM B 173, or ASTM B 174 as applicable.

2.6.1 The 5 percent diameter tolerance for solid and stranded conductors is provided to enable a designer of connectors to determine the range of conductor sizes which will fit a particular connector; however, a conductor meeting the minimum diameter requirement does not necesarily meet the requirement for maximum dc resistance in 2.5.

2.6.2 If one or more layers of any concentric lay-stranded Class B, C, or D conductor is compressed to reduce the noncompressed outside diameter, the compression shall not exceed 3 percent.

2.7 STRESS CONTROL LAYER (CONDUCTOR SHIELD)

Conductors to be insulated for a rated circuit voltage above 2000 volts shall be covered with a separate stress controlling material compatible with the conductor and

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

the insulation. The material shall have allowable operating temperatures at least equal to those given for the insulation.

2.7.1 Material

The stress control layer shall be a polymeric covering consisting of a conducting tape, an extruded material or an extruded material over a conducting tape. The layer shall have a minimum thickness of 2.5 mils (0.06 mm).

2.7.2 Physical and Aging Requirements

Extruded material, prior to application to the conductor, when tested according to 6.11 shall meet the following requirements.

Elongation after air oven test for 168 hours at 121°C ±1°C for insulations rated 90°C at 136°C ± 1°C for insulations rated 105°C	
Minimum percent	100
Brittleness temperature not warmer than	-10°C

2.7.3 Electrical Requirements

2.7.3.1 The dc resistance of a conducting tape at room temperature, when measured according to ASTM D 4496, shall not exceed 10,000 ohms per unit square.

2.7.3.2 The resistivity of extruded conducting material, when measured according to 6.24 shall not exceed 1000 ohm meter at room temperature and at the maximum normal operating temperature of the cable.

2.7.3.3 The permittivity and dielectric strength of extruded nonconducting stress controlling material, when tested according to 6.31, shall meet the following requirements at room temperature and at the maximum normal operating temperature of the cable:

Permittivity (SIC), range	8 – 1000
60 Hz ac voltage withstand stress, volts per mil (kV/mm), minimum	1500 (59)/ Permittivity

2.7.3.4 The presence of the extruded nonconducting layer on the conductor shall be verified according to ICEA T-27-581 using a 2000 volt dc spark test potential applied to the layer prior to covering with insulation.

Table 2-3
Schedule for Establishing Maximum DC Resistance Per Unit of Length of Completed Cable

NON-PORTABLE CABLES

Cable Type	Maximum DC Resistance
Single Conductor Cable Flat Parallel Cable	Table 2-4* Value Plus 2% (R max = R × 1.02)
Multiple Conductor Cables	Table 2-4* Value Plus 2% Plus One of the Following:
Twisted Asssemblies of Single Conductor Cables	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)

*For conductor strandings or sizes not listed in Tables 2-4 through 2-6, the nominal dc resistance per unit length of a completed single conductor cable shall be calculated from the factors given in Table 2-8 using the following formula:

$R = 10^{-3} f/A$

Where: R = Conductor resistance in Ω/1000 ft.
f = Factor from Table 2-8
A = Cross-sectional area of conductor in kcmil (See 2.5.2 for cross-sectional area determination)

†For 20 AWG and 18 AWG Class K conductors specified in Table 2-6, this value shall be 3 percent.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

Table 2-4
Nom. dc Resistance in ohms per 1000 ft.† at 25°C (77°F) of Solid & Concentric Lay Stranded Conductor

Conductor Size	Solid			Concentric Lay Stranded*				
	Aluminum	Copper		Aluminum	Copper			
AWG or kcmil		Uncoated	Coated	Class B, C, D	Uncoated	Coated		
					Class B, C, D	Class B	Class C	Class D
22	27.1	16.5	17.2	27.4	16.7	17.9	...	...
20	16.9	10.3	10.7	17.3	10.5	11.1	...	...
19	13.5	8.20	8.52	13.7	8.33	8.83	...	...
18	10.7	6.51	6.76	10.9	6.67	7.07	...	...
17	8.45	5.15	5.35	8.54	5.21	5.52	...	...
16	6.72	4.10	4.26	6.85	4.18	4.43	...	...
15	5.32	3.24	3.37	5.41	3.30	3.43	...	...
14	4.22	2.57	2.67	4.31	2.63	2.73	2.79	2.83
13	3.34	2.04	2.12	3.41	2.08	2.16	2.21	2.22
12	2.66	1.62	1.68	2.72	1.66	1.72	1.75	1.75
11	2.11	1.29	1.34	2.15	1.31	1.36	1.36	1.39
10	1.67	1.02	1.06	1.70	1.04	1.08	1.08	1.11
9	1.32	0.808	0.831	1.35	0.825	0.856	0.856	0.874
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	0.325	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
2500	...	...	...	0.00715	0.00436	0.00448	...	...
3000	...	...	...	0.00596	0.00363	0.00374	...	...
3500	...	...	...	0.00515	0.00314	0.00323	...	...
4000	...	...	...	0.00451	0.00275	0.00283	...	...
4500	...	...	...	0.00405	0.00247	0.00254	...	...
5000	...	...	...	0.00364	0.00222	0.00229	...	...

*Concentric lay stranded includes compressed and compact conductors.

†Resistance values in milliohms per meter shall be obtained by multiplying the above values by 3.28.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

Table 2-5
Nominal DC Resistance in Ohms Per 1000 Feet* at 25°C (77°F) for Flexible Aluminum Conductors

Conductor Size AWG or kcmil	Class G	Class H	Class I
8	...	...	1.07
7	0.858	...	0.850
6	0.681	...	0.687
5	0.540	...	0.545
4	0.428	...	0.432
3	0.340	...	0.343
2	0.269	0.272	0.272
1	0.216	...	0.216
1/0	0.171	0.172	0.172
2/0	0.136	0.136	0.137
3/0	0.107	0.108	0.109
4/0	0.0852	0.0857	0.0861
250	0.0725	0.0728	0.0735
300	0.0604	0.0607	0.0613
350	0.0518	0.0520	0.0525
400	0.0453	0.0455	0.0460
450	0.0403	0.0405	0.0409
500	0.0363	0.0364	0.0368
550	0.0331	0.0334	0.0334
600	0.0304	0.0306	0.0306
650	0.0280	0.0283	0.0286
700	0.0260	0.0263	0.0265
750	0.0243	0.0245	0.0247
800	0.0228	0.0230	0.0232
900	0.0202	0.0204	0.0206
1000	0.0182	0.0184	0.0186
1100	0.0166	0.0167	0.0169
1200	0.0152	0.0153	0.0155
1250	0.0146	0.0147	0.0148
1300	0.0140	0.0141	0.0143
1400	0.0130	0.0131	0.0133
1500	0.0121	0.0123	0.0124
1600	0.0115	0.0115	0.0116
1700	0.0108	0.0108	0.0109
1750	0.0105	0.0105	0.0106
1800	0.0102	0.0102	0.0103
1900	0.00968	0.00968	0.00977
2000	0.00919	0.00919	0.00928

*Resistance values in milliohms per meter shall be obtained by multiplying the above values by 3.28.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS

Not for Resale

Table 2-6
Nominal DC Resistance in Ohms per 1000 Feet* at 25°C (77°F) for Flexible Annealed Copper Conductors

Conductor Size	Uncoated					Coated				
AWG or kcmil	Class G	Class H	Class I	Class K	Class M	Class G	Class H	Class I	Class K	Class M
20	...	...	...	10.6	10.6	...	...	...	11.4	11.4
18	...	...	...	6.66	6.66	...	...	...	7.15	7.15
16	...	...	...	4.18	4.18	...	...	...	4.49	4.49
14	2.65	...	...	2.62	2.62	2.81	...	...	2.82	2.82
12	1.67	...	...	1.65	1.68	1.77	...	...	1.77	1.81
10	1.05	...	1.04	1.04	1.06	1.11	...	1.08	1.12	1.14
9	0.832	...	0.824	0.840	0.840	0.884	...	0.857	0.902	0.902
8	0.660	0.666	0.653	0.666	0.666	0.701	0.708	0.679	0.715	0.715
7	0.523	0.528	0.518	0.528	0.533	0.544	0.561	0.539	0.567	0.573
6	0.415	0.419	0.419	0.419	0.423	0.432	0.445	0.436	0.450	0.454
5	0.329	0.332	0.332	0.332	0.336	0.342	0.353	0.346	0.357	0.360
4	0.261	0.263	0.263	0.263	0.266	0.271	0.280	0.274	0.283	0.286
3	0.207	0.209	0.209	0.211	0.213	0.215	0.222	0.217	0.227	0.227
2	0.164	0.166	0.166	0.167	0.169	0.171	0.172	0.172	0.180	0.181
1	0.131	0.132	0.131	0.133	0.134	0.137	0.140	0.137	0.142	0.144
1/0	0.104	0.105	0.105	0.105	0.106	0.108	0.109	0.109	0.113	0.114
2/0	0.0826	0.0830	0.0834	0.0842	0.0850	0.0859	0.0863	0.0868	0.0904	0.0913
3/0	0.0655	0.0659	0.0662	0.0668	0.0674	0.0682	0.0685	0.0688	0.0717	0.0724
4/0	0.0520	0.0522	0.0525	0.530	0.0535	0.0541	0.0543	0.0546	0.0569	0.0574
250	0.0442	0.0444	0.0448	0.448	0.0453	0.0460	0.0462	0.0466	0.0481	0.0486
300	0.0368	0.0370	0.0374	0.374	0.0377	0.0383	0.0385	0.0389	0.0401	0.0405
350	0.0316	0.0317	0.0320	0.0323	0.0323	0.0328	0.0330	0.0333	0.0347	0.0347
400	0.0276	0.0278	0.0280	0.0283	0.0283	0.0287	0.0289	0.0291	0.0304	0.0304
450	0.0246	0.0247	0.0249	0.0251	0.0251	0.0255	0.0257	0.0259	0.0270	0.0262
500	0.0221	0.0222	0.0224	0.0226	0.0226	0.0230	0.0231	0.0233	0.0243	0.0243
550	0.0202	0.0204	0.0204	0.0206	0.0206	0.0210	0.0212	0.0212	0.0221	0.0221
600	0.0185	0.0187	0.0187	0.0189	0.0189	0.0192	0.0194	0.0194	0.0203	0.0202
650	0.0171	0.0172	0.0174	0.0174	0.0174	0.0178	0.0179	0.0181	0.0187	0.0187
700	0.0159	0.0168	0.0162	0.0162	0.0162	0.0165	0.0167	0.0168	0.0174	0.0174
750	0.0148	0.0149	0.0151	0.0151	0.0151	0.0154	0.0155	0.0157	0.0162	0.0162
800	0.0139	0.0140	0.0141	0.0141	0.0141	0.0144	0.0146	0.0147	0.0152	0.0152
900	0.0123	0.0125	0.0126	0.0126	0.0126	0.0128	0.0130	0.0131	0.0135	0.0135
1000	0.0111	0.0112	0.0113	0.0113	0.0113	0.0115	0.0117	0.0118	0.0122	0.0121
1100	0.0101	0.0102	0.0103	...	...	0.0105	0.0106	0.0107	...	...
1200	0.00925	0.00934	0.00943	...	...	0.00962	0.00971	0.00981	...	...
1250	0.00888	0.00897	0.00905	...	...	0.00924	0.00933	0.00941	...	...
1300	0.00854	0.00862	0.00870	...	...	0.00888	0.00897	0.00905	...	...
1400	0.00793	0.00801	0.00808	...	...	0.00825	0.00833	0.00841	...	...
1500	0.00740	0.00747	0.00754	...	...	0.00770	0.00777	0.00785	...	...
1600	0.00701	0.00701	0.00707	...	...	0.00729	0.00729	0.00735	...	...
1700	0.00659	0.00659	0.00666	...	...	0.00686	0.00686	0.00692	...	...
1750	0.00641	0.00641	0.00647	...	...	0.00666	0.00666	0.00672	...	...
1800	0.00623	0.00623	0.00629	...	...	0.00648	0.00648	0.00654	...	...
1900	0.00590	0.00590	0.00596	...	...	0.00614	0.00614	0.00619	...	...
2000	0.00561	0.00561	0.00566	...	...	0.00583	0.00583	0.00588	...	...

*Resistance values in milliohms per meter shall be obtained by multiplying the above values by 3.28.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

Table 2-7
Nominal Diameters for Copper and Aluminum Conductors

Conductor Size		Nominal Diameters*					
			Concentric Lay Stranded				
		Solid	Compact	Compressed	Class B	Class C	Class D
AWG	kcmil	Inch	Inch	Inch	Inch	Inch	Inch
22	0.812	0.0253	...	...	...	...	...
20	1.02	0.0320	...	...	...	...	...
19	1.29	0.0359	...	...	...	...	...
18	1.62	0.0403	...	...	...	...	...
17	2.05	0.0453	...	...	...	...	...
16	2.58	0.0508	...	...	...	...	...
15	3.26	0.0571	...	0.0629	0.0648	...	...
14	4.11	0.0641	...	0.0704	0.0727	0.0735	0.0735
13	5.18	0.0720	...	0.0792	0.0816	0.0825	0.0826
12	6.53	0.0808	...	0.0888	0.0915	0.0925	0.0931
11	8.23	0.0907	...	0.0998	0.103	0.104	0.104
10	10.38	0.1019	...	0.112	0.116	0.117	0.117
9	13.09	0.1144	...	0.126	0.130	0.131	0.132
8	16.51	0.1285	0.134	0.141	0.146	0.148	0.148
7	20.82	0.1443	...	0.158	0.164	0.166	0.166
6	26.24	0.1620	0.169	0.178	0.184	0.186	0.186
5	33.09	0.1819	...	0.200	0.206	0.208	0.209
4	41.74	0.2043	0.213	0.225	0.232	0.234	0.235
3	52.62	0.2294	0.238	0.252	0.260	0.263	0.264
2	66.36	0.2576	0.268	0.283	0.292	0.296	0.297
1	83.69	0.2893	0.299	0.322	0.332	0.333	0.333
1/0	105.6	0.3249	0.336	0.361	0.372	0.374	0.374
2/0	133.1	0.3648	0.376	0.406	0.418	0.420	0.420
3/0	167.8	0.4096	0.423	0.456	0.470	0.471	0.472
4/0	211.6	0.4600	0.475	0.512	0.528	0.529	0.530
	250	0.5000	0.520	0.558	0.575	0.576	0.576
	300	0.5477	0.570	0.611	0.630	0.631	0.631
	350	0.5916	0.616	0.661	0.681	0.681	0.682
	400	0.6325	0.659	0.706	0.728	0.729	0.729
	450	0.6708	0.700	0.749	0.772	0.773	0.773
	500	0.7071	0.736	0.789	0.813	0.814	0.815
	550	...	0.775	0.829	0.855	0.855	0.855
	600	...	0.813	0.866	0.893	0.893	0.893
	650	...	0.845	0.901	0.929	0.930	0.930
	700	...	0.877	0.935	0.964	0.965	0.965
	750	...	0.908	0.968	0.998	0.999	0.998
	800	...	0.938	1.000	1.030	1.032	1.032
	900	...	0.999	1.061	1.094	1.093	1.095
	1000	...	1.060	1.117	1.152	1.153	1.153
	1100	...	...	1.173	1.209	1.210	1.211
	1200	...	...	1.225	1.263	1.264	1.264
	1250	...	...	1.251	1.289	1.290	1.290
	1300	...	...	1.275	1.314	1.316	1.316
	1400	...	...	1.323	1.365	1.365	1.365
	1500	...	...	1.370	1.412	1.413	1.413
	1600	...	...	1.415	1.459	1.460	1.460
	1700	...	...	1.459	1.504	1.504	1.504
	1750	...	...	1.480	1.526	1.527	1.527
	1800	...	...	1.502	1.548	1.548	1.549
	1900	...	...	1.542	1.590	1.590	1.591
	2000	...	...	1.583	1.632	1.632	1.632

*Diameters in millimeters shall be obtained by multiplying the above values in inches by 25.4.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS

Not for Resale

Table 2-8*
Factors† for Determining Nominal Resistance of Stranded Conductors per 1000 Feet

			Diameter of Individual Coated Copper Wires in Inches for Stranded Conductors				
	All Sizes, Uncoated		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 0.111 to 0.0010, Inclusive
	Aluminum	Copper					
Conductivity Percent	**61**	**100**	**97.66**	**97.16**	**96.16**	**94.16**	**93.15**
	25°C	25°C	25°C	25°C	25°C	25°C	25°C
Rope Stranded							
49 strands	17865	10892	11153	11210	11327	11568	...
133 strands	18038	10998	11261	11319	11437	11681	...
259 strands	18125	11051	11315	11374	11492	11737	...
427 strands	18212	11104	11370	11428	11547	11793	...
Over 427 strands	18385	11209	11478	11537	11657	11905	...
Bunch Stranded							
All Sizes	17691	10786	...	...	11217	11456	11579
Rope-stranded Bunches							
7 ropes of bunched strand	18038	10998	...	...	11437	11681	11806
19, 37, or 61 ropes of bunched strand	18212	11104	...	...	11547	11793	11920
7 x 7 ropes of bunched strand	18385	11209	...	...	11657	11905	12033
19, 37, or 61 x 7 ropes of bunched strand	18559	11315	...	...	11767	12018	12147
Concentric Stranded							
Up to 2000 kcmil	17692	10786	11045	11102	11217	11456	11580
> 2000 to 3000 kcmil	17865	10892	11153	11211	11327	11568	11694
> 3000 to 4000 kcmil	18039	10998	11261	11319	11437	11680	11807
> 4000 to 5000 kcmil	18212	11104	11369	11428	11547	11792	11921

*The factors given in Table 2-8 shall be 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 or ASTM B 189 for coated copper.
   3. A volume resistivity of 17.345 Ω • cmil/ft (61% conductivity) at 25°C for aluminum

B. Increase in Resistance Due to Stranding

   1. The value of K (weight increment factor) given in Table 2-2.

† See Table 2-3 for Use of Factors.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS

Not for Resale

PART 3
INSULATION

3.1 MATERIAL

The insulation shall be an ethylene-propylene rubber meeting the dimensional, electrical, and physical requirements specified in Part 3.

This insulation is suitable for use on cables in wet or dry locations at not more than 35,000 volts between phases at the 100 percent insulation level and at not more than 25,000 volts at the 133 percent insulation level. The conductor temperature shall not exceed:

Insulation Type	Normal Operation	Emergency Overload Condition*
I, II and IV	90°C	130°C
III	105°C	140°C

* See Appendix D

The conductor temperature shall not exceed 250°C for short circuit conditions in accordance with ICEA P-32-382 and P-45-482.

3.2 INSULATION THICKNESSES

The insulation thicknesses given in Table 3-1A and Table 3-1B are based on the rated circuit voltage, phase-to-phase, and on the cable insulation level.

The thicknesses of insulation given in Table 3-1A and Table 3-1B shall apply to single-conductor cables and to the individual conductors of multiple-conductor cables. For exceptions see 3.3.

The average thickness of the insulation shall be not less than given in Table 3-1A and Table 3-1B. The minimum thickness shall be not less than 90 percent of values given in Table 3-1A and Table 3-1B. (See 6.4 for method of measurement).

The thickness of insulation for various systems shall be determined as follows:

3.2.1 Three-Phase Systems With 100 or 133 Percent Insulation Level

Use the thickness values given in the respective columns of Table 3-1A or Table 3-1B as applicable.

3.2.2 Delta Systems over Where One Leg May be Grounded for Periods over 1 Hour

See 173 percent level in note following Table 3-1B.

3.2.3 Single-and Two-Phase Systems with 100 and 133 Percent Insulation Level

For nonshielded cables, multiply the voltage to ground by 1.73 and use the resulting voltage value to select the corresponding insulation thickness from Column A or Column B of Table 3-1A, as applicable.

For shielded cables, multiply the voltage to ground by 1.73 and select the corresponding insulation thickness from the 100 percent insulation level or 133 percent insulation level Column in Table 3-1B, as applicable.

3.2.4 Direct Current Systems

Up to and including 2000 volts, consider the same as three-phase ac systems in accordance with 3.2.1. Over 2000 volts, consult the manufacturer.

3.3 Insulation Thickness for Submarine Power Cable

The insulation thickness shall be given in Table 3-1A and Table 3-1B with the following exceptions for voltage classifications up to and including 5 kV:

a. When Type I, III or IV insulation (see 3.6, 3.8 or 3.9) are used, the average thickness of insulation in cables without a metallic sheath shall be increased by 30 mils (0.76 mm);
b. When Type II insulation (see 3.7) is used without a jacket or sheath, the average shall not be less than 60 mils (1.52 mm).

3.4 REPAIRS

Repairs or joints in the insulation shall conform to the limitations on insulation thickness given in 3.2. Each length of insulated conductor containing repairs or joints shall meet the electrical requirements of 3.6 or 3.7, 3.8 or 3.9, as applicable.

3.5 INSULATION TYPES AND REQUIREMENTS

3.5.1 Insulation Types

The insulation shall be either Type I (see 3.6) or Type II (see 3.7). Type III (see 3.8) or Type IV (see 3.9).

3.5.2 Voltage Tests

(See 6.27). Each length of completed cable shall be tested in accordance with the paragraphs specified in Table 3-2. The cable shall withstand, without failure, the test voltages given in Table 3-1A and Table 3-1B as applicable.

The test voltages shall be based on the rated voltage of the cable and the size of the conductor and not on the apparent thickness of the insulation.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

3.5.3 Insulation Resistance Constants

The insulation resistance constants of insulations shall be in accordance with 3.6, 3.7, 3.8 or 3.9, as applicable. (See 6.28).

3.5.4 Inspection for Evidence of Water

Each length of completed shielded cable 2001 volts and above shall be inspected for evidence of water in accordance with 6.33. If evidence of water is present, the affected cable length shall be dried by a suitable method.

3.6 TYPE I INSULATION

This insulation is suitable for use on single-conductor cables having a covering over the insulation and on multiple-conductor cables having an overall covering.

3.6.1 Physical and Aging Requirements

When tested in accordance with Part 6, the insulation shall meet the following requirements:

Physical Requirements	
Tensile Strength, minimum	
psi	700
MPa	4.8
Elongation at rupture, minimum percent	250
Aging Requirements	
After Air Oven Test at 121°C±1°C for 168 hours—Tensile Strength and Elongation at Rupture, Minimum Percentage of Unaged Value	75
After Hot Creep Test at 150°C±2°C	
Hot Creep Elongation, Maximum Percent	50
Hot Creep Set, Maximum Percent	5

3.6.2 Electrical Requirements

3.6.2.1 VOLTAGE TESTS

See 3.5.2.

3.6.2.2 INSULATION RESISTANCE

(See 6.28) Each insulated conductor in the completed cable shall have an insulation resistance not less than that corresponding to a constant of 20,000 at 15.6°C (60°F).

3.6.2.3 PARTIAL-DISCHARGE EXTINCTION LEVEL

(See ICEA T-24-380). Each length of completed power cable rated at 2001 volts and above with insulation shielding on the individual conductors shall comply with the following table:

Rated Circuit Voltage, Phase-to-Phase, Volts	Minimum Partial-Discharge Extinction Level, kV	
	100 Percent Insulation Level	133 Percent Insulation Level
2001–5000	4	5*
5001–8000	6	8
8001–15000	11	16
15001–25000	19	26
25001–28000	21	...
28001–35000	26	...

*Unless otherwise indicated, the cable will be rated at the 100 percent insulation level.

3.6.3 Additional Requirements

3.6.3.1 CAPACITY AND POWER FACTOR (DISSIPATION FACTOR)

(See 6.22.) The insulation on cables rated 5001 volts and above shall have a specific inductive capacitance not exceeding 4.0 and a power factor (dissipation factor, tan δ) not exceeding 2.0 percent.

3.6.3.2 ACCELERATED WATER ABSORPTION REQUIREMENTS

The insulation shall meet the following requirements when tested in accordance with the Accelerated Water Absorption Test, EM-60 as specified in ICEA T-27-581/NEMA WC 53 at the temperature specified in the table below:

Electrical Method 60 Hz at 75 ± 1°C	
Dielectric constant after 24 hours, maximum.	4.0
Increase in capacitance, maximum, percent	
1 to 14 days	3.5
7 to 14 days	1.5
Stability factor after 14 days, maximum*	1.0
Alternate to stability factor-stability factor difference, 1 to 14 days, maximum*	0.5

* Only one of these two requirements need be satisfied, not both.

3.7 TYPE II INSULATION

This insulation is suitable for use on single-conductor cables having a covering over the insulation and on multiple-conductor cables having an overall covering. Also, it is suitable for use on single-conductor cables, without covering, rated at voltages up through 2000 volts. When used without a covering, the insulation shall be carbon-black pigmented to provide resistance to sunlight.

3.7.1 Physical and Aging Requirements

When tested in accordance with Part 6, the insulation shall meet the following requirements:

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

Table 3-1a
Nonshielded Cables
Conductor Sizes, Insulation Thicknesses and Test Voltages

Phase to Phase Volts***	Conductor Size, AWG kcmil	Insulation Thickness* mils	mm	mils	mm	ac Test Voltage, kV**		dc Test Voltage, kV		dc Spark Test Voltage, kV		ac Spark Test Voltage, kV**	
		Column A		Column B		Column A	Column B	Column A	Column B	Column A	Column B	Column A	Column B+
0-600	14-9++	45	1.14	30	0.76	4.0	3.5	12.0	10.5	16.0	10.5	10.0	7.5
	8-2	60	1.52	45	1.14	5.5	5.5	16.5	16.5	21.0	16.5	15.0	10.0
	1-4/0	80	2.03	55	1.40	7.0	7.0	21.0	21.0	28.0	21.0	17.5	12.5
	225-500	95	2.41	65	1.65	8.0	8.0	24.0	24.0	33.5	24.0	20.0	15.0
	525-1000	110	2.79	80	2.03	10.0	10.0	30.0	30.0	38.5	30.0	27.5	17.5
	1025-2000	125	3.18	100	2.54	11.5	11.5	34.0	34.0	44.0	34.0	31.0	20.0
601-2000	14-9++	60	1.52	45	1.14	5.5	5.5	16.5	16.5	21.0	16.5	15.0	10.0
	8-2	70	1.78	55	1.40	7.0	7.0	21.0	21.0	24.5	21.0	17.5	12.5
	1-4/0	90	2.29	65	1.65	8.0	8.0	24.0	24.0	31.5	24.0	20.0	15.0
	225-500	105	2.67	75	1.90	9.5	9.5	28.5	28.5	37.0	28.5	25.0	17.5
	525-1000	120	3.05	90	2.29	11.5	11.5	34.5	34.5	42.0	34.5	30.0	20.0
	1025-2000	140	3.56	115	2.92	13.5	13.5	40.0	40.0	49.0	40.0	35.0	24.0
2001-5000	8-1000+++												

* Column A thickness (2000 volts or less) apply to single-conductor power cables for general application which employ a sunlight-resistant, carbon-black pigmented insulation without further covering. See 3.7.

Column B thicknesses (2000 volts or less) apply to multiple-conductor cables with an outer covering and to single-conductor cables with an outer covering.

The Column B thicknesses are considered adequate for electrical purposes and may be specified for single-conductor cables employing sunlight-resistant, carbon black pigmented insulation without further covering. These cables may be used in applications where installation and service conditions are such that the additional thickness for mechanical protection is not considered necessary for satisfactory operation. All AC Voltages are RMS values

Column A and Column B insulation thickness are adequate for both 100 percent and 133 percent insulation levels. For 173 percent insulation level, consult the manufacturer. Refer to Table 3-2B for insulation level definitions.

** All AC voltages are RMS values.

*** The actual operating voltage shall not exceed the rated circuit voltage by more than (a) 5 percent during continuous operation or (b) 10 percent during emergencies lasting not more than 15 minutes.

\+ Column B ac spark test voltages for conductor sizes through 1000 kcmill are taken from paragraph 42.1 of UL Standard 44, *Rubber Insulated Wires and Cables*, 13th Edition.

++ Single-conductor cables in sizes 9 AWG and smaller shall not be used for direct earth burial.

+++ For single conductor cables with or without jacket see 7.9 and 7.10. For single and multiple-conductor cables with a metallic sheath or armor and for multiple-conductor cables with a discharge-resistant jacket (see Table 4-1), the insulation thickness shall be 90 mils (2 29 mm) and the test voltage shall be 13 kV ac or 35 kV dc (see 3 5.2).

Table 3-1b
Shielded Cables
Conductor Sizes, Insulation Thicknesses and Test Voltages+++

Rated Circuit Voltage, Phase+ Volts	Conductor Size, AWG or kcmil++	Insulation Thickness * 100 Percent Insulation Level mils	mm	133 Percent Insulation Level mils	mm	ac Test Voltage, kV** 100 Percent Insulation Level	133 Percent Insulation Level	dc Test Voltage, kV 100 Percent Insulation Level	133 Percent Insulation Level
2001–5000	8–1000	90	2.29	90	2.29	13	13	–	–
5001–8000	6–1000	115	2.92	140	3.56	18	22	45	45
8001–15000	2–1000	175	4.45	215	5.46	27	33	70	80
15001–25000	1–1000	260	6.60	345	8.76	38	*49*	100	125
25001–28000	1–1000	280	7.11	–	–	42	–	105	–
28001–35000	1/0–1000	345	8.76	–	–	49	–	125	–

* The selection of the cable insulation level to be used in a particular installation shall be made on the basis of the applicable phase-to-phase voltage and the general system category as outlined below:

100 Percent 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 1 minute. While these cables are applicable to the great majority of cable installations which are on grounded systems, they may also be used on other systems for which the application of cable is acceptable (see note below) provided the above clearing requirements are met in completely de-energizing the faulted section.

Where additional insulation thickness is desired, it shall be the same for the 133 percent insulation level for rated circuit voltages over 5000 volts.

133 Percent 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 percent level category cannot be met, and yet there is adequate assurance that the faulted section will be de-energized in a time not exceeding 1 hour. They may be used when additional insulation strength over the 100 percent level category is desirable for rated circuit voltages over 5000 volts.

173 Percent 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 recommended also for resonant grounded systems. Consult the manufacturer for insulation thicknesses.

** *All ac voltages are RMS values*

\+ The actual operating voltage shall not exceed the rated circuit voltage by more than (a) 5 percent during continuous operation or (b) 10 percent during emergencies lasting no more than 15 minutes.

++ To limit the maximum voltage stress on the insulation at the conductor to a safe value, the conductor size shall not be less than the minimum size shown for each rated circuit voltage category

+++ Consult the manufacturer for recommended insulation thicknesses and corresponding test voltages which are not listed.

NOTE—In common with other electrical equipment, the use of cables is not recommended on systems where the ratio of the zero to positive phase reactance of the system at the point of cable application lies between -1 and - 0 since excessively high voltages may be encountered in the case of ground faults.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS

Not for Resale

Table 3-2
VOLTAGE TESTS

	Single Conductor Cable	Assemblies of Insulated Single Conductors	Assemblies of Insulated and Uninsulated Conductors	Multiple-conductor Cables with Common Covering
1. Cables Without Inulsation Shield				
a. 0–2000 volts				
1. Without metallic sheath or armor	6.27.2 or 6.27.3 or 6.27.4a or 6.27.4b	6.27.2 or 6.27.3 or 6.27.4a or 6.27.4b	6.27.2 or 6.27.3	6.27.2 or 6.27.3
2. Without metallic sheath or armor	6.27.2 or 6.27.3	6.27.2 or 6.27.3	6.27.2 or 6.27.3	6.27.2 or 6.27.3
b. 2001–5000 volts	6.27.2 or 6.27.3	6.27.2 or 6.27.3	6.27.2 or 6.27.3	6.27.2 or 6.27.3
2. Cables With Insulation shield				
a. 0–5000 volts	6.27.2	6.27.2	6.27.2	6.27.2
b. 5001 volts and over	6.27.2 and 6.27.3	6.27.2 and 6.27.3	6.27.2 and 6.27.3	6.27.2 and 6.27.3

See Part 6 for:

6.27.2 AC voltage test
6.27.3 DC voltage test
6.27.4a AC spark test
6.27.4b DC spark test

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS

Not for Resale

Physical Requirements	
Tensile Strength, minimum	
psi	1200
MPa	8.2
Elongation at rupture, minimum percent	150
Tensile stress at 100 percent elongation, minimum	
psi	500
MPa	3.4
Aging Requirements	
After Air Oven Test at 121°C±1°C for 168 hours—Tensile Strength and Elongation at Rupture, Minimum Percentage of Unaged Value	75
After Hot Creep Test at 150°C±2°C	
Hot Creep Elongation, Maximum Percent	50
Hot Creep Set, Maximum Percent	5

3.7.2 Electrical Requirements

Each insulated conductor in the completed cable shall meet the requirements of 3.6.2, except that the insulation resistance constants shall be:

0–2000 volts	10,000
2001–35000 volts	20,000

3.7.3 Additional Requirements

3.7.3.1 Capacity and Power Factor (Dissipation Factor)

(See 6.22.) The insulation on cables rated 5001 volts and above shall have a specific inductive capacitance not exceeding 4.0 and a power factor (dissipation factor, tan δ) not exceeding 2.0 percent.

3.7.3.2 Accelerated Water Absorption Requirements

The insulation shall meet the following requirements when tested in accordance with the Accelerated Water Absorption Test, EM-60 as specified in ICEA T-27-581/NEMA WC 53 at the temperature specified in the table below:

Water Absorption Requirements for Type II Insulations

Electrical Method 60 Hz @ 75°± 1°C	0–2000 Volts	2001–35000 Volts
Dielectric constant after 24 hours, maximum	6.0	4.0
Increase in capacitance, maximum, percent		
1 to 14 days	5.0	3.5
7 to 14 days	3.0	1.5
Stability factor after 14 days, maximum*	1.0	1.0
Alternate to stability factor (stability factor difference), 1 to 14 days maximum*	...	0.5

* Only one of these two requirements need be satisfied, not both.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

3.8 TYPE III INSULATION

This insulation is suitable for use on shielded cables rated 2001 volts and above. It is suitable for use on single-conductor cables having a covering over the insulation and on multiple-conductor cables having an overall covering.

Lower temperatures for normal operation (see 3.1) may be required because of the type of material used in the cable joints and terminations or because of cable environmental conditions.

Because of the maximum temperature rating of this insulation (see 3.1), all the coverings given in Part 4 are not necessary suitable. Consult the cable manufacturer for further information.

3.8.1 Physical and Aging Requirements

When tested in accordance with Part 6, the insulation shall meet the following requirements:

Physical Requirements	
Tensile Strength	
Minimum, psi (MPa)	700 (4.8)
Elongation at rupture, minimum percent	250
Aging Requirements	
After Air Oven Test at 136°C ±1°C for 168 hours—Tensile Strength and Elongation at Rupture, Minimum Percentage of Unaged Value	75
After Hot Creep Test at 150°C±2°C	
Elongation, Maximum Percent	50
Set, Maximum Percent	5

3.8.2 Electrical Requirements

3.8.2.1 Voltage Tests

(See 3.5.2)

3.8.2.2 Insulation Resistance Test

(See 6.28.) Each insulated conductor in the completed cable shall have an insulation resistance not less than that corresponding to a constant of 20,000 at 15.6°C.

3.8.2.3 Partial Discharge Extinction Level

(See 6.29.) Each length of completed power cable rated at 2001 volts and above with insulation shielding on the individual conductors shall comply with the following table:

Rated Circuit Voltage Phase-to-Phase, Volts	Minimum Partial-Discharge Extinction Level, kV	
	100 Percent Insulation Level	133 Percent Insulation Level
2001 – 5000	4	5*
5000 – 8000	6	8
8001 – 15000	11	15
15001 – 25000	19	26
25001 – 28000	21	–
28001 – 35000	26	–

* Unless otherwise indicated, the cable shall be rated at the 100 percent insulation level.

3.8.3 Additional Requirements

3.8.3.1 Capacity and Power Factor (Dissipation Factor)

(See 6.22.) The insulation on cables rated 5001 volts and above shall have a specific inductive capacitance not exceeding 4.0 and a power factor (dissipation factor, tan δ) not exceeding 2.0 percent.

3.8.3.2 Accelerated Water Absorption

The insulation shall meet the following requirements when tested in accordance with the Accelerated Water Absorption Test, EM-60 as specified in ICEA T-27-581/NEMA WC 53 at the temperature specified in the table below:

Electrical Method (60 Hz)	
Dielectric constant after 24 hours, maximum.	4.0
Increase in capacitance, maximum, percent	
1 to 14 days	3.5
7 to 14 days	1.5
Stability factor after 14 days, maximum*	1.0
Alternate to stability factor-stability factor difference, 1 to 14 days, maximum*	0.5

* Only one of these two requirements need be satisfied, not both.

3.8.3.3 Dry Electrical Test

(See 6.33.) A completed cable core with this insulation shall meet the following requirements:

a. Demonstrate a partial discharge level not greater than 5 picocoulomb at 150 volts per mil (5.9 kV/mm) ac electrical stress before and after testing.

b. Demonstrate no more than a 10 percent increase in dissipation factor (tan δ) after testing.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

3.9 TYPE IV INSULATION

This insulation has specific discharge resistance requirements and is suitable for use on cables rated 2001 through 35,000 volts as single-conductor cables having a covering over the insulation and on multiple-conductor cables having an overall covering.

3.9.1 Physical and Aging Requirements

When tested in accordance with Part 6, the insulation shall meet the following requirements:

Physical Requirements	
Tensile Strength	
Minimum, psi (MPa)	550 (3.8)
Elongation at rupture, minimum percent	250
Aging Requirements	
After Air Oven Test at 121°C ±1°C for 168 hours—Tensile Strength and Elongation at Rupture, Minimum Percentage of Unaged Value	75
Elongation at Rupture, Minimum, Percent	50
After Hot Creep Test at 150°C±2°C	
Elongation, Maximum Percent	50
Set, Maximum Percent	5

3.9.2 Electrical Requirements

3.9.2.1 VOLTAGE TESTS

(See 3.5.2.)

3.9.2.2 INSULATION RESISTANCE TEST

(See 6.28.) Each insulated conductor in the completed cable shall have an insulation resistance not less than that corresponding to a constant of 20,000 at 15.6°C (60°F).

3.9.3 Additional Requirements

3.9.3.1 CAPACITY AND POWER FACTOR (DISSIPATION FACTOR)

(See 6.22.) The insulation on cables rated at 5001 volts and above shall have a specific inductive capacitance not exceeding 4.0 and a power factor (dissipation factor, tan δ) not exceeding 2.5 percent

3.9.3.2 ACCELERATED WATER ABSORPTION

The insulation shall meet the following requirements when tested in accordance with the Accelerated Water Absorption Test, EM-60 as specified in ICEA T-27-581/NEMA WC 53 at the temperature specified in the table below:

Electrical Method (60 Hz)	Voltage Rating, Volts	
	2001–28000	28000–35000
Dielectric Constant (SIC), After 24 Hours, Maximum	4.0	4.0
Increase in Capacitance, Maximum Percent		
1 to 14 days	7.0	3.5
7 to 14 days	4.0	1.5
Stability Factor After 14 Days, Maximum*	1.0	1.0
Alternate to Stability Factor (Stability Factor Difference 1 to 14 Days), Maximum*	0.5	0.5

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

3.9.3.3 INSULATION CORONA DISCHARGE RESISTANCE TEST

(See 6.23.4.) Insulation specimens (minimum of three for each test temperature), when tested at 25°C ±5°C in a 20 ±5% relative humidity environment and at 90°C in a 20% maximum relative humidity environment, shall withstand a 60 Hz test voltage of 21 kV applied for 250 hours and shall not exhibit surface erosion when examined visually with 15 times magnification.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

Part 4
SHIELDING AND COVERINGS
SHIELDING (SEE APPENDIX G)

4.1 SHIELDING OF INSULATED CABLE

Shielding of insulated cables shall consist of conductor stress control layer and insulation shielding. For stress control layer see 2.7.

4.1.1 Insulation Shield

The insulation shield system shall consist of a nonmetallic covering directly over the insulation and a nonmagnetic metal component directly over or embedded in the nonmetallic covering. The nonmetallic covering shall comply with 4.1.1.1. The metal component shall comply with 4.1.1.2. The insulation shield system shall be resistant to or protected against chemical action from other cable components.

4.1.1.1 NONMETALLIC COVERING

A conducting nonmetallic covering that meets the requirements of Table 4a or 4b shall be applied over the insulation in one or more layers in direct contact and shall be plainly identified as being conducting. Identification shall be provided for each distinct layer.

If one of the layers is a coating, it shall be applied directly over the insulation.

For cables employing Types I, II, or III insulations, the tension necessary to remove an extruded covering from cable at room temperature shall be not less than 3 pounds (13.3 N) for cables 2001 through 25,000 volts and not less than 4 pounds (17.8 N) for cables rated 25,001 through 35,000 volts (see Part 6). For cables employing Type IV insulation, no minimum stripping force is specified.

See Appendix G, Paragraph G6.1, regarding the removal of insulation shielding at splices and terminations.

4.1.1.2 METAL COMPONENT

A nonmagnetic metal component consisting of a tape or tapes, wires, straps, or sheaths shall be applied over or embedded in the conducting nonmetallic covering. The metal components shall be electrically continuous throughout each cable length and shall be in contact with the nonmetallic covering. Metal components shall be applied in such a manner that electrical continuity or contiguity will not be distorted or disrupted during normal installation bending (see Appendix H).

Metal tape(s) shall be copper at least 2.5 mils (0.0635 mm) thick or of other nonmagnetic metal tape(s) having equivalent conductance. Wires, straps, or sheaths shall be of copper and have a total area at any cross section of at least 5000 circular mils per inch (0.1 mm^2/mm) of insulated conductor diameter, or of other nonmagnetic metals having equivalent conductance.

Metal tapes, wires, straps, and sheaths may be used in combination providing they are compatible and meet the requirements of the preceding paragraph.

Metal components embedded in a conducting nonmetallic covering shall not be exposed nor become exposed during normal installation bending (see Appendix H).

NOTE—Additional conductance may be required in the metal component depending upon installation and electrical system characteristics, particularly in regard to the functioning of overcurrent protective devices, available fault current, and the manner in which the system may be grounded. (This paragraph is approved by NEMA as Authorized Engineering Information.)

4.1.2 Multiple-Conductor Cables

When shielding is required on multiple-conductor cables (see 4.2), the shields shall be applied over the individual conductors.

4.1.3 Conductor Identification

See 5.3.

4.2 SHIELDING LIMITS FOR POWER CABLE FOR FIXED LOCATIONS

4.2.1 Insulation shielding shall be used on power cables for fixed locations when intended for operation above the three-phase (line-to-line) operating voltages given in Table 4-1. To obtain the equivalent three-phase voltage for single-phase or two-phase ac systems or for dc systems, multiply the line-to-line voltage by the factors given in Table 4-1.

4.2.2 Shielding should be considered where any of the following conditions apply:

a. Connections to aerial lines;
b. Transition from conducting to nonconducting environment;
c. Transition from moist to dry earth;
d. Dry soil, such as in the desert; or
e. Damp conduits.

(This paragraph is approved by NEMA a Authorized Engineering Information.)

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS

Not for Resale

Table 4a
Requirement for Nonmetallic Conducting Coverings Using Nonembedded Metal Components

		Cross-Linked	
	Thermoplastic	Rated 90°C	Rated 105°C
Aging Requirements (see Part 6)			
After air oven test at 100°C ± 1°C for 48 hours, elongation at rupture, minimum, percent	100*		
After air oven test at 121°C ± 1°C for 168 hours, Elongation at rupture, minimum, percent		100*	
After air oven test at 136°C ± 1°C for 168 hours, Elongation at rupture, minimum percent			100*
Brittleness Temperature, not warmer than	-10°C	-10°C	-10°C
Volume Resistivity, maximum at room temperature and at rated temperature ± 1°C, ohm meter	500	500	500

* For extruded coverings only

Table 4b
Requirements for Extruded Nonmetallic Conducting Coverings Using Embedded Metal Components

Thickness, Minimum, (See Part 6)	
Total	In accordance with 4.4.12
Between insulation and metal component, mils (mm)	5 (0.127)
Physical Requirements (See Part 6)	
Tensile strength, minimum, psi (MPa)	1200 (8.27)
Elongation at rupture, minimum, percent	100
Aging Requirements (See Part 6)	
After air oven test for 168 hours at 121°C ± 1°C for insulations rated 90°C at 136°C ± 1°C for insulations rated 105°C	
Tensile strength, minimum percent of unaged value	85
Elongation at rupture, minimum, percent	100
Brittleness Temperature, not warmer than	-10°C
Volume Resistivity, maximum at room temperature and at rated temperature ± 1°C, ohm meter	500

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

Table 4-1
Operating Voltage Limits, kV, Above Which Insulation Shielding Is Required

Power Cable—100 and 133 Percent Insulation Level	
1. Single conductor (including assemblies of single conductors)	
a. With metallic sheath or armor	5 kV
b. All others	2 kV
2. Multiple conductor with common covering	
a. With discharge-resisting jacket	5 kV
b. With nondischarge-resisting jacket	2 kV
c. With metallic sheath or armor	5 kV

Multiplying Factors for Equivalent Three-phase Voltages for Single- or Two-phase AC Systems or for DC Systems		
Single- and Two-phase AC Systems* and DC Systems 5000 Volts or Less	Single- and Two-phase AC Systems* Over 5000 Volts	
	One Side Grounded	Ungrounded and Midpoint Grounded
1	1.73	0.866

* Where it is not definitely specified that a line operates as an isolated single- or two-phase system, it shall be considered as a branch of a 100 percent insulation level three-phase circuit, and the rating shall be the line-to-line voltage of this 100 percent insulation level three-phase circuit.

JACKETS

4.3 GENERAL

Jackets shall be one of the types covered in 4.4 except that, for cable with an embedded metal component, the jacket shall be a nonmetallic conducting covering meeting the requirements of Table 4b. For jackets over metallic coverings, see 4.5.

4.3.1 Repairs

The jacket may be repaired in accordance with good commercial practice. Cables with repaired jackets must be capable of meeting all applicable requirements of this standard.

4.4 RUBBER OR THERMOPLASTIC JACKETS

These jackets consist of a durable moisture-resisting cross-linked natural- or synthetic-rubber compound or jacket on insulated wires or cables. They shall meet the applicable requirements of 4.4.1 through 4.4.15. The tests shall be made only on jackets having a nominal wall thickness of 30 miles (0.76 mm) or greater.

4.4.1 Natural Rubber

This jacket shall consist of a vulcanized rubber compound containing not less than 60 percent of natural rubber and shall meet the following requirements:

Physical Requirements (see 6.5)	
Tensile Strength, minimum	
psi	3500
MPa	24.1
Tensile stress at 200 percent elongation, minimum	
psi	500
MPa	3.45
Elongation at rupture, minimum percent	500
Set, maximum, percent	15
Aging Requirements (see 6.5)	
After oxygen pressure test at 70°C ± 1°C for 96 hours	
Tensile strength, minimum	
psi	2500
MPa	17.2
Elongation at Rupture, Minimum, Percent	400
Tear resistance, minimum (see 6.12)	
pounds per inch	40
N/m	7000

4.4.2 Synthetic Rubber

This jacket shall consist of a vulcanized SBR synthetic rubber compound and shall meet the following requirements.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

Physical Requirements (see 6.5)	
Tensile Strength, minimum	
psi	1800
MPa	12.4
Elongation at rupture, minimum percent	300
Set, maximum, percent	20
Aging Requirements (see 6.5)	
After air oven test at 70°C ±1°C for 168 hours	
Tensile strength, minimum	
psi	1600
MPa	11.0
Elongation at rupture, minimum, percent	250
After oil immersion test at 70°C ±1°C for 96 hours	
Tensile strength, minimum	
psi	1600
MPa	11.0
Elongation at rupture, minimum percent	250

4.4.3 Neoprene, Heavy-duty Black

This jacket shall consist of a vulcanized black neoprene compound and shall meet the following requirements and, when applicable, the requirements given in 4.4.14.

Physical Requirements (see 6.5)	
Tensile Strength, minimum	
psi	1800
MPa	12.4
Tensile stress at 200 percent elongation minimum	
psi	500
MPa	3.45
Elongation at rupture, minimum, percent	300
Set, maximum, percent	20
Aging Requirements (see 6.5)	
After air oven test at 100°C ±1°C for 168 hours	
Tensile strength and elongation at rupture, minimum, percentage of unaged value	50
After oil immersion test at 121°C ±1°C for 18 hours—tensile strength and elongation, minimum, percentage of unaged value	60

4.4.4 Neoprene, General Purpose

This jacket shall consist of a vulcanized neoprene compound, and shall meet the following requirements and, when applicable, the requirements given in 4.4.14.

Physical Requirements (see 6.5)	
Tensile Strength, minimum	
psi	1500
MPa	10.3
Elongation at rupture, minimum, percent	250
Set, maximum, percent	20
Aging Requirements (see 6.5)	
After air oven test at 100°C±1°C for 168 hours-tensile strength and elongation at rupture, minimum, percentage of unaged value	50
After oil immersion test at 121°C±1°C for 18 hours—tensile strength and elongation, minimum, percentage of unaged value	60

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS

Not for Resale

4.4.5 Polyvinyl Chloride

This jacket shall consist of a polyvinyl chloride compound suitable for a minimum installing temperature of -10°C (14°F), and shall meet the following requirements and, when applicable, the requirements given in 4.4.14.

Physical Requirements (see 6.5)	
Tensile Strength, minimum	
psi	1500
MPa	10.3
Elongation at rupture, minimum percent	100
Aging Requirements (see 6.5)	
After air oven test at 100°C±1°C for 5 days	
Tensile strength, minimum, percentage of unaged value	85
Elongation at rupture, minimum, percentage of unaged value	60
After oil immersion test at 70°C±1°C for 4 hours	
Tensile strength, minimum, percentage of unaged value	80
Elongation at rupture, minimum, percentage of unaged value	60
Heat distortion, 121°C±1°C, maximum, percent (see 6.17)	50
Heat shock, 121°C (see 6.16)	No cracks
Cold bend, -35±1°C (see 6.18)	No cracks

4.4.6 Polyethylene, Black.

This jacket shall consist of a black polyethylene compound suitable for exposure to sunlight and other atmospheric environments at temperature between -55°C (-67°F) through 75°C (+167°F) and a minimum installing temperature of -40°C(-40°F). The jacket shall meet the following requirements and, when applicable, the requirements given in 4.4.14:

Type I Polyethylene (LDPE/LLDPE), Black

Physical Requirements	
Tensile Strength, minimum	
psi	1700
MPa	11.7
Elongation at rupture, minimum percent	350
Base Resin Density (D^{23C}, g/cm^3)	0.910-0.925**
Aging Requirements	
After air oven test at 100°C ± 1°C, for 48 hours, tensile strength and elongation at rupture, minimum, percentage of unaged value	75
Heat Distortion, 100°C ± 1°C, maximum, percent of original thickness	30
Environmental cracking* (ASTM D1693)	No cracks
Absorption coefficient, minimum milli (absorbance/meter)	320**

Type II Polyethylene (MDPE), Black

Physical Requirements	
Tensile Strength, minimum	
psi	2300
MPa	15.9
Elongation at rupture, minimum percent	350
Base Resin Density (D^{23C}, g/cm^3)	0.926-0.940**
Aging Requirements	
After air oven test at 100°C ± 1°C, for 48 hours, tensile strength and elongation at rupture, minimum, percentage of unaged value	75
Heat Distortion, 110°C ± 1°C, maximum, percent of original thickness	30
Environmental cracking* (ASTM D1693)	No cracks
Absorption coefficient, minimum milli (absorbance/meter)	320**

Type III Polyethylene (HDPE), Black

Physical Requirements	
Tensile Strength, minimum	
psi	2500
MPa	17.2
Elongation at rupture, minimum percent	350
Base Resin Density (D^{23C}, g/cm^3)	0.941-0.965**
Aging Requirements	
After air oven test at 100C ± 1°C, for 48 hours, tensile strength and elongation at rupture, minimum, percentage of unaged value	75
Heat Distortion, 110°C ± 1°C, maximum, percent of original thickness	30
Environmental cracking* (ASTM D1693)	No cracks
Absorption coefficient, minimum milli (absorbance/meter)	320**

* Use Condition A for Type I and use Condition B for Type 2 and 3 with a full strength solution of Igepal CO-630 or equivalent as defined in ASTM D1693

** In lieu of testing finished cable jackets, a certification by the manufacturer of the polyethylene compound that this requirement has been complied with shall suffice.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS

Not for Resale

4.4.7 Chlorinated Polyethylene, Thermoplastic

This jacket shall consist of a thermoplastic chlorinated polyethylene compound. The jacket shall meet the following requirements and, when applicable, the requirements given in 4.4.14:

Physical Requirements	
Tensile Strength, minimum	
psi	1400
MPa	9.65
Tensile stress at 100 percent elongation, minimum	
psi	1000
MPa	6.9
Elongation at rupture, minimum, percent	150
Aging Requirements (see 6.5)	
After air oven test at 121°C ±1°C for 168 hours	
Tensile strength, minimum, percentage of unaged value	85
Elongation at rupture, minimum, percentage of unaged value	50
After oil immersion test at 100°C ±1°C for 18 hours	
Tensile strength, minimum, percentage of unaged value	80
Elongation at rupture, minimum, percentage of unaged value	60
Heat distortion, 121°C ±1°C, maximum, percent (see 6.17)	25
Cold bend, -35 ±1°C (see 6.18)	No cracks

4.4.8 Nitrile-Butadiene/Polyvinyl-Chloride, Heavy Duty

This jacket shall consist of a vulcanized acrylonitrilel-butadiene/polyvinyl-chloride compound suitable for a

(Text continued on page 23)

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS

Not for Resale

minimum installing temperature of –25°C (–13°F). It shall be based on a fluxed blend of acrylonitrile-butadiene synthetic rubber and polyvinyl-chloride resin. The jacket shall meet the following requirements and, when applicable, the requirements given in 4.4.14:

Physical Requirements (see 6.5)	
Tensile strength, minimum	
psi	1800
MPa	12.4
Tensile stress at 200 percent elongation, minimum	
psi	500
MPa	3.45
Elongation at rupture, minimum, percent	300
Set, maximum, percent	30
Aging Requirements (see 6.5)	
After air oven test at 100°C±1°C for 168 hours—tensile strength and elongation at rupture, minimum, percentage of unaged value	50
After oil immersion test at 121°C±1°C for 18 hours—tensile strength and elongation, minimum, percentage of unaged value	60

4.4.9 Nitrile-Butadiene/Polyvinyl-Chloride, General-Purpose Duty

This jacket shall consist of a vulcanized acrylonitrile-butadiene/polyvinyl-chloride compound suitable for a minimum installing temperature of –25°C (–13°F). It shall be based on a fluxed blend of acrylonitrile-butadiene synthetic rubber and polyvinyl-chloride resin. The jacket shall meet the following requirements and, when applicable, the requirements given in 4.4.14:

Physical Requirements (see 6.5)	
Tensile strength, minimum	
psi	1500
MPa	10.3
Elongation at rupture, minimum, percent	250
Set, maximum, percent	30
Aging Requirements (see 6.5)	
After air oven test at 100°C±1°C for 168 hours—tensile strength and elongation at rupture, minimum, percentage of unaged value	50
After oil immersion test at 121°C±1°C for 18 hours—tensile strength and elongation, minimum, percentage of unaged value	60

4.4.10 Chlorosulfonated Polyethylene, Heavy Duty

This jacket shall consist of a vulcanized chloro-sulfonated-polyethylene compound, shall meet the following requirements and, when applicable, the requirements given in 4.4.14:

Physical Requirements (see 6.5)	
Tensile strength, minimum	
psi	1800
MPa	12.4
Tensile stress at 200 percent elongation, minimum	
psi	500
MPa	3.45
Elongation at rupture, minimum, percent	300
Set, maximum, percent	30
Aging Requirements (see 6.5)	
After air oven test at 100°C±1°C for 168 hours	
Tensile strength, minimum, percentage of unaged value	85
Elongation at rupture, minimum, percentage of unaged value	65
After oil immersion test at 121°C±1°C for 18 hours—tensile strength and elongation at rupture, minimum, percentage of unaged value	60

4.4.11 Chlorinated Polyethylene, Heavy-Duty Cross-Linked (Thermoset)

This jacket shall consist of a cross-linked chlorinated polyethylene compound. The jacket shall meet the following requirements and, when applicable, the requirements given in 4.4.14:

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

Physical requirements	
Tensile Strength, minimum	
psi	1800
MPa	12.4
Tensile Stress at 200 percent elongation, minimum	
psi	500
MPa	3.45
Elongation at rupture, minimum, percent	300
Set, maximum, percent	30

Aging requirements	
After air oven test at 100°C±1°C for 168 hours	
Tensile strength, minimum, percentage of unaged value	85
Elongation at rupture, minimum, percentage of unaged value	55
After oil immersion test at 121°C±1°C for 18 hours	
Tensile strength and elongation at rupture, minimum, percentage of unaged value	60

Table 4-2
Single-Conductor Nonshielded Cable 2000 Volts or Less
(For All Uses: Conduit, Trays, Troughs, Underground Duct, Aerial, and Direct Burial†)

Size	Jacket Thickness			
	0–600 Volts		601–2000 Volts	
AWG or kcmil	mils	mm	mils	mm
14	15	0.38	15	0.38
12	15	0.38	15	0.38
10	15	0.38	15	0.38
9	15	0.38	15	0.38
8	15	0.38	15	0.38
6	30	0.76	30	0.76
4	30	0.76	30	0.76
2	30	0.76	30	0.76
1	45	1.14	45	1.14
1/0	45	1.14	45	1.14
2/0	45	1.14	45	1.14
3/0	45	1.14	45	1.14
4/0	45	1.14	45	1.14
250	65	1.65	65	1.65
300	65	1.65	65	1.65
350	65	1.65	65	1.65
400	65	1.65	65	1.65
450	65	1.65	65	1.65
500	65	1.65	65	1.65
600	65	1.65	65	1.65
750	65	1.65	65	1.65
1000	65	1.65	65	1.65

†Single-conductor cables in sizes 9 AWG and smaller shall not be used for direct earth burial.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

4.4.12 Jacket Thickness

(See 6.4.) The average thickness of jackets shall be not less than those given in Tables 4-2, 4-3, 4-4, or 4-5. For the jacket thicknesses of cables not shown in these tables, see Table 4-6. The minimum thickness shall be not less than 80 percent of the values given in these tables. The tables do not apply to communication and portable cables and portable cords.

4.4.13 Separator Under Jacket

If used, a separator shall consist of compatible material.

4.4.14 Discharge-Resisting Jacket

(See Table 4-1.) For single-conductor nonshielded cables rated 2001–5000 volts phase-to-phase, see 7.9 and 7.10.

For multiple-conductor nonshielded cables rated 2001–5000 volts phase-to-phase, the overall jacket shall meet the requirements of 4.4.3, 4.4.4, 4.4.5, 4.4.6, 4.4.7, 4.4.8, 4.4.9, 4.4.10, or 4.4.11 and, in addition, shall have a specific surface resistivity of not less than 200,000 megohms (see 6.23.1 and 6.23.2).

4.4.15 Irregularity Inspection of Jackets Over Metallic Shielded Power Cable

Jackets shall not have irregularities as determined by the procedure of ICEA T-27-581. The methods to be used for the jackets specified in paragraph 4.4.1 through 4.4.11 inclusive are:

Method A	Method B	Method C
Neoprene (4.4.3)	Natural Rubber (4.4.1)	Polyvinyl Chloride (4.4.5)
Neoprene (4.4.4)	SBR (4.4.2)	Polyethylene (4.4.6)
	Chlorinated Polyethylene Thermoplastic (4.4.7)	Chlorinated Polyethylene Thermoset (4.4.11)
	Nitrile-butadiene/Polyvinyl-Chloride (4.4.8)	
	Nitrile-butadiene/Polyvinyl-Chloride (4.4.9)	
	*Chlorosulfonated Polyethylene (4.4.10)	

*Also known as Chlorosulfonyl Polyethylene

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS

Not for Resale

Table 4-3
Single-Conductor Metallic Shielded Cables
(For All Uses: Conduit, Trays, Troughs, Underground Duct, Aerial, and Direct Burial)

Size, AWG or kcmil	Jacket Thickness									
	2001–5000 Volts*		5001–8000 Volts				8001-15000 Volts			
	100 and 133 percent Insulation Level		100 Percent Insulation Level		133 Percent Insulation Level		100 Percent Insulation Level		133 Percent Insulation Level	
	mils	mm	mils	mm	mils	mm	mils	mm	mils	mm
8	45	1.14	...	...	...	...	...	...	...	...
6	60	1.52	60	1.52	60	1.52	...	...	...	...
4	60	1.52	60	1.52	60	1.52	...	...	...	...
2	60	1.52	60	1.52	60	1.52	80	2.03	...	...
1	60	1.52	60	1.52	80	2.03	80	2.03	80	2.03
1/0	60	1.52	60	1.52	80	2.03	80	2.03	80	2.03
2/0	60	1.52	80	2.03	80	2.03	80	2.03	80	2.03
3/0	80	2.03	80	2.03	80	2.03	80	2.03	80	2.03
4/0	80	2.03	80	2.03	80	2.03	80	2.03	80	2.03
250	80	2.03	80	2.03	80	2.03	80	2.03	80	2.03
300	80	2.03	80	2.03	80	2.03	80	2.03	80	2.03
350	80	2.03	80	2.03	80	2.03	80	2.03	80	2.03
400	80	2.03	80	2.03	80	2.03	80	2.03	80	2.03
450	80	2.03	80	2.03	80	2.03	80	2.03	80	2.03
500	80	2.03	80	2.03	80	2.03	80	2.03	80	2.03
600	80	2.03	80	2.03	80	2.03	80	2.03	80	2.03
750	80	2.03	80	2.03	80	2.03	80	2.03	110	2.79
1000	80	2.03	80	2.03	110	2.79	110	2.79	110	2.79

Size, AWG or kcmil	Jacket Thickness							
	15001–25000 Volts		15001–25000 Volts		250001–28000 Volts		28001–35000 Volts	
	100 Percent Insulation Level		133 Percent Insulation Level		100 Percent Insulation Level		100 Percent Insulation Level	
	mils	mm	mils	mm	mils	mm	mils	mm
8	...	...	...	...	...	...	...	...
6	...	...	...	...	...	...	...	...
4	...	...	...	...	...	...	...	...
2	...	...	...	...	...	...	...	...
1	80	2.03	80	2.03	80	2.03	...	...
1/0	80	2.03	80	2.03	80	2.03	80	2.03
2/0	80	2.03	80	2.03	80	2.03	80	2.03
3/0	80	2.03	80	2.03	80	2.03	80	2.03
4/0	80	2.03	80	2.03	80	2.03	80	2.03
250	80	2.03	80	2.03	80	2.03	80	2.03
300	80	2.03	80	2.03	80	2.03	80	2.03
350	80	2.03	80	2.03	80	2.03	80	2.03
400	80	2.03	110	2.79	80	2.03	110	2.79
450	80	2.03	110	2.79	80	2.03	110	2.79
500	80	2.03	110	2.79	80	2.03	110	2.79
600	110	2.79	110	2.79	110	2.79	110	2.79
750	110	2.79	110	2.79	110	2.79	110	2.79
1000	110	2.79	110	2.79	110	2.79	110	2.79

For all other sizes and voltages not tabulated above, see Table 4-6, Column 2.

*See 4.1 and 4.2 for shielding requirements.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

Table 4-4
Individual Conductors of Multiple-Conductor Cables Under a Common Covering

Calculated Diameter of Individual Conductor Under Jacket		Jacket Thickness*	
inches	mm	mils	mm
0.250 or less	6.35 or less	15	0.38
0.251–0.425	6.38–10.80	25	0.64
0.426–0.700	10.82–17.78	30	0.76
0.701–1.500	17.81–38.10	50	1.27
1.501–2.500	38.13–63.50	80	2.03

*These thicknesses apply to jackets only and do not apply to colored coatings on the individual conductors of multiple-conductor cables.

Table 4-5
Common Overall Jacket of Multiple-Conductor Cables (For All Voltages and All Uses)

Calculated Diameter of Cable Under Jacket		Jacket Thickness	
inches	mm	mils	mm
0.425 or less	10.80 or less	45	1.14
0.426–0.700	10.82–17.78	60	1.52
0.701–1.500	17.81–38.10	80	2.03
1.501–2.500	38.13–63.50	110	2.79
2.501 and larger	63.53 and larger	140	3.56

NOTE 1 – Table 4-5 applies to all round multiple-conductor cables having a common overall jacket.

NOTE 2 – For flat twin cable, use the calculated major core diameter under the jacket to determine the jacket thickness.

Table 4-6
Single- and Multiple-Conductor Wires and Cables (All Uses Except Communication and Portable Cables‡)

Calculated Diameter of Cable Under Jacket		Jacket Thickness							
		Single-Conductor Cable				Multiple-Conductor Cables*			
		(1) Nonshielded		(2) Shielded**		(3) Individual Conductors†		(4) Overall	
inches	mm	mils	mm	mils	mm	mils	mm	mils	mm
0.250 or less	6.35 or less	15	0.38	45	1.14	15	0.38	45	1.14
0.251–0.425	6.38–10.80	30	0.76	45	1.14	25	0.64	45	1.14
0.426–0.700	10.82–17.78	45	1.14	60	1.52	30	0.76	60	1.52
0.701–1.500	17.81–38.10	65	1.65	80	2.03	50	1.27	80	2.03
1.501–2.500	38.13–63.50	95	2.41	110	2.79	80	2.03	110	2.79
2.501 and larger	63.53 and larger	125	3.18	140	3.56	...	...	140	3.56

*Under common jacket.

†These thicknesses apply to jackets only and do not apply to colored coatings used for the purpose of circuit identification on the individual conductors of multiple-conductor cables.

‡Single-conductor cables in sizes 9 AWG and smaller shall not be used for direct earth burial.

**In calculating the diameter under the jacket of single-conductor shielded cables, 90 mils (2.29 mm) (which was used in calculating the values given in Table 4-3) shall be added to the metallic conductor diameter plus twice the insulation thickness given in Table 3-1.

NOTE – For flat twin cable, use the calculated major core diameter under the jacket to determine the jacket thickness from Column 4.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

METALLIC AND ASSOCIATED COVERINGS

4.5 METALLIC AND ASSOCIATED COVERINGS

4.5.1 Scope

This section covers the following:

Division I. (See 4.5.3 through 4.5.16). Materials, constructions, and requirements for metallic and associated coverings recommended for use under normal conditions of installation, operation, and maintenance of power and lighting circuit wires, and cables. It also covers submarine cables.

Division II. (See 4.5.17 through 4.5.23.) Round wire armor for borehole, dredge, shafts, and vertical riser cable.

Division III. (See 4.5.24 through 4.5.26.) Round wire armor for buried cable.

The requirements of Division I as pertaining to quality of materials, design, and construction apply. Also Division II and III, except as to particular details expressly set forth in the following sections or as otherwise modified.

4.5.2 General

4.5.2.1 Unusual Conditions

The standards given in this section apply under usual installation, operating, and service conditions. Where unusual installation, operating, or service conditions exist, modifications may be necessary and these conditions should be defined before cable design is completed.

4.5.2.2 Types of Metallic Coverings and Conditions of Installation

a. Metallic sheath, lead, or aluminum
   1. Conduit, ducts, troughs, or raceways.
   2. Suspended from aerial messenger.
   3. When protected by metal armor or nonmetallic coverings for other types of installation.

b. Flat metal tape armor
   1. Direct burial in trenches.
   2. Suspended from aerial messenger.

Plain or galvanized-steel tape armor, depending upon soil and water conditions, with an outer fibrous covering is for use on cables for direct burial and for shaft installations where the cable can be clamped at intervals.

Galvanized-steel tape armor without an outer fibrous covering is for use on cables to be suspended from an aerial messenger strand.

c. Interlocked metal tape armor.
   1. Direct burial in trenches.
   2. Troughs.
   3. Racks.
   4. Raceways.
   5. Suspended from aerial messenger.

Interlocked-metal tape armor without an outer covering of either a fibrous bedding or thermoplastic jacket under the armor is for cables for indoor use and for outdoor aerial service.

Interlocked-metal tape armor with either a fibrous bedding or a thermoplastic jacket under the armor and either a fibrous covering or a thermoplastic jacket over the armor is for underground installations.

d. Galvanized steel wire armor.
   1. Submarine cable
   2. Dredge cable.
   3. Vertical riser, borehole, and shaft cable for end suspension.
   4. Direct burial in trenches and subjected to unusual longitudinal stress.

Jute covering is not required on dredge and vertical riser cable. It is required on submarine, borehole, and shaft cable where severe installation and service conditions exist. It is required for direct burial cable.

Jute covering may be desirable where the conditions of transportation require protection for the galvanizing on the armor wires.

Division I
Metallic and Associated Coverings for Use Under Normal Conditions

4.5.3 Scope

Division I applies to the metallic coverings described in the following sections, together with the necessary fibrous, thermosetting, or thermoplastic beddings and protective coverings; to nonmetallic coverings over metallic sheath; and to their application over insulated electric cable for use on power and lightning circuits.

4.5.4 Metallic Sheath

A lead or smooth aluminum sheath shall be used with or without supplementary protection when an impervious covering is required.

4.5.4.1 Lead Sheath

4.5.4.1.1 Type of Lead

A sheath of commercially pure lead (or an alloyed lead) shall be tightly formed around the core of the cable. This lead shall meet the requirements of ASTM B 29.

If lead stripped from new cable is used, it shall comply with the requirements given herein.

4.5.4.1.2 Thickness of Lead

The average thickness of the lead sheath shall be not less than the values given in Table 4-7. The minimum

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS

Not for Resale

thickness shall be not less than 90 percent of the values given in the table. If protective jackets are used over the lead sheath, see 4.5.14.3 and 4.5.15.6 for the thickness of the lead sheath.

Table 4-7
Thickness of Lead Sheath

Calculated Diameter of Cable Under Sheath*		Sheath Thickness	
inches	mm	mils	mm
0–0.425	0–10.80	45†	1.14
0.426–0.700	10.82–17.78	65†	1.65
0.701–1.050	17.81–26.67	80	2.03
1.051–1.500	26.70–38.10	95	2.41
1.501–2.000	38.13–50.80	110	2.79
2.001–3.000	50.83–76.20	125	3.18
3.001 and larger	76.23 and larger	140	3.56

*The thickness of lead sheath for flat twin cable shall be based on the calculated major core diameter.

†For submarine cables, these thicknesses shall be 80 mils (2.03 mm).

There are special cases where the above thicknesses may require an increase, especially on the smaller sizes of cable, if several cables are to be pulled in together in one duct; if the sections are extra long; or if the handling is severe or awkward during installation as in some transformer vaults. (This sentence is approved by NEMA as Authorized Engineering Information.)

4.5.4.1.3 Measurement of Thickness of Lead

The thickness shall be measured in accordance with 6.15.

4.5.4.1.4 Reapplication of Lead Sheaths

When the sheath does not meet the requirements of these standards, it shall not be repaired.

The lead may be stripped from the entire length of the cable and the cable releaded. (This sentence is approved by NEMA as Authorized Engineering Information.)

4.5.4.2 Aluminum Sheath

4.5.4.2.1 Type of Aluminum

A smooth sheath of aluminum 1060 or 1350 or equivalent shall be tightly formed around the core of the cable.

4.5.4.2.2 Thickness of Aluminum

The average thickness of the aluminum sheath shall be in accordance with Table 4-8. The minimum thickness shall be not less than 90 percent of the thickness given in the table.

Table 4-8
Thickness of Aluminum Sheath

Calculated Diameter of Cable Under Sheath*		Sheath Thickness	
inches	mm	mils	mm
0.400 or less	10.16 or less	35	0.89
0.401–0.740	10.19–18.80	45	1.14
0.741–1.050	18.82–26.67	55	1.40
1.051–1.300	26.70–33.02	65	1.65
1.301–1.550	33.05–39.37	75	1.90
1.551–1.800	39.40–45.72	85	2.16
1.801–2.050	45.75–52.07	95	2.41
2.051–2.300	52.10–58.42	105	2.67
2.301–2.550	58.45–64.77	115	2.92
2.551–2.800	64.80–71.12	125	3.18
2.801–3.050	71.15–77.47	135	3.43
3.051–3.300	77.50–83.82	145	3.68
3.301–3.550	83.85–90.17	155	3.94
3.551–3.800	90.20–96.52	165	4.19
3.801–4.050	96.55–102.9	175	4.45

*The thickness of the aluminum sheath for flat twin cable shall be based on the calculated major core diameter.

4.5.4.2.3 Measurement of Thickness of Aluminum

The thickness shall be measured in accordance with 6.15.

4.5.4.2.4 Reapplication of Aluminum Sheaths

When the sheath does not meet the requirements of these standards, it shall not be repaired.

The aluminum may be stripped from the entire length of cable and the cable resheathed. (This sentence is approved by NEMA as Authorized Engineering Information.)

4.5.5 Jute Serving over Metallic Sheath without Metallic Armor

4.5.5.1 Jute Servings

(See 6.13). The average thickness of one serving (or two servings) of jute applied over metallic-sheathed cable for mechanical protection shall be not less than that given in Table 4-9.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

Table 4-9
Thickness of Jute Servings Over Metallic Sheath (Without Metallic Cover)

Calculated Diameter of Cable Under Jute Serving*		Average Thickness of Jute Serving			
		One Serving		Two Servings	
inches	mm	mils	mm	mils	mm
1.000 or less	25.40 or less	65	1.65	95	2.41
1.001–2.500	25.43–63.50	65	1.65	110	2.79
2.501 and larger	63.52 and larger	65	1.65	125	3.18

*The thickness of jute servings over metallic sheath for flat twin cable shall be based on the calculated major core diameter.

4.5.5.2 APPLICATION

When jute servings are required, the metallic-sheathed cable shall be run through hot asphalt or tar compound and served with a closely wound lay of No. 16/3 impregnated jute yarn, or plied jute of equivalent thickness. If two servings are required, they shall be closely wound and applied with opposite directions of lay. The inner serving shall be an impregnated jute yarn that shall be run through hot asphalt or tar compound before the application of the outer serving that shall be No. 16/3 impregnated jute yarn, or plied jute of equivalent thickness.

For either one or two servings, the outer serving shall be run through hot asphalt or tar compound and coated with some suitable material which will prevent sticking of adjacent turns of the cable when wound on a reel.

4.5.6 Flat Metal Tape Armor

4.5.6.1 SCOPE

This section covers 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 the hot-dip or the electro-galvanizing process such that all surfaces of the finished tape width are coated, including edges.

4.5.6.2 TENSILE STRENGTH AND ELONGATION

The plain and zinc-coated strip shall have a tensile strength of not less than 40,000 psi (276 MPa) nor more than 70,000 psi (482 MPa). 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 (254 mm). The elongation shall be the permanent increase in length of a marked section of the strip, originally 10 inches (254 mm) 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.

4.5.6.3 GALVANIZING TEST

4.5.6.3.1 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 (100.8 grams/meter^2) of exposed surface. The weight of coating specified is the total amount on both surfaces, and edges shall be determined in accordance with the method described in ASTM A90.

4.5.6.3.2 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 (3.18 mm) 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.

4.5.6.4 WIDTH

The nominal width of metal tape may be less than but shall not be greater than that given in Table 4-10.

For nominal widths 1.000 inch (25.4 mm) or less, the tolerance in width shall be ±30 mils. For nominal widths greater than 1.000 inch (25.4 mm), the tolerance in width shall be ±45 mils.

4.5.6.5 THICKNESS

(See 6.14.) The average thickness of metal tape shall be not less than that given in Table 4-11.

The tolerance in the thickness of an individual tape shall be ±3 mils.

The zinc-coated tape shall not at any place be more than 20 percent thicker than the stripped tape thickness, which should be the specified average thickness

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

of bare metal.

The tolerance for the thickness of bare metal should apply to the stripped tape.

Table 4-10
Width of Metal Tape for Flat Armor
(Plain or Zinc Coated)

Calculated Diameter of Cable Under Jute Bedding*		Nominal Width of Metal Tape	
inches	mm	inches	mm
0.450 or less	11.43 or less	0.750	19.0
0.451–1.000	11.46–25.40	1.000	25.4
1.001–1.400	25.43–35.56	1.250	31.8
1.401–2.000	35.59–50.80	1.500	38.1
2.001–3.500	50.83–88.90	2.000	50.8
3.501 and larger	88.93 and larger	3.000	76.2

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

Table 4-11
Thickness of Metal Tape for Flat Armor
(Plain or Zinc Coated)

Calculated Diameter of Cable Under Jute Bedding*		Average Thickness of Metal Tape	
inches	mm	mils	mm
1.000 or less	25.40 or less	20	0.51
1.001 and larger	25.43 and larger	30	0.76

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

4.5.6.6 Application, Lay, and Spacing

Two metal tapes shall be applied helically in the same direction over the jute bedding except that they may be applied in opposite directions where the total area of the conductors is less than 50,000 circular mils (25.34 mm^2). The direction of lay of the inner tape shall be opposite to that of the jute bedding. When applied in the same direction as the inner tape, the outer tape shall be approximately centered over the spaces between the convolutions of the inner tape. The maximum space between turns shall not exceed 20 percent of the width of the tape or 0.200 inch (5.08 mm), whichever is the greater.

During or prior to application, the tapes shall be flushed with a suitable compound to deter corrosion.

4.5.7 Interlocked Metal Tape Armor

4.5.7.1 Scope

This section covers flat metallic strip in coils for use as interlocking armor for electrical cables. All tests shall be made prior to the application of the strip to the cable.

4.5.7.2 Steel Tape

Steel tape (except stainless) without a protective covering shall be zinc-coated. The zinc coating shall be applied by either the hot-dip or the electro-galvanizing process such that all surfaces of the finished tape width are coated, including the edges. If an outer jute or other protective covering is furnished, plain steel tape may be used. The quality of the steel tape and the requirements for the galvanizing shall be those specified in 4.5.6.2 and 4.5.6.3 for flat steel tape.

4.5.7.3 Width

The nominal width of metal tape may be less than but shall not be greater than that given in Table 4-12.

Table 4-12
Width of Metal Tape for Interlocked Armor

Calculated Diameter of Cable Under Armor		Nominal Width of Metal Tape Armor	
inches	mm	inches	mm
0.500 or less	12.70 or less	0.500	12.7
0.501–1.000	12.73–25.40	0.750	19.0
1.001–2.000	25.43–50.80	0.875	22.2
2.001 and larger	50.83 and larger	1.000	25.4

4.5.7.4 Thickness

(See 6.14.) The average thickness of metal tape shall be not less than that given in Table 4-13.

The tolerance in the thickness of an individual tape shall be ±3 mils.

The zinc-coated tape shall not, at any place, be more

Table 4-13
Thickness of Metal Tape for Interlocked Armor

Calculated Diameter of Cable Under Armor		Average Thickness			
		Ambrac, Brass, Steel, Stainless Steel, Bronze, and Monel Tape		Aluminum and Zinc Tape	
inches	mm	mils	mm	mils	mm
1.500 or less	38.10 or less	20	0.51	25	0.64
1.501 and larger	38.13 and larger	25	0.64	30	0.76

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

than 20 percent thicker than the stripped tape thickness, which should be the specified thickness for bare metal.

The tolerance for thickness of bare metal should apply to the stripped tape.

4.5.7.5 NONMAGNETIC TAPE

When nonmagnetic tapes, such as aluminum, brass, bronze, zinc, or stainless steel tapes are used, the widths shall be in accordance with 4.5.7.3 and the thicknesses in accordance with 4.5.7.4.

Representative values of tensile strength and elongation for the nonmagnetic metals are given in Appendix B.

4.5.7a Continuously Corrugated Metal Armor

4.5.7a.1 Scope

This section covers the requirements applicable to continuously corrugated metal armored cable. The metal armor is formed by 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.

4.5.7a.2 Type of Metal

4.5.7a.2.1 When metal armor is formed by a flat metal tape, the tapes used shall be aluminum, copper, steel or alloys thereof.

4.5.7a.2.2 When metal armor is formed by applying a seamless sheath or tube the metal shall be aluminum or an aluminum alloy.

4.5.7a.2.3 The minimum thickness of tape or of the sheath or tube before corrugation shall be as shown in Table 4-13A.

4.5.7a.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.

4.5.7a.4 Corrosion Protection

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

4.5.8 Galvanized Steel Wire Armor

4.5.8.1 SCOPE

This section covers zinc-coated low-carbon-steel wire for use in the armoring of borehole, vertical riser, submarine, and underground cables used for power, control, and lighting circuits for normal use. For wire armor for Division II and III applications, see 4.5.17 through 4.5.26. All tests shall be made prior to application of the wire to the cable.

4.5.8.2 TENSILE STRENGTH, ELONGATION, AND TORSION

4.5.8.2.1 TENSILE STRENGTH

The zinc-coated wire shall have a tensile strength of not less than 50,000 psi (345 MPa) and not more than 70,000 psi (482 MPa). The tensile strength shall be tested in accordance with ASTM E 8. (See Appendix E.)

4.5.8.2.2 ELONGATION

The zinc-coated wire shall have an elongation of not less than 10 percent in 10 inches (254 mm). The elongation shall be the permanent increase in length of a marked section of the wire originally 10 inches (254 mm) in length and shall be determined after the specimen has fractured.

Table 4-13A
Minimum Thickness of Metal for Corrugated Armor

Calculated Diameter of Cable Under Armor		Aluminum		Copper		Steel	
inches	mm	mils	mm	mils	mm	mils	mm
0–2.180	0– 55.37	22	0.56	...	...	...	...
2.181–3.190	55.40– 81.03	29	0.74	...	...	...	...
3.190–4.200	81.05–106.7	34	0.86	...	...	...	...
0–2.365	0– 60.7	...	...	17	0.43	...	...
2.366–3.545	60.10– 90.4	...	...	21	0.53	...	...
3.546–4.200	90.07–106.7	...	...	25	0.64	...	...
0–1.905	0– 48.39	...	...	...	...	16	0.41
1.906–3.050	48.41– 72.39	...	...	...	...	20	0.51
3.051–4.200	72.42–106.7	...	...	...	...	24	0.61

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

4.5.8.2.3 TORSION TEST

The zinc-coated wire shall withstand, without fracture, the minimum number of twists specified in Table 4-14. This test shall be made on a sample of wire having an initial length of 6 inches (152 mm) between jaws of a standard torsion machine or equivalent with one head of the machine movable horizontally. The effective speed of rotation shall not exceed 60 rpm.

Table 4-14
Number of Twists (Torsion Test)

Nominal Diameter of Coated Wire		Minimum Number of Twists
mils	mm	
238–166	6.05–4.22	7
165–110	4.19–2.79	10
109– 65	2.77–1.65	14

4.5.8.3 GALVANIZING TESTS

4.5.8.3.1 WEIGHT OF ZINC COATING

The weight of zinc coating shall be determined before the wire is applied to the cable. The wire shall have a minimum weight of coating per square foot of uncoated wire surface in accordance with Table 4-15. The zinc coating shall be tested for weight by a stripping test in accordance with ASTM A 90. (See Appendix E.)

4.5.8.3.2 ADHERENCE OF COATING

The zinc coating shall remain adherent when the wire is wrapped at a rate of not more than 15 turns per minute in a closed helix of at least two turns around a cylindrical mandrel of the diameter specified in Table 4-16. The zinc coating shall be considered as meeting this requirement if, when the wire is wrapped about the specified mandrel, the coating does not flake and none of it can be removed from the wire by rubbing it with the fingers.

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

4.5.8.4 SIZE OF ARMOR

The sizes of armor wire for Division I applications, including submarine cables, shall be given in Table 4-17.

If the service requirements are exceptionally severe, larger sizes of armor wire may be required. (This sentence is approved by NEMA as Authorized Engineering Information.)

The tolerance in diameter for galvanized steel wire shall be given in Table 4-18.

4.5.8.5 LAY

The length of lay of the armor wires shall be not less than seven nor more than twelve times their pitch diameter for all constructions except for dredge cable. For dredge cable, see 4.5.20.

"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."

4.5.8.6 DIRECTION OF LAY

Successive layers of jute and armor shall be laid in opposite directions. The direction of lay of the armor wires shall be so chosen that birdcaging of the armor will be reduced to a minimum.

4.5.9 Jute Bedding for Armored Cable

(See 4.5.11 for Interlocked Armored Cable.)

4.5.9.1 APPLICATION

Metallic-sheathed cable to be armored shall be run through hot asphalt or tar compound before being served with a bedding of impregnated jute yarn or roving, each layer of which shall be run through hot asphalt or tar compound. If the cable is without metallic sheath, the core shall be covered as specified in 4.5.12 before it is run through the first application of compound.

4.5.9.2 DIRECTION OF LAY

The direction of lay of the jute bedding or serving shall be opposite to that of the armor directly in contact with it, except as allowed in 4.5.8.6. Adjacent layers of jute shall be applied with opposite directions of lay.

4.5.9.3 THICKNESS

(See 6.13.) The average thickness of jute bedding under the armor in the finished cable shall be not less than that given in Table 4-19.

4.5.10 Jute Serving Overall for Armored Cable

(See 4.5.11 for Interlocked Armored Cable.)

4.5.10.1 APPLICATION

When an outer jute serving is required, the armored cable shall be run through hot asphalt or tar compound, then served with a layer of number sixteen three-ply (No. 16/3) impregnated jute yarn applied with a short close lay, again run through hot asphalt or tar compound, and finished by running through some suitable material that will prevent sticking of adjacent turns of the cable when wound on a reel.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

Table 4-15
Minimum Weights of Zinc Coating

Diameter of Coated Wire			Minimum Weight of Zinc Coating	
mils	mm	Size, BWG	Ounces per Square Foot of Exposed Wire Surface	Grams per Square Meter of Exposed Wire Surface
238	6.05	4	1.00	305
220	5.59	5	1.00	305
203	5.16	6	1.00	305
165	4.19	8	0.90	275
134	3.40	10	0.80	244
109	2.77	12	0.80	244
83	2.11	14	0.60	183

Table 4-16
Mandrel Diameter for Adherence of Coating Tests

Wire Diameter		
mils	mm	Mandrel Diameter
238–134	6.05–3.40	3 times wire diameter
133 and smaller	3.38 and smaller	2 times wire diameter

Table 4-17
Size of Galvanized Steel Armor Wire for Cables for Division I Applications, Including Submarine Cables

Calculated Diameter of Cable Under Jute Bedding		Size of Armor Wire		
Inches	mm	BWG	mils	mm
0–0.750	0–19.05	12	109	2.77
0.751–1.000	19.08–25.40	10	123	3.40
1.001–1.700	25.43–43.18	8	165	4.19
1.701–2.500	43.21–63.50	6	203	5.16
2.501 and larger	63.53 and larger	4	238	6.05

Table 4-18
Tolerance in Diameter

Diameter of Coated Wire		
mils	mm	Tolerance, mils
238–166	6.05–4.22	± 5
165–109	4.20–2.77	± 4
108–65	2.74–1.65	± 3

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS

Not for Resale

4.5.10.2 DIRECTION OF LAY

The direction of lay of the jute serving shall be opposite to that of the armor in contact with it.

4.5.11 Jute for Interlocked Armored Cable

4.5.11.1 JUTE BEDDING

(See 6.13.) If jute bedding is required, the application and direction of lay shall be in accordance with 4.5.9.1 and 4.5.9.2. The thickness shall be as specified for metal taped cable in Table 4-19.

4.5.11.2 JUTE SERVING OVERALL

If jute serving overall is required, it shall be in accordance with 4.5.10.

4.5.12 Core Covering for Nonsheathed and Nonjacketed Cable with Metallic Armor

Over the core of nonsheathed and nonjacketed cable with metallic armor, there shall be applied tape, saturated cotton braid, jute, or other suitable protective coverings. Tape shall be used over cores having a diameter of 0.300 inch (7.62 mm) or larger.

4.5.13 Core Covering for Thermosetting and Thermoplastic Jacketed Cable Under Armor

4.5.13.1 FLAT STEEL TAPE ARMOR

If a flat steel tape armor is used, a jute bedding shall be applied over the jacket before application of the armor. The thickness of the jute bedding shall be as given in Table 4-19 (see 6.13).

4.5.13.2 INTERLOCKED ARMOR

Interlocked armor shall be applied directly over the jacket or tape in which it is vulcanized, no bedding being necessary.

4.5.13.3 ROUND WIRE ARMOR

If round wire armor is used, a jute bedding shall be applied over the jacket before application of the armor. The thickness of the jute bedding shall be as given in Table 4-19 (see 6.13).

4.5.14 Thermosetting Coverings over Metallic Sheath

4.5.14.1 THERMOSETTING COVERING

A thermosetting covering over a metallic sheath shall consist of a combination of treated fibrous reinforcing tapes and a neoprene compound.

The neoprene compound shall meet the following requirements:

Physical Requirements (see 6.5)	
Tensile strength, minimum	
psi	1200
MPa	8.27
Elongation at rupture, minimum, percent	250
Set, maximum, percent	20
Aging Requirements (see 6.5)	
After air oven test as 70°C±1°C for 168 hours	
—Tensile strength, minimum	
psi	1000
MPa	6.89
Elongation at rupture, minimum, percent	200
After oil immersion test at 121°C±1°C for 18 hours—Tensile strength and elongation, minimum, percentage of unaged value	60

Table 4-19
Thickness of Jute Bedding for Armored Cable

Calculated Diameter of Cable Under Jute Bedding*		Thickness of Jute Bedding					
		Metal Taped		Round Wire Armoured Cable			
				Sheathed or Jacketed		Nonsheathed or Nonjacketed	
inches	mm	mils	mm	mils	mm	mils	mm
0–0.450	0–11.43	30	0.76	45	1.14	80	2.03
0.451–0.750	11.46–19.05	45	1.14	45	1.14	80	2.03
0.751–1.000	19.08–25.40	45	1.14	65	1.65	95	2.41
1.001–2.500	25.43–63.50	65	1.65	80	2.03	110	2.79
2.501 and larger	63.53 and larger	65	1.65	95	2.41	125	3.18

*The thickness of jute bedding for flat twin cable shall be based on the calculated major core diameter.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

Tests shall be made on samples removed from the finished cable or, where this is impractical, on a sample of the neoprene compound that is identical with that on the cable and that has been given the same treatment.

4.5.14.2 THICKNESS

The average thickness of the thermosetting jacket shall be not less than that given in Table 4-20. The thickness shall be determined by the use of a diameter tape and shall be considered as one-half of the difference in measurement under and over the jacket.

The minimum thickness shall be not less than 80 percent of the values given in Table 4-20.

Table 4-20
Thickness of Thermosetting Jacket Over Metallic Sheath

Calculated Diameter Over Sheath		Thickness	
inches	mm	mils	mm
0–1.500	0–38.10	65	1.65
1.501–3.000	38.13–76.20	95	2.41
3.001 and over	76.23 and over	125	3.18

4.5.14.3 THICKNESS OF LEAD SHEATH

(See 6.15.) If a cross-linked jacket is applied over a lead sheath, the average thickness of the lead sheath shall be not less than that given in Table 4-21. The minimum thickness shall be not less than 90 percent of the values given in the table.

Table 4-21
Thickness of Lead Sheath for Cables Having a Cross-Linked Jacket or Thermoplastic Jacket Over Lead Sheath

Calculated Diameter of Core*		Sheath Thickness	
inches	mm	mils	mm
0–0.425	0–10.80	45†	1.14†
0.426–0.700	10.82–17.78	55†	1.40†
0.701–1.050	17.81–26.67	70	1.78
1.051–1.500	26.70–38.10	85	2.16
1.501–2.000	38.13–50.80	95	2.41
2.001–3.000	50.83–76.20	110	2.79
3.001 and larger	76.23 and larger	125	3.18

*The thickness of lead sheath for flat twin cable shall be based on the calculated major core diameter.

†For submarine cables, these thicknesses shall be 70 mils (1.78 mm).

4.5.14.4 THICKNESS OF ALUMINUM SHEATH

(See 6.15.) If a cross-linked jacket is applied over an aluminum sheath, the thickness of the aluminum sheath shall be as given in 4.5.4.2.2.

4.5.15 Thermoplastic Jacket Over Metallic Sheath

4.5.15.1 THERMOPLASTIC JACKET

If used, a thermoplastic jacket shall be extruded over the metallic sheath and shall fit tightly thereto. It shall be either:

a. Polyvinyl chloride meeting the requirements of 4.4, except that the cold-bend requirements shall be as given in 4.5.15.4; or
b. Black polyethylene meeting the requirements of 4.4.; or
c. Black chlorinated polyethylene meeting the requirements given in 4.4 except that the cold bend requirements shall be as given in 4.5.15.4.

4.5.15.2 THICKNESS

The average thickness of jacket shall be taken as one-half the difference in diameters and under the jacket as determined by circumference measurements and shall be not less than that given in Table 4-22. The minimum thickness of the jacket shall be determined by direct measurements with a micrometer, a steel scale with pocket glass, or a microscope on a ring of jacket removed from the cable and shall be not less than 70 percent of the values given in Table 4-22.

Table 4-22
Thickness of Thermoplastic Jacket Over Metallic Sheath

Calculated Diameter Over Sheath		Jacket Thickness	
inches	mm	mils	mm
0.750 or less	19.05 or less	50	1.27
0.751–1.500	19.08–38.10	65	1.65
1.501–2.250	38.13–57.15	80	2.03
2.251–3.000	57.18–76.20	95	2.41
3.001 and larger	76.23 and larger	110	2.79

4.5.15.3 TIGHTNESS OF POLYETHYLENE JACKET TO SHEATH

The jacket shall be removed for 5 inches (127 mm) from each end of a 12-inch (305 mm) sample of cable, leaving a 2 inch (50.8 mm) ring intact and undisturbed at the center. The sample shall then be inserted vertically in a hole in a flat rigid plate which is at least 10 mils (0.254 mm) larger than the diameter over the sheath but not over 40 mils (1.02 mm) larger. There shall be no movement of the cable in relation to the

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

ring within a period of 1 minute when weight is applied to the upper end of the sample. The weight to be applied shall be equal to 10 pounds per inch (1770 N/m) of outside diameter of the metallic sheath minus the weight of the prepared sample, rounded off to the nearer half pound.

4.5.15.4 COLD BEND

(See 6.18.) Polyvinyl-chloride-jacketed cable shall show no cracks at a test temperature of -10°C or colder. In lieu of this test, the manufacturer may submit evidence that the jacket compound has been tested on similar cable and meets this requirement.

4.5.15.5 IRREGULARITY INSPECTION

Jackets shall not have irregularities as determined by the procedure of ICEA T-27-581. The methods to be used are:

Method B	Method C
Chlorinated Polyethylene Thermoplastic	Polyvinyl. Chloride Polyethylene

(Table 4-23 was deleted on July 22, 1987.)

4.5.15.6 Thickness of Lead Sheath (see 6.15)

If a thermoplastic jacket is applied over a lead sheath, the average thicknesses of the lead sheath shall be in accordance with 4.5.14.3

4.5.15.7 Thickness of Aluminum Sheath (see 6.15)

If a thermoplastic jacket is applied over an aluminum sheath, the average thickness of the aluminum sheath shall be as given in 4.5.4.2.2.

4.5.16 Jackets over Metallic Armor

Jackets, when used, shall be either thermoplastic as described in 4.5.16.1 or crosslinked as described in 4.15.16.2.

4.5.16.1 THERMOPLASTIC TYPES

Thermoplastic jackets, when used, shall be extruded over the metallic armor and shall fit tightly thereto. They shall be either:

1. Polyvinyl Chloride meeting the requirements of 4.4.5 except that the cold bend requirements shall be as given in 4.5.15.4, or
2. Black polyethylene meeting the requirements of 4.4.6, or
3. Chlorinated polyethylene meeting the requirements given in 4.4.7 except that the cold bend requirements shall be given in 4.5.15.4.

4.5.16.2 CROSSLINKED TYPES

Crosslinked jackets, when used, shall be extruded over the metallic armor and shall fit tightly thereto. A separator shall be permitted to be used over the armor. The coverings shall be either:

1. Neoprene meeting the requirements of 4.4.3, or
2. Chlorosulfonated polyethylene meeting the requirements of 4.4.10, or
3. Chlorinated polyethylene meeting the requirements of 4.4.11.

4.5.16.3 THICKNESS

The average thickness of the jacket shall be not less than that specified in Table 4-24. The minimum thickness shall be not less than 70 percent of the value given in the table. The minimum and maximum thickness of the jacket shall be determined directly with a micrometer, a steel scale with pocket glass, or a micrometer microscope on a ring of jacket removed from the cable. The average of these determinations shall be taken as the average thickness of the jacket.

4.5.16.4 IRREGULARITY INSPECTION

Jackets shall not have irregularities as determined by the procedure of ICEA T-27-581. The methods to be used are:

Method A	Method B	Method C
Neoprene (4.4.3)	Chlorinated polyethylene thermoplastic (4.4.7)	Polyvinyl chloride (4.4.5)
	Chlorsulfonated Polyethylene (4.4.10)	Polyethylene (4.4.6)
		Chlorinated polyethylene, cross-linked (4.4.11)

Table 4-24
Thickness of Jacket Over Metallic Armor

Calculated Diameter of Cable Under Jacket		Jacket Thickness: All Cables (Except Interlocked or Corrugated Armored)		Jacket Thickness: Cables with Interlocked or Corrugated Armor	
inches	mm	mils	mm	mils	mm
0.750 or less	19.05 or less	50	1.27	50	1.27
0.751–1.500	19.08 –38.10	65	1.65	50	1.27
1.501–2.250	38.13–57.15	80	2.03	60	1.52
2.251–3.000	57.18–76.20	95	2.41	75	1.91
3.001 and larger	76.23 and larger	110	2.79	85	2.16

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

Division II
Round Wire Armor for Borehole Dredge, Shaft, and Vertical Riser Cable

4.5.17 Scope

Division II gives details of construction of armor applicable particularly to borehole, dredge, shaft, and vertical riser cables.

4.5.18 General

The requirements of Division I (4.5.3 through 4.5.16) pertaining to quality of materials design and construction, apply also to borehole, dredge, shaft, and vertical riser cable (which are designed for special uses), except as to the particular details expressly set forth in the following sections for the respective types of cable, or as otherwise modified.

4.5.19 Borehole Cable (Suspended at One End Only)

4.5.19.1 ARMOR

Galvanized round steel wire shall be used for borehole cable.

4.5.19.2 SIZE OF ARMOR WIRES

The size of the armor wires shall be as given in Table 4-25.

The tensile safety factor [based on 50,000 psi (345 MPa)] shall be not less than five. If the required tensile safety factor is not maintained, the next larger size wire given in the table shall be used.

Table 4-25
Size of Galvanized Steel Armor Wires for Borehole Cable

Calculated Diameter of Cable Under Jute Bedding		Nominal Size of Armor Wires		
inches	mm	BWG	mils	mm
0.750 or less	19.05 or less	12	109	2.77
0.751–1.000	19.08–25.40	10	134	3.40
1.001–1.700	25.43–43.18	8	165	4.13
1.701–2.500	43.21–63.50	6	203	5.16
2.501 and larger	63.53 and larger	4	238	6.05

4.5.19.3 LAY

The length of lay of the armor wires shall be not less than seven nor more than twelve times their pitch diameter. The armor shall be applied closely without appreciable space between the wires.

"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."

4.5.20 Dredge Cable

4.5.20.1 ARMOR

Galvanized round steel wire shall be used for dredge cable and shall be applied with a short lay.

4.5.20.2 SIZE OF ARMOR WIRES

The size of the armor wires shall be as given in Table 4-26.

Table 4-26
Size of Galvanized Steel Armor Wires for Dredge Cable

Calculated Diameter of Cable Under Jute Bedding		Nominal Size of Armor Wires		
inches	mm	BWG	mils	mm
1.700 or less	43.18 or less	12	109	2.77
1.701–2.500	43.21–63.50	1	134	3.40
2.501 and larger	63.53 and larger	8	165	4.19

4.5.20.3 PITCH RATIO

The minimum pitch ratio shall be as given in Table 4-27.

Table 4-27
Pitch Ratio of Galvanized Wire Armor for Dredge Cable

Calculated Diameter over the Armor Wires		Minimum Pitch Ratio
inches	mm	
0–2.500	0–63.50	2.5
2.501 and larger	63.53 and larger	3.0

The pitch ratio is taken as the quotient resulting from dividing the length of lay of the armor wires by the pitch diameter of the armor wires.

Where unusual service conditions exist, it may be desirable to modify the above pitch ratio. If so, it should be defined before the cable design is finalized. (This paragraph is approved by NEMA as Authorized Engineering Information.)

4.5.21 Shaft Cable

If shaft cable is to be clamped to the shaft structure or wall, the metallic covering (either tape or wire) shall comply with the requirements of 4.5.3 through 4.5.16. If the shaft cable is to be suspended from one end, galvanized round steel wire armor shall be used.

The size of the armor wires shall be in accordance with 4.5.22.2, but the tensile safety factor shall be not less than five.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS

Not for Resale

4.5.22 Vertical Riser Cable (Suspended at One End Only) for Installation Within Buildings

4.5.22.1 Armor

Galvanized round steel wire shall be used for vertical riser cable.

4.5.22.2 Size of Armor Wires for Nonsheathed Cable

The size of the armor wires shall be as given in Table 4-28.

The tensile safety factor [based on 50,000 psi (345 MPa)] shall be not less than seven. If the required tensile safety factor is not maintained, the next larger size wire given in the table shall be used.

4.5.22.3 Size of Armor Wires for Sheathed Vertical Riser Cable

The size of armor wires for sheathed vertical riser cable for indoor installation shall be in accordance with 4.5.19.2 for borehole cable, but with a tensile safety factor of not less than four.

4.5.23 Wire-Band Serving

If wire band servings are used for cable suspended vertically from one end, No. 12 BWG (109 mils) (2.77 mm) wire shall be applied over the armor. The length of the serving band and the spacing of the band throughout the length of the cable shall be as given in Table 4-29.

The wire bands shall be applied sufficiently tightly to prevent their movement along the cable as a result of handling the cable during installation.

Table 4-28
Size of Galvanized Steel Armor Wires for Shaft Cable and Vertical Riser Cable

Calculated Diameter of Cable Under Jute Bedding		Nominal Size of Armor Wires		
inches	mm	BWG	mils	mm
0–1.000	0–25.40	12	109	2.77
1.001–1.700	25.43–43.18	10	134	3.40
1.701–2.500	43.21–63.50	8	165	4.19
2.501 and larger	63.53 and larger	6	203	5.16

Division III
Round Wire Armor for Buried Cable

4.5.24 Scope

Division III gives details of construction of armor for buried land cables where greater longitudinal strength than that provided by flat tape armor is required, but not the strength of the regular armor required for submarine service.

4.5.25 General

The requirements of Division I (4.5.3 through 4.5.16) pertaining to quality of materials, design and construction apply also to buried round wire armored cables, except as to particular details expressly set forth in 4.5.26.

4.5.26 Armor Wire and Jute Beddings and Servings (Sheathed and Nonsheathed Cables)

The size of armor wire and thickness of jute bedding shall be as given in Table 4-30. (See 6.13.)

The length of lay of the armor wires shall be not less than three nor more than twelve times their pitch diameter. The armor shall be applied closely without appreciable space between the wires.

A jute serving in accordance with 4.5.10 shall be applied over the armor.

Table 4-29
Spacing and Length of Band Servings

Calculated Diameter over Armor Wire		Maximum Band Spacing		Length of Band	
inches	mm	feet	meters	inches	mm
0–1.500	0–38.10	50	15.2	3	76.2
1.501–2.500	38.13–63.50	35	10.7	4	102
2.501 and larger	63.53 and larger	25	7.6	4	102

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

Table 4-30
THICKNESS OF JUTE BEDDING AND SIZE OF ARMOR WIRES

Calculated Diameter of Cable Under Jute Bedding		Minimum Thickness of Jute Bedding		Nominal Size of Armor Wires		
inches	mm	mils	mm	BWG	mils	mm
0–0.750	0–19.05	45	1.14	14	83	2.11
1.751–1.000	19.08–25.40	65	1.65	12	109	2.77
1.001–1.700	25.43–43.18	80	2.03	10	134	3.40
1.701–2.500	43.21–63.50	80	2.03	8	165	4.19
2.501 and larger	63.53 and larger	95	2.41	6	203*	5.16*

*For cable diameters over 2.500 inches (63.50 mm) where greater strength is desired than is obtainable with No. 6 BWG (203 mils) (5.16 mm) or where the required number of wires exceeds the capacity of the armoring machine, a No. 4 BWG (238 mils (6.05 mm) wire may be used.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS

Not for Resale

Part 5
ASSEMBLY, FILLERS, AND CONDUCTOR IDENTIFICATION

5.1 ASSEMBLY OF MULTIPLE-CONDUCTOR CABLES

Multiple-conductor cables shall be assembled in accordance with Part 5 unless otherwise modified by Part 7.

5.1.1 Multiple-Conductor Round Cables

Where cables consist of one layer of conductors, that layer shall have a left-hand lay; where 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 in the outer layer of cables with a common covering shall not exceed the value calculated from the factor given in Table 5-1. Where there is more than one layer of conductors, the conductors in 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.

The length of lay of the individual conductors in 2, 3- or 4- conductor cables without a common covering shall not exceed 60 times the largest conductor* diameter.

Table 5-1
CONDUCTOR MULTIPLYING FACTORS

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

*The "largest conductor" is the insulated or uninsulated conductor having the largest calculated overall diameter.

5.1.2 Flat Twin Cables

Flat twin cables shall consist of two insulated conductors laid parallel under a common covering. The diameter over the insulation of each conductor shall not exceed 1 inch (25.4 mm).

5.2 FILLERS

Fillers shall be used in the interstices of multiple-conductor round cable with a common covering where necessary to give the completed cable a substantially circular cross section.

For flat twin cables with diameters over the individual conductor of 0.500 inch (12.70 mm) or less, fillers are not required. For flat twin cables with diameters over the individual conductor of more than 0.500 inch (12.70 mm), fillers shall be used to give a substantially flat surface parallel to the plane of the major axis.

Fillers shall be of suitable material which is separate or integral with the jacket.

5.3 CONDUCTOR IDENTIFICATION

5.3.1 Power Cables

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

5.3.2 Control Cables

Paragraph deleted.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS

Not for Resale

Part 6
TESTING AND TEST METHODS

6.1 TESTING

All wires and cables shall be tested at the factory in accordance with Part 6 to determine their compliance with those standards. To determine which tests are to be made, refer to Parts 2, 3, 4, 5 and 7. 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.

Tests shall consist of the following, as required, namely, (1) tests on samples (see 6.4 to 6.26, inclusive and 6.30 to 6.32 inclusive), (2) tests on entire lengths of completed cables (see 6.27 to 6.29, inclusive and 6.33), and (3) conductor tests (see 6.3) on samples or on entire lengths of completed cables.

6.2 SELECTION OF SAMPLES

Tests shall be made on samples selected at random. Each test sample shall be taken from an accessible end of different coils or reels. Each coil or reel selected and the corresponding sample shall be identified. The number and lengths of samples shall be as specified under the individual tests.

6.3 CONDUCTOR TEST METHODS

When samples are measured, they shall be selected in accordance with NEMA Standards Publication WC 54/ICEA T-26-465, Plan A.

6.3.1 Method for DC Resistance Determination

Measurements shall be made either on a sample at least 1 foot (30.5 cm) long or on the entire length of completed cable. When the nominal resistance is less than 1 ohm, the measurement shall be made with a Kelvin-type bridge or a potentiometer. When the nominal resistance is 1 ohm or more, the measurement shall be made with a Kelvin-type bridge, or a Wheatstone bridge, or a potentiometer.

When measurements are made on a sample, either as original measurements or for verification, the following precautions shall be taken:

1. Current contacts shall be made in such a way as to assure essentially uniform current density among the wires.
2. When potential leads are used, the distance between each potential contact and the corresponding current contact shall be at least equal to 1½ times the circumference of the specimen. When a Kelvin-type bridge is used, the yoke resistance (between reference standard and test specimen) shall be appreciably smaller than that of either the reference standard or the test specimen unless a suitable lead compensation is used, or it is known that the coil and lead ratios are sufficiently balanced so that variation in yoke resistance will not decrease the bridge accuracy below that given in item 4.
3. The distance between potential electrodes shall be measured to an accuracy of ±0.05 percent. To assure this accuracy in measuring the length between potential contacts, the surface in contact with the test specimen shall be a substantially sharp knife edge.
4. Resistance measurements shall be made to an accuracy of ±0.15 percent. To ensure a correct reading, the reference standard and the test specimen should be allowed to come to the same temperature as the surrounding medium. (If the reference standard is made of manganin, it is possible to obtain correct readings with the test specimen at reference temperatures other than room temperature.)
5. In all resistance measurements, the measuring current raises the temperature of the medium. Therefore, the magnitude of the current shall be low and the time of its use short enough so that changes in resistance cannot be detected with the galvanometer.
6. In bridge measurements, the potential contact resistance shall be as low as possible. If low contact resistance cannot be achieved, appropriate contact-resistance corrective circuits shall be used. To eliminate errors due to contact potential, two readings, one direct and one with current reversed, shall be taken in direct succession. Check tests shall be permitted to be made by turning the specimen end for end and repeating the test. The material used for the two potential contacts shall be the same to minimize imbalanced contact potentials. If necessary, the contact surfaces shall be cleaned.

6.3.2 Methods for Cross-sectional Area Determination

6.3.2.1 Cross-sectional Area by Diameter Measurement

The cross-sectional area shall be calculated as follows:

$$A = 10^{-3} \sum_{i=1}^{n} d_i^2$$

Where:
A = cross-sectional area in kcmil

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS Not for Resale

d_i = diameter of the ith wire in mils determined according to 6.3.3.1

n = total number of wires in conductor

6.3.2.2 Cross-Sectional Area by Weight

The cross-sectional area shall be determined in accordance with ASTM B 263.

6.3.3 Methods for Diameter Determination

6.3.3.1 Diameter by Micrometer Measurement

Diameter measurements shall be made with a micrometer or other suitable instrument readable to at least 0.0001 inch. Round wires shall be measured at each end of the sample and near the middle of the sample. The average of the three measurements shall be taken as the diameter.

Stranded conductors shall be measured around the circumference of the conductor perpindicular to the axis of the conductor and on the extensions of a line through the center of the conductor and through the center of two wires in the outer layer which are 180 degrees apart. The average of three measurements shall be taken as the diameter.

6.3.3.2 Diameter by Tape Measurement

A diameter tape readable to at least 0.005 inch shall be wrapped one turn (360°) around the circumference of the conductor, tightly and perpendicular to the axis of the conductor. The average diameter of the conductor shall be read directly from the diameter tape.

6.4 THICKNESS MEASUREMENTS FOR INSULATIONS AND NONMETALLIC JACKETS

6.4.1 Number of Thickness Measurements

When the lot of wire to be inspected consists of two coils or reels, or less, at least one determination of the thickness shall be made on each coil or reel. When the lot consists of more than two coils or reels and less than 20 coils or reels, at least one determination of the thickness shall be made on each of two coils or reels, taken at random. If the lot consists of 20 or more coils or reels, not less than 10 percent of the coils or reels shall be selected at random and at least one determination of the thickness shall be made on each coil or reel so selected. Measurements on the individual conductors of multiple-conductor cables shall be made before they are cabled.

6.4.2 Measurement of Thickness

The measurement of thickness for cables with unbonded components shall be made with either a micrometer or microscope but, for cables with bonded components, shall be made only with a microscope. The micrometer and microscope shall be capable of making measurements accurate to at least 0.001 inch.

Table 6-1
Factors for Converting Measured DC Resistance to 25°C (77°F)

Temperature, Degrees C	Multiplying Factor for Copper	Multiplying Factor for Aluminum
0	1.107	1.110
5	1.084	1.085
10	1.061	1.063
15	1.040	1.041
20	1.020	1.020
25	1.000	1.000
30	0.981	0.981
35	0.963	0.962
40	0.945	0.944
45	0.928	0.927
50	0.912	0.910
55	0.896	0.894
60	0.881	0.878
65	0.866	0.863
70	0.852	0.849
75	0.838	0.835
80	0.825	0.821
85	0.812	0.808
90	0.800	0.796

The correction factors are based upon copper having 100 percent conductivity and aluminum having 61 percent conductivity. The factors are derived from the formulae:

$$R_1 = R_2 \frac{259.5}{234.5 + T_2} \text{ for copper}$$

$$R_1 = R_2 \frac{253}{228 + T_2} \text{ for aluminum}$$

Where:

R_1 = Resistance at 25°C

R_2 = Measured resistance at test temperature T_2.

For more accurate determination of resistance, allowing for different conductivities, see "Copper Wire Tables," National Institute of Standards and Technology (formerly National Bureau of Standards) Handbook 100 or "Aluminum Wire Tables," National Institute of Standards and Technology (formerly National Bureau of Standards) Handbook 109 and ASTM B 193. (This paragraph is approved by NEMA as Authorized Engineering Information.)

6.4.2.1 Micrometer Measurements

When a micrometer is used, the average thickness of the insulation shall be taken as one-half of the difference between the mean of the maximum and minimum diameters over the insulation at one point and the average diameter over the conductor or any separator measured at the same point. The minimum thickness of the insulation shall be taken as the dif-

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS Not for Resale

Table 6-2
Number of Samples

deleted

Table 6-3
Deleted

Table 6-4
Number and Length of Samples

Quantity of Completed Cable Ordered		Size of Conductor		Number of Samples	Minimum Length of Each Sample	
feet	meters	kcmil	mm^2		conductor feet	conductor meters
Less than 2000	Less than 610	Less than 250	Less than 127	none	...	...
Less than 1000	Less than 305	250 and larger	127 and larger	none	...	...
2000–50,000	610–15,240	Less than 250	Less than 127	1	6	1.8
1000–25,000	305–7620	250 and larger	127 and larger	1	3	0.9
More than 25,000	More than 7620					
First 25,000	First 7620	250 and larger	127 and larger	1	3	0.9
Each additional 25,000	Each additional 7620	250 and larger	127 and larger	1	3	0.9
More than 50,000	More than 15,240					
First 50,000	First 15,240	Less than 250	Less than 127	1	6	1.8
Each additional 50,000	Each additional 15,240	Less than 250	Less than 127	1	6	1.8

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS

Table 6-5
Number and Length of Samples

Quantity of Completed Cable Ordered		Nominal Overall Diameter of Cable		Number of Samples	Minimum Length of Each Sample	
feet	meters	inches	mm		cable, feet	cable, meters
Less than 200	Less than 610	Less than 1.0	Less than 25.4	none	. . .	. . .
Less than 1000	Less than 305	1.0 and larger	25.4 and larger	none	. . .	. . .
2000–50000	610–15240	Less than 1.0	Less than 25.4	1	6	1.8
1000–25000	305–7620	1.0 and larger but less than 2.0	25.4 and larger but less than 50.8	1	3	0.9
		2.0 and larger	50.8 and larger	1	2	0.6
More than 50000	More than 15240					
First 5000	First 15240	Less than 1.0	Less than 25.4	1	6	1.8
Each additional 50000	Each additional 15240	Less than 1.0	Less than 25.4	1	6	1.8
More than 250000	More than 7620					
First 25000	First 7620	1.0 and larger but less than 2.0	25.4 and larger but less than 50.8	1	3	0.9
Each additional 25000	Each additional 7620	1.0 and larger but less than 2.0	25.4 and larger but less than 50.8	1	3	0.9
More than 25000	More than 7620					
First 25000	First 7620	2.0 and larger	50.8 and larger	1	2	0.6
Each additional 25000	Each additional 7620	2.0 and larger	50.8 and larger	1	2	0.6

Not for Resale

ference between a measurement made over the conductor or any separator plus the thinnest insulation wall, and the diameter over the conductor or any separator. The first measurement shall be made after slicing off the opposite side of the insulation. The thickness of any separator shall not be included in the thickness of insulation.

If the wire or cable has a jacket, the jacket shall be removed and the minimum and maximum thickness of the jacket determined directly with a micrometer. The average of these determinations shall be taken as the average thickness of the jacket.

6.4.2.2 MICROSCOPE MEASUREMENTS

When a microscope is used, the maximum and minimum thickness shall be determined from a specimen cut perpendicular to the axis of the sample so as to expose the full cross-section. The average of these determinations shall be taken as the average thickness.

6.4.3 Thickness Conformance

If the thickness is found to be less than the specified value, the coil or reel from which the sample was taken shall be considered as not conforming to this standard, and a thickness measurement shall be made each of the remaining coils or reels.

6.5 PHYSICAL AND AGING TESTS FOR INSULATIONS, JACKETS, AND NON-METALLIC STRESS CONTROL AND INSULATION SHIELD MATERIALS

See 6.6 through 6.11.

6.5.1 Sampling

6.5.1.1 INSULATIONS

Samples of insulated conductors for the unaged and aged physical tests shall be selected in accordance with Table 6-4.

Samples shall be taken after vulcanization and prior to the application of any covering except those applied before vulcanization. Cable tapes applied prior to vulcanization shall be removed from the samples prior to testing.

6.5.1.2 Jackets

Samples of jacketed cable for the unaged and aged physical tests shall be selected in accordance with Table 6-5. No tests shall be made on jackets less than 30 mils (0.76 mm) in thickness.

6.5.1.3 Nonmetallic Stress Control and Insulation Shield Materials

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

6.5.2 Number of Specimens

Three test specimens shall be prepared from each of the samples selected in accordance with 6.5.1.

When one sample is selected in accordance with 6.5.1, all three test specimens shall be tested and the results averaged. When additional samples are required, only one test specimen out of three for each for each additional sample shall be tested and the other two specimens held in reserve.

6.5.3 Size and Preparation of Specimens

The test specimens shall be prepared using either ASTM D412 Die B or E with specimen length not less than 6 inches (152 mm) or ASTM D412 Die C or D with specimen length not less than 4.5 inches (114 mm). The specimens shall be free of surface incisions and shall be as free as possible from other imperfections. For wire and cable smaller than 6 AWG having an insulation thickness of 90 mils (2.29 mm) or less, the test specimen may be the entire section of the insulation. When the full cross-section is used, the specimens shall not be cut longitudinally. For wire and cable 6 AWG and larger, or for wire and cable smaller than 6 AWG having an insulation thickness greater than 90 mils (2.29 mm), specimens rectangular in section with a cross-section not greater than 0.025 square inch (16 mm2) shall be cut from the insulation. [(In extreme cases, it may be necessary to use a segmental specimen. (This sentence is approved by NEMA as Authorized Engineering Information.)] Except when a full cross-section is used, surface irregularities such as corrugations due to stranding, and so forth, shall be removed so that the test specimen will be smooth and of uniform thickness.

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 segment cut with a sharp knife, or a shaped specimen cut out with a die, and shall have a cross-sectional area not greater than 0.025 square inch (16 mm) after irregularities, corrugations, and reinforcing cords or wires have been removed.

Where jackets are bonded to the insulation, separate smoothed samples of the insulation and jacket shall be prepared. Test specimens shall be die-cut from the samples after they have been allowed to recover for at least 30 minutes.

6.5.4 Calculation of Area of Test Specimens

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

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

6.5.4.2 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 whose diameter is that of the insulation. The height of the segment is the wall of insulation on the side from which the slice is taken. [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.

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

This applies either to a straight test piece or to one stamped out with a die and assumes that corrugations have been removed. (This sentence is approved by NEMA as Authorized Engineering Information.)

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

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

6.5.5 Physical Test Procedures

Physical tests on both the unaged and aged test specimens shall be made at approximately the same time. Tests shall be made not earlier than 24 hours nor later than 60 days after vulcanization.

6.5.5.1 Test Temperature

Physical tests shall be made at a room temperature not less than 20°C (68°F) nor more than 28°C (82.4°F). The test specimens shall be kept at room temperature for not less than 30 minutes prior to the test.

6.5.5.2 Type of Testing Machine

The testing machine shall be in accordance with 6.1 of ASTM D 412.

6.5.6 Retests

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

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

6.6 Paragraph deleted

6.7 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

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS Not for Resale

calculated in accordance with ASTM D 412. The tensile stress shall be calculated on the area of the unstretched specimen.

6.8 ELONGATION TEST

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

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

6.9 SET TEST

The set test shall be made on test specimens which have been prepared, marked, and stretched in accordance with 6.6 until the gauge marks are 6 inches (152 mm) 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 (50.8 mm) gauge length, expressed as a percentage of the original gauge length.

6.10 AGING TESTS

6.10.1 Test Specimens

Test specimens of similar size and shape shall be prepared from each sample selected in accordance with 6.5.1 through 6.5.3, three for the determination of the initial or unaged properties, and three for each aging test required for the insulation or jacket being tested.

When the entire cross-section of insulation is used, the insulation shall be subjected to the aging condition with the conductor removed and each end of the specimen suitably plugged.

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

Simultaneous aging of different compounds should be avoided. (This paragraph 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 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.

6.10.2 Oxygen Pressure Test

The test specimens shall be heated in an atmosphere of oxygen at a pressure of 290 to 310 psi (0.204 to 0.218 kgf/mm^2) at the temperature and for the period specified. The specimen shall have not more than 2 grams of rubber or oxidizable substance per cubic inch of bomb space. The bomb pressure shall be reduced at a uniform rate, requiring at least 5 minutes to reach atmospheric pressure, at which time the specimens shall be removed. The bomb temperature shall be controlled to within ±1°C and recorded continuously.

6.10.3 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.

6.10.4 Air Pressure Heat Test

The test specimens shall be heated in air at a pressure of 77 to 82 psi (0.054 to 0.058 kgf/mm^2) at the temperature and for the period specified. The test shall be conducted in a steam-jacketed bomb or other suitable and uniformly heated chamber. The bomb shall be so regulated that the temperature inside the chamber will reach the test temperature within 15 minutes after inserting the test specimens. The air shall be substantially free from oil and moisture. The specimen shall have not more than 2 grams of rubber or oxidizable substance per cubic inch of bomb space. The bomb pressure shall be reduced at a uniform rate, requiring at least 5 minutes to reach atmospheric pressure, at which time the specimens shall be removed. The bomb temperature shall be controlled to within ±1°C and recorded continuously.

6.10.5 Oil Immersion Test for Polyvinyl-Chloride Jacket

The test specimens shall be immersed in ASTM Oil No. 2, described in Table 1 of ASTM D 471, at 70°C ±1°C for 4 hours. At the end of this time, the specimens shall be removed from the oil and blotted.

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.

6.10.6 Oil Immersion Test for Thermosetting Jacket

The test specimens shall be completely immersed in ASTM Oil No. 2, described in Table 1 of ASTM D 471, at 121°C±1°C for 18 hours. The specimens shall then be removed from the oil, blotted lightly, and

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS

Not for Resale

suspended in air at room temperature for only 4 hours ± ½ hour 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 the gauge marks applied to the specimen before immersion in the oil.

6.11 PHYSICAL TESTS FOR NONMETALLIC STRESS CONTROL AND INSULATION SHIELD MATERIALS INTENDED FOR EXTRUSION

6.11.1 Test Sample (See 6.5.1.3.)

6.11.2 Test Specimens

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

6.11.3 Elongation

Elongation shall be determined in accordance with 6.8 and 6.10.3.

6.11.4 Brittleness

Brittleness shall be determined in accordance with ASTM D 746, using Specimen A.

6.12 TEAR TEST

The tear test shall be made on a minimum of six individual test specimens prepared as follows:

Each specimen shall be cut with a sharp knife or die. After irregularities, corrugations, and reinforcing cords or wires have been removed, each test specimen shall have the dimensions shown in Figure 6-1, shall be not more than 0.150 inch (3.81 mm) and not less than 0.040 inch (1.02 mm) thick. Specimens shall be cut longitudinally with a new razor blade to a point 0.150 inch (3.81 mm) from the wider end.

The two halves of the split end of the test specimen shall be placed in the jaws of the testing machine and the jaws separated at the rate of 20 inches ± 10 percent (508 mm) per minute. The tear resistance shall be determined by dividing the load in pounds required to tear the section by the thickness of the test specimen in inches. The average of the results obtained on all test specimens shall be considered as the value of the tear resistance.

6.12.1 Retests

When the tear resistance of the first set of six specimens fail to meet the requirements, two additional sets of six specimens shall be tested. Failure of either of the additional sets of specimens shall indicate failure of the sample to conform with this standard.

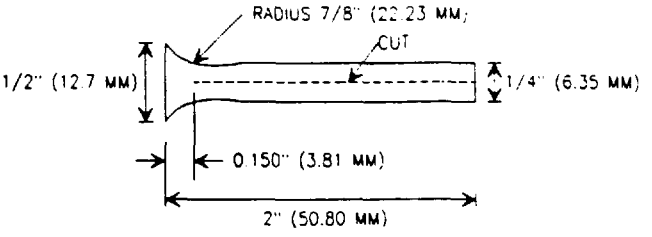

Figure 6-1
TEST SPECIMEN FOR TEAR TEST

6.13 THICKNESS OF JUTE BEDDINGS AND SERVINGS

The thickness of jute beddings and servings shall be determined by the use of a diameter tape and shall be considered as ½ of the difference between the measurements under and over the jute. The measurement in each case shall be the average of five readings taken at different points along the cable.

6.14 THICKNESS OF METALLIC TAPES

Metallic tape shall be removed from no less than 6 inches (152 mm) of the insulated conductor or assembled core. The thickness of the tape shall be measured by means of a micrometer caliper having flat surfaces on both the anvil and the end of spindle and graduated to read directly at least to mils, and preferably to tenths of a mil. Five readings shall be taken at different points on the sample, and the average of these readings shall be taken as the thickness of the tape.

6.15 THICKNESS OF METALLIC SHEATHS

One 3 inch (76.2 mm) specimen of the sheath, free from external mechanical injury, shall be removed from each end of a reel length of cable. The ends of the specimens shall be cut perpendicular to the axis of the cable.

The thickness shall be determined by measurements made with a micrometer caliper having rounded anvil. At least five separate measurements, approximately equally spaced around the circumference, shall be made on each specimen, and the average of all the measurements on the two specimens shall be considered as the average thickness of the sheath. The minimum of all of the measurements obtained shall be considered as the minimum thickness of the sheath.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS

Not for Resale

6.16 HEAT SHOCK

Each sample of jacketed cable selected in accordance with Table 6-5 shall be wound tightly around a mandrel having a diameter in accordance with Table 6-6, held firmly in place, and subjected to a temperature of 121°C±1°C for 1 hour.

6.17 HEAT DISTORTION

6.17.1 Test Specimen

A sample (see 6.5.1.2) of the jacket approximately 8 inches (203 mm) long shall be prepared to have a thickness of 50 mils (1.27 mm) ±10 mils and smooth surfaces. From this sample, three test specimens (see 6.5.2) each 1 inch (25.4 mm) long and 9/16 inch (14.3 mm) ± 1/16 inch wide shall be prepared. Where the diameter of the cable does not permit the preparation of a specimen 1/16 inch (14.3 mm) wide, the specimens shall be taken from a molded sheet of the same compound.
The thickness of each specimen, T1, shall be measured with a Randall & Stickney, or equivalent, gauge having a 3/8 inch (9.5 mm) foot with no loading other than the 85 grams of the gauge.

6.17.2 Test Procedures

Each test shall be completed with 3 hours.
The Randall & Stickney, or equivalent, gauge with a load of 2,000 grams on the foot shall be placed in an oven which is preheated to the specified temperature. At the end of 1 hour, the test specimen shall be placed in the oven, and both the gauge and the test specimen shall remain in the oven for 1 hour.
At the end of this 1 hour period, the specimen shall be placed directly under the foot of the gauge all allowed to remain in the oven under load for 1 hour at the specified temperature.
At the end of this period, the thickness, T2, shall be read on the dial of the gauge.

The distortion shall be calculated as 1follows:

$$\text{Distortion, percent} = \frac{T_1 - T_2}{T_1} \times 100$$

6.18 COLD BEND

Each sample of completed cable selected in accordance with Table 6-5 shall be subjected to the specified temperature for 1 hour and then bent 180 degrees around a mandrel having a diameter in accordance with Table 6-7 immediately upon its removal from the cooling chamber. The bend shall be made at a uniform rate, and the time required shall not exceed 1 minute.

6.19 ENVIRONMENTAL CRACKING

Except as otherwise specified in 6.19.1 and 6.19.2 the test shall be made in accordance with ASTM D 1693.

6.19.1 Test Specimens

The number and length of samples shall selected in accordance with Table 6-5. Three test specimens, approximately 1.5 inches (38.1 mm) long, 0.5 inches (12.7 mm) wide, shall be molded from material taken from the completed cable. The thickness shall be 0.125 inches (3.18 mm) thick for low density polyethylene (Type I), and 0.075 (1.9 mm) inches thick for medium and high density polyethylene (Type II and Type III).The temperature of the molded specimens shall be lowered at any suitable rate. A slit made with a razor blade, approximately 0.75 inch (19.0 mm) long and from 0.020 to 0.025 inches (0.51 to 0.64 mm) deep for Type I and from 0.012 to 0.015 (0.3 to 0.38 mm) inches deep for Type II and Type III. shall be centrally located on one of the 1.5 inch by 0.5 inch (38.1 by 12.7 mm) surfaces.

6.19.2 Test Procedures

The specimens shall be bent with the slit on the outside and placed in a test tube 200 mm long and 32 mm in outside diameter. The cracking agent (Igepal CO-630 made by the GAF Corporation, or its equivalent) shall be added to completely cover the specimen. The test tube, suitably closed by means such as a foil-covered cork, shall be placed in an oven at 50°C +1°C for 48 hours. At the end of this period, the specimens shall be removed, allowed to cool to room temperature, and inspected for cracking.

6.20 ABSORPTION COEFFICIENT

Test specimens (see 6.5.2) shall be prepared from test samples selected in accordance with Table 6-5. The absorption coefficient of jacket compounds shall be determined in accordance with ASTM D 3349.

6.21 ACCELERATED WATER ABSORPTION

6.21.1 General

Text deleted.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

Table 6-6

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

Table 6-7

Outside Diameter of Wire or Cable		Diameter of Mandrel as a Multiple of the Outside Diameter of Cable
inches	mm	
0–0.800	0–20.32	8
0.801 and over	20.35 and over	10

6.21.2 Electrical Method (EM-60)

Text deleted.

6.21.3 Galvimetric Method

Text deleted.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS Not for Resale

6.22 CAPACITY AND POWER FACTOR (DISSIPATION FACTOR, tan δ

The Capacity and Power Factor (Dissipation Factor) test is applicable only to power cables rated 5001 volts and above and shall be made in accordance with ICEA T-28-562 with the cable at room temperature.

One test sample shall be taken for the first 5,000 to 20,000 feet (1,524 to 6,096 meters) of each cable construction and one additional sample for each additional 100,00 feet (30,480 meters).

6.23 TESTS FOR DISCHARGE RESISTANCE

6.23.1 Test Samples

The samples shall be taken from the completed cable. No sample shall be taken from the first 5000 feet (1524 meters). One sample shall be taken from the first 5001 to 20,000 feet (1524 to 6096 meters) of each cable construction and one additional sample for each additional 100,000 feet (30,480 meters).

6.23.2 Specific Surface Resistivity

A sample of the completed cable of suitable length shall be immersed, except for the ends, in water at room temperature for 48 hours. At the end of this period, the sample shall be removed from the water, blotted and allowed to retain at room temperature for 10 minutes. Two 1 inch (25.44 mm) wide foil electrodes spaced 6 inches (152 mm) apart shall be wound around the cable surface which was immersed. A 250-50 volt dc potential shall be applied between the two electrodes ant the resistance shall be measured in accordance with ASTM D 257. The following surface resistivity shall be calculated as follows:

$$P = 0.524\ RD$$

Where—

P = Specific surface resistivity.

R = Measured resistance in megohms per 6-inch spacing.

D = Cable diameter in inches.

6.23.3 U-bend Discharge

A sample of the completed cable shall be bent, in the form of a U, 180 degrees around a mandrel having a diameter in accordance with Table 6-8.

Table 6-8

Conductor Size, AWG or kcmil	Diameter of Mandrel as a Multiple of the Outside Diameter of Cable
8–2	6
1–3/0	8
4/0–500	10
Over 500	12

The sample shall be mounted with the apex of the U above and in contact with a smooth metal plate and with the legs of the U perpendicular to the plate. After not less than 30 minutes nor more than 45 minutes following the bending, a source of 60 Hz ac potential shall be applied between the conductor and the metal plate continuously for at least 6 hours. This test shall be made at room temperature.

6.23.4 Insulation Discharge Test for Type IV Insulation

The Insulation Discharge Resistance Test shall be performed in accordance with the ICEA T-27-581/NEMA WC 53 Standard.

6.24 VOLUME RESISTIVITY

6.24.1 Test Samples

One sample shall be taken from each 25,000 feet (7620 meters) or major fraction thereof for each cable construction.

6.24.2 Conductor Stress Control

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

The power of the test circuit shall not exceed 100 milliwatts. The test shall be made at the specified

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS

Not for Resale

temperature with either ac or dc voltage.

The volume resistivity shall be calculated as follows:

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

Where–

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

6.24.3 Insulation Shield

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

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

The volume resistivity shall be calculated as follows:

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

Where–

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

6.25 STRIPPING TEST

Test samples shall be selected in accordance with Table 6-5. One test specimen shall be prepared from each sample. The test specimen shall be approximately 15 inches (381 mm) long, and all coverings over the extruded insulation shall be removed.

Starting at one end, two parallel longitudinal cuts ½ inch (12.7 mm) apart and not less than 12 inches (305 mm) long shall be made through the insulation shield. The specimen shall be rotated 180 degrees and two identical cuts shall be made starting from the same end. Each ½ inch (12.7 mm) strip shall be peeled back from the cut end for a distance of 2 inches (50.8 mm).

The specimen shall be mounted horizontally in a testing machine and secured at each end. The 2 inch (50.8 mm) end of the peeled strip shall be gripped in the testing machine in such a manner that it can be pulled at an angle of 90 degrees to the cable axis.

Each strip shall be peeled from the cable at a constant speed not exceeding ½ inch (12.7 mm) per second for a distance of not less than 10 inches (254 mm).

The angle of pull shall be maintained as close as possible to 90 degrees throughout the test.

The tension necessary to remove the strip shall be monitored continuously and the minimum value shall be recorded.

6.26 RETESTS FOR TESTS COVERED BY 6.13 THROUGH 6.25 AND 6.30, 6.31, 6.32

6.26.1 If all of the samples pass the applicable tests described in 6.13 through 6.25 and 6.30 and 6.31, the quantity of cable that they represent shall be considered as meeting the requirements of this standard.

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

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

ELECTRICAL TESTS ON COMPLETED CABLES

6.27 VOLTAGE TESTS

6.27.1 General

These tests consist of voltage tests on each length of completed cable. Except for the dc spark test and the ac spark test, the voltage shall be applied between the conductor or conductors and the metallic sheath, metallic shield, metallic armor, or water, and the rate of increase from the initially applied voltage to the specified test voltage shall be approximately uniform and shall be not more than 100 percent in 10 seconds nor less than 100 percent in 60 seconds.

6.27.1.1 Cables Without Metallic Sheath, Metallic Shield, or Metallic Armor

Except for the dc spark test (see 6.27.4b) and the ac spark test (see 6.27.4a), single-conductor cables of this type which are twisted together into an assembly of two

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

or more conductors without an overall jacket or covering shall be immersed in water for at least 1 hour and tested while still immersed; all other single-conductor and multiple-conductor cables of this type shall be immersed in water for at least 6 hours and tested while still immersed. Each insulated conductor shall be tested against all other conductors connected to the grounded water tank.

6.27.1.2 Cables with Metallic Sheath, Metallic Shield, or Metallic Armor

All cables of this type shall be tested with the metallic sheath, shield or armor grounded, without immersion in water, at the test voltage specified. For cables having a metallic sheath, shield or armor over the individual conductor(s), the test voltage shall be applied between the insulated conductor(s) and ground. For multiple-conductor cables with nonshield individual conductors having a metallic sheath, shield or armor over the cable assembly, the test voltage shall be applied between each insulated conductor and all other conductors and ground.

6.27.2 AC Voltage Test

This test shall be made with an alternating potential from a transformer and generator of ample capacity but in no case less than 5 kilovoltamperes. The frequency of the test voltage shall be nominally between 25 and 60 hertz and shall have a wave shape approximating a sine wave as closely as possible.

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

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

6.27.3 DC Voltage Test

This test is applicable to cables without insulation shield rated up through 5000 volts and to all cables rated 5001 volts and above and shall be made after the insulation resistanc test described in 6.28. The equipment for the dc voltage test shall consist of a battery, generator, or suitable rectifying equipment and shall be of ample capacity.

The initially applied dc voltage shall be not greater than 3.0 times the rated ac voltage of the cable.

The duration of the dc voltage test shall be 15 minutes for cables with insulation shield and 5 minutes for cables without insulation shield.

6.27.4a AC Spark Test

6.27.4a.1 Application

This test shall apply to single-conductor cable and assemblies of single-conductor cables rated 0 through 2000 volts.

This test shall not apply to:

a. Multiconductor cables other than assemblies of single-conductor cables.
b. Cables with insulation shield.
c. Cables with metallic sheath or armor.
d. Assemblies containing uninsulated conductors.
e. Cables rated above 2000 volts.

6.27.4a.2 Test Apparatus

Test apparatus shall consist of:

a. A source of single-phase ac potential capable of maintaining the required voltage under all normal leakage current conditions.
b. An electrode capable of maintaining contact, throughout its length, with the periphery of the cable under test.
c. A means of measuring voltage between electrode and ground.
d. A means of indicating a fault (failure).

6.27.4a.3 Test Procedure

One side of the potential source shall be connected to the electrode and the other side of the potential source shall be connected to ground. The conductor(s) in the cable shall be tested to assure continuity when grounded at one or both ends. All ground connections shall be bonded (common). The fault indicator shall be connected to indicate abnormal current between electrode and ground.

After the specified voltage is applied, the entire length of cable shall be passed through the electrode in a manner and at a speed such that every section of cable surface will have maintained electrode contact for not less that 18 positive and negative voltage crests.

The maximum speed of the cable under test may be determined in either U.S. customary units or in metric equivalents as follows: (This paragraph is approved by NEMA as Authorized Engineering Information.)

a. U.S. Customary Units Formula for Determining Maximum Speed of Cable

$$MS = 5/9 \times F \times EL$$

Where –
MS = Maximum speed in feet per minute.
F = Frequency in Hertz.
EL = Electrode length in inches.

b. Equivalent Metric Formula for Determining Maximum Speed of Cable.

$$MS = 1/150 \times F \times EL$$

Where –
MS = Maximum speed in meters per minute.
F = Frequency in Hertz.
EL = Electrode length in millimeters.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

6.27.4a.4 Failure

Any indication by the fault indicator shall constitute a failure.

6.27.4b DC Spark Test

This test is applicable to single-conductor cables and assemblies of insulated single-conductor cables without insulation shield, and without metallic sheath or metallic armor, rated 0 through 2000 volts. The equipment for the dc spark test shall consist of a dc sparker of ample voltage and a suitable electrode. The sparker shall be capable of maintaining the specified test voltage under all normal conditions of leakage current. The voltage shall be applied between the outside surface of the cable and the conductor(s) for not less than 0.05 second. The conductor(s) shall be grounded.

The electrode shall make contact with the entire exposed surface of a single-conductor cable and of an assembly of twisted single-conductor cables.

Where an assembly of twisted single-conductor cables is subjected to the dc spark test, the individual conductors shall be similarly tested prior to assembly.

6.27.5 Voltage Tests after Installation

If voltage tests are made after installation, they shall be made immediately. The test voltage shall be a dc voltage as given in Table 6-9 and shall be applied in accordance with 6.27.1 and 6.27.3.

6.28 INSULATION RESISTANCE

6.28.1 Test Apparatus

The test apparatus shall be in accordance with ASTM D 257. The test potential shall be a steady source of 100 through 500 volts dc.

6.28.2 Test Procedure

Single conductor cables shall be tested between the conductor and metallic sheath or water. Multiple conductor cables with nonshielded conductors shall be tested between each conductor and all other conductors and sheath or water. Multiple-conductor cables with shielded conductors shall be tested between the conductor and shield. The conductor under test shall be connected to the negative terminal of the test equipment and readings shall be taken after an electrification of 1 minute.

Each coil, reel or length of wire or cable shall have an insulation resistance in megohms-1000 feet at a temperature of 15.6°C (60°F) of not less than the value of R calculated as follows:

$$R = K \log_{10} \frac{D}{d}$$

Where—

R = Insulation resistance in megohms-1000 feet.
K = Constant for the grade of insulation. (See Part 3)
D = Diameter over the insulation.
d = Diameter under the insulation.

If the temperature at the time of measurement differs from 15.6°C (60°F), the insulation resistance shall be corrected to that at 15.6°C (60°F) by multiplying the measured value by the proper correction factor given in Table 6-13, using the coefficient (see 6.12.3) for the particular grade of insulation and temperature in question. The temperature of the water shall be not less than 10°C (50°F) nor more than 29.4°C (85°F).

6.28.3 Determination of Temperature Correction Factors for Insulation Resistance

Three samples, preferably of 14 AWG solid wire

Table 6-9
DC Test Voltages After Installation, kV

Rated Circuit Voltage, Phase-to-Phase, Volts	Conductor Size, AWG or kcmil	Test Voltage, kV	
		100 Percent Insulation Level	133 Percent Insulation Level
2001–5000	8–1000	25	25
5001–8000	6–1000	35	35
8001–15000	2–1000	55	65
15001–25000	1–1000	80	100
25001–28000	1–1000	85	...
28001–35000	1/0–1000	100	...

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

Table 6-10
Temperature Correction Factors for Insulation Resistance to 15.6°C (60°F)

Temperature		Coefficient for 1°F									
F	C	1.03	1.04	1.05	1.06	1.07	1.08	1.09	1.10	1.11	1.12
50	10.0	0.75	0.68	0.62	0.56	0.51	0.46	0.42	0.38	0.35	0.32
51	10.6	0.77	0.70	0.65	0.59	0.54	0.50	0.46	0.42	0.39	0.36
52	11.1	0.79	0.73	0.68	0.63	0.58	0.54	0.50	0.47	0.43	0.40
53	11.7	0.82	0.76	0.71	0.67	0.62	0.58	0.55	0.51	0.48	0.45
54	12.2	0.84	0.79	0.75	0.70	0.67	0.63	0.60	0.56	0.54	0.51
55	12.8	0.87	0.82	0.78	0.75	0.71	0.68	0.65	0.62	0.60	0.57
56	13.3	0.89	0.86	0.82	0.76	0.76	0.74	0.71	0.69	0.66	0.64
57	13.9	0.92	0.89	0.87	0.84	0.82	0.80	0.78	0.76	0.73	0.71
58	14.4	0.94	0.93	0.91	0.90	0.88	0.86	0.85	0.83	0.82	0.80
59	15.0	0.97	0.96	0.96	0.95	0.94	0.93	0.92	0.91	0.90	0.89
60	15.6	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
61	16.1	1.03	1.04	1.05	1.06	1.07	1.08	1.09	1.10	1.11	1.12
62	16.7	1.06	1.08	1.10	1.13	1.15	1.17	1.19	1.21	1.24	1.27
63	17.2	1.09	1.13	1.16	1.19	1.23	1.26	1.30	1.34	1.38	1.42
64	17.8	1.13	1.17	1.22	1.26	1.31	1.36	1.41	1.47	1.53	1.58
65	18.3	1.16	1.22	1.28	1.34	1.40	1.47	1.54	1.62	1.70	1.78
66	18.9	1.20	1.27	1.35	1.42	1.50	1.59	1.69	1.78	1.88	1.98
67	19.4	1.23	1.32	1.41	1.51	1.62	1.72	1.84	1.96	2.09	2.21
68	20.0	1.27	1.37	1.48	1.60	1.72	1.85	1.99	2.15	2.31	2.48
69	20.6	1.31	1.43	1.55	1.69	1.84	2.00	2.18	2.36	2.57	2.77
70	21.1	1.35	1.48	1.63	1.79	1.97	2.17	2.38	2.60	2.85	3.10
71	21.7	1.39	1.54	1.72	1.90	2.11	2.34	2.59	2.87	3.17	3.46
72	22.2	1.43	1.60	1.80	2.02	2.26	2.53	2.82	3.15	3.52	3.90
73	22.8	1.47	1.67	1.89	2.14	2.42	2.72	3.08	3.46	3.90	4.37
74	23.3	1.52	1.74	1.98	2.27	2.58	2.94	3.35	3.81	4.31	4.88
75	23.9	1.56	1.80	2.08	2.40	2.76	3.18	3.65	4.19	4.78	5.47
76	24.4	1.61	1.87	2.19	2.54	2.96	3.43	3.98	4.61	5.30	6.12
77	25.0	1.66	1.95	2.30	2.70	3.17	3.70	4.34	5.08	5.88	6.85
78	25.6	1.71	2.02	2.41	2.86	3.39	4.00	4.73	5.59	6.51	7.68
79	26.1	1.76	2.11	2.53	3.03	3.62	4.33	5.16	6.14	7.27	8.59
80	26.7	1.81	2.19	2.66	3.21	3.87	4.67	5.61	6.72	8.07	9.65
81	27.2	1.87	2.28	2.80	3.40	4.15	5.04	6.12	7.43	8.98	10.8
82	27.8	1.92	2.37	2.94	3.60	4.43	5.45	6.69	8.18	9.92	12.1
83	28.3	1.98	2.47	3.08	3.82	4.72	5.89	7.28	9.00	11.0	13.6
84	28.9	2.04	2.57	3.23	4.05	5.04	6.35	7.92	9.90	12.2	15.2
85	29.4	2.10	2.67	3.40	4.30	5.42	6.84	8.67	10.8	13.5	17.0

with a 45 mil (1.14 mm) wall of insulation, shall be selected as representative of the insulation under consideration. The samples shall be of sufficient length to yield insulation resistance values under 25000 megohms at the lowest water bath temperature.

The three samples shall be immersed in a water bath equipped with heating, cooling, and circulating facilities, with the ends of the samples extended at least 2 feet (0.6 meter) above the surface of the water and properly prepared for minimum leakage. The samples shall be left in the water at room temperature for 16 hours before adjusting the bath temperature to 10°C or before transferring the samples to a 10°C test temperature bath.

The resistance of the conductor shall be measured at suitable intervals until it remains unchanged for at least 5 minutes. The insulation will then be at the temperature of the bath as read on the bath thermometer. Insulation resistance shall then be measured in accordance with 6.28.2.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS

Not for Resale

Each of the three samples shall be exposed to successive water temperatures of 10,16,22,28 and 35°C and, returning, 28,22,16 and 10°C. Insulation resistance readings shall be taken at each temperature after equilibrium has been established.

The two sets of readings taken at the same temperature shall be averaged and, together with the reading at 35°C, plotted on semi-log paper. The insulation resistance value at 15.6°C (60°F) shall be read from the plot.

The 0.55°C (1°F) coefficient shall be calculated by dividing the insulation resistance at 15.6°C (60°F) by that at 16.1°C (61°F).

6.29 PARTIAL-DISCHARGE TEST PROCEDURE

Refer to ICEA Publication T-24-380.

6.30 METHOD FOR FLEXIBILITY TEST FOR CONTINUOUSLY CORRUGATED ARMOR

6.30.1 A suitable length of armored cable with jacket removed, if any, shall be bent in a "U" bend around a mandrel having a diameter equal with sufficient tension so it conforms closely to the periphery of the cylinder, straightened and then bent 180 degrees in the reverse direction completing one cycle. The rate of bend shall be such that the test is completed within 1 minute. The test is performed at room temperature.

6.31 METHOD FOR DETERMINING PERMITTIVITY (S.I.C.) AND DIELECTRIC STRENGTH OF EXTRUDED NONCONDUCTING POLYMERIC STRESS CONTROL LAYERS

The test specimen shall be an 18 inch (45.7 mm) length of conductor over which 0.015–0.030 inch (0.038–0.076 mm) of nonconducting stress control material has been extruded.

The central 12 inch (30.5 mm) length shall be shielded using a silver-painted electrode or equivalent applied to the surface of the stress control material.

The capacity C, in picofarads, shall be measured at the required temperature using a suitable bridge and a 60 Hz potential. The specimen shall be held at the required temperature for at least 15 minutes prior to measurement.

The geometric capacitance C_o in picofarads, shall be calculated for the 12 inch (30.5 mm) specimen as follows:

$$C_o = 7.354/\log_{10} (D/d)$$

The ratio of measured capacitance divided by the geometric capacitance, C/C_o, shall be the permittivity (S.I.C.) of the stress control material.

Following the capacitance measurement and while the specimen is held at the required temperature, a 60 Hz ac potential shall be applied between the conductor and the grounded shield (painted electrode) with an increasing rate of rise not in excess of 100 volts per second until dielectric failure occurs. The dielectric withstand stress, in volts per mil* shall be calculated as follows:

$$S = 2\,V/(D-d)\,1000$$

D and d in inches
V in volts, actual breakdown level

*S(V/mil) shall be expressed as MV/m by dividing by 25.4.

6.32 HOT CREEP TEST

The hot creep test shall be determined in accordance with ICEA Publication T-28-562. When samples are measured, they shall be selected in accordance with NEMA Standards Publication No. WC 54/ICEA T-26-524, Plan D.

6.33 INSPECTION FOR EVIDENCE OF WATER

A visual inspection for evidence of water shall be performed at the time of preparing the cable ends for voltage test on completed cable in accordance with Section 6.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

Part 7
CONSTRUCTIONS OF SPECIFIC TYPES

The requirements of Parts 1 through 6 shall be met except as otherwise modified in Part 7.

7.1 MINE POWER CABLES

7.1.1 Scope

This section covers ethylene-propylene-rubber-insulated shielded cross-linked or thermoplastic jacketed cables in sizes 6 AWG through 500 kcmil for use as connections between units of mine distribution systems at nominal ac voltages of 2001 to 15,000 volts at 100 or 133 percent insulation level. These cables shall be one of the following types:

Type MP – three power conductors and three grounding conductors.

Type MP-GC – three power conductors and two grounding conductors and one ground check conductor.

Ampacities are given in Appendix I.

Recommended minimum bending radii are given in Appendix H.

7.1.2 Conductors

7.1.2.1 Power Conductors

Power conductors shall be Class B or C stranded annealed coated or uncoated copper or ¾ hard-drawn aluminum 1350 and shall meet the requirements given in Part 2.

In addition, those power conductors used for borehole and shaft cables shall have a minimum factor of safety of 7 when calculated by the formula F = AT/W. If the minimum factor of safety as calculated by the formula is less than 7, medium hard-drawn copper in accordance with ASTM B 2 or B 235 before stranding shall be used. In no case shall the factor of safety be less than 7.

Where –

F = Factor of safety.

A = Area of the three power conductors in square inches.

T = Tensile strength of conductor shall be as tabulated below.

	psi
Annealed copper	24000
Medium hard copper	40000
1350 aluminum	17000

W = Weight of cable in pounds.

The conductor size shall be in accordance with Table 7.1-1 and shall meet the requirements given in Part 2. When the size of medium hard-drawn copper power conductors is determined in accordance with 6.3.1, the dc resistance shall not exceed by more than 2 percent the values given in Table 7.1-5.

A stress control layer in accordance with 2.7 shall be applied over each power conductor.

7.1.2.2 Grounding Conductors

Grounding conductors shall be Class B or C stranded annealed coated copper and shall meet the requirements given in Part 2. The size of each grounding conductor shall be in accordance with Table 7.1-1.

7.1.2.3 Ground Check Conductor

The ground check conductor shall be Class B or C stranded annealed coated or uncoated copper of the minimum size shown in Table 7.1-1 and shall meet the requirements given in Part 2.

7.1.3 Insulation

The insulation shall meet the requirements given in Part 3.

The average thickness of the insulation on the power conductors shall be not less than that given in Tables 7.1-2 and 7.1-3. The average thickness of the insulation on ground check conductors shall be not less than 45 mils (1.14 mm) for 8 AWG and not less than 30 mils (0.76 mm) for 10 AWG. The minimum thickness shall be not less than 90 percent of these values.

7.1.4 Insulation Shielding

Each power conductor shall be shielded in accordance with 4.1.

7.1.5 Identification

Power conductors shall be identified as black, white, and red.

The ground check conductor shall be covered with a closely woven cotton or rayon braid that is colored yellow, or with a yellow colored insulation.

7.1.6 Conductor Assembly

The conductor assembly shall have a left-hand lay. A grounding conductor shall be placed in continuous contact with the metallic shields in each interstices of Type MP cables and in two interstices of Type MP-GC cables. The ground check conductor of Type MP-GC cables

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

shall be placed between the black and white conductors. Fillers of suitable materials hall be used to produce an essentially round cross-section in the completed cable. When required, a binder tape and/or threads shall be used over the conductor assembly.

7.1.7 Jacket

A cross-linked jacket that meets the requirements of 4.4.3, 4.4.8, 4.4.10, or .4.11 or a thermoplastic jacket that meets the requirements of 4.4.5 or 4.4.7 shall be applied over the conductor assembly. The average thickness of the jacket shall be not less than that given in table 7.1-4, and the minimum thickness shall be not less than 80 percent of these values.

7.1.8 Outside Diameters

The outside diameter of the completed cable shall be within plus 8 and minus 5 percent of the values given in Tables 7.1-2 and 7.1-3.

7.1.9 Tests

The cable shall be tested in accordance with Part 6 and shall meet the requirements specified in 7.1.

The insulated power conductors shall meet the test voltage and partial-discharge requirements given in Table 7.1-2 or 7.1-3.

The voltage test on the insulated ground check conductor shall be made between that conductor and the grounding conductors by applying an ac voltage of 3.0 kV for 15 seconds. The insulation resistance test is not required.

7.2 PORTABLE SINGLE-AND MULTIPLE-CONDUCTOR POWER CABLES

Text deleted.

Table 7.1-1
Conductor Sizes

Size of Power Conductors, AWG or kcmil		Copper Grounding Conductors		
Copper	Aluminum	Type MP Cables, Size in Each, Interstice, AWG	Type MP-GC Cables, Size in Each of Two Interstices, AWG	Copper Ground Check Conductor, Minimum Size, AWG
6	4	10	10	10
4	2	8	8	8
2	1/0	8	6	8
1	2/0	7	5	8
1/0	3/0	6	4	8
2/0	4/0	5	3	8
3/0	250	4	2	8
4/0	350	3	1	8
250	400	2	1/0	8
300	450	1	1/0	8
350	500	1	2/0	8
400	—	1/0	3/0	8
450	—	1/0	3/0	8
500	—	2/0	4/0	8

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS

Not for Resale

Table 7.1-2
Insulation Thicknesses and Outside Diameters—2001 to 5000 Volts*—100 and 133 Percent Insulation Levels

Conductor Size, AWG or kcmil	Insulation Thickness		Outside Diameter		AC Test Voltage, kV	Minimum Partial-discharge Extinction Level, kV†	
						Insulation Level	
	mils	mm	inches	mm		100 percent	133 percent
6	90	2.29	1.21	30.7	13	4	5
4	90	2.29	1.32	33.5	13	4	5
2	90	2.29	1.45	36.8	13	4	5
1	90	2.29	1.53	38.9	13	4	5
1/0	90	2.29	1.63	41.4	13	4	5
2/0	90	2.29	1.74	44.2	13	4	5
3/0	90	2.29	1.88	47.8	13	4	5
4/0	90	2.29	2.00	50.8	13	4	5
250	90	2.29	2.13	54.1	13	4	5
300	90	2.29	2.25	57.2	13	4	5
350	90	2.29	2.35	59.7	13	4	5
400	90	2.29	2.45	62.2	13	4	5
450	90	2.29	2.55	64.8	13	4	5
500	90	2.29	2.64	67.0	13	4	5

*The actual operating voltage shall not exceed the rated circuit voltages by more than (a) 5 percent during continuous operation or (b) 10 percent during emergencies lasting not more than 15 minutes.

†Unless otherwise indicated, the cable will be rated at 100 percent insulation level.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS

Table 7.1-3
Insulation Thicknesses and Outside Diameters

Conductor Size, AWG or kcmil	100 Percent Insulation Level							133 Percent Insulation Level						
	Insulation Thickness		Outside Diameter		Test Voltage, kV		Minimum Partial-discharge Extinction Level, kV	Insulation Thickness		Outside Diameter		Test Voltage, kV		Minimum Partial-discharge Extinction Level, kV
	mils	mm	inches	mm	AC	DC		mils	mm	inches	mm	AC	DC	
5001 to 8000 Volts*														
6	115	2.92	1.33	33.8	18	45	6	140	3.56	1.45	36.8	22	45	8
4	115	2.92	1.43	36.3	18	45	6	140	3.56	1.54	39.1	22	45	8
2	115	2.92	1.55	39.4	18	45	6	140	3.56	1.68	42.7	22	45	8
1	115	2.92	1.65	41.9	18	45	6	140	3.56	1.78	45.2	22	45	8
1/0	115	2.92	1.75	44.5	18	45	6	140	3.56	1.90	48.3	22	45	8
2/0	115	2.92	1.88	47.7	18	45	6	140	3.56	2.00	50.8	22	45	8
3/0	115	2.92	2.00	50.8	18	45	6	140	3.56	2.12	53.8	22	45	8
4/0	115	2.92	2.12	53.8	18	45	6	140	3.56	2.25	57.1	22	45	8
250	115	2.92	2.25	57.2	18	45	6	140	3.56	2.35	59.7	22	45	8
300	115	2.92	2.35	59.7	18	45	6	140	3.56	2.48	63.0	22	45	8
350	115	2.92	2.46	62.5	18	45	6	140	3.56	2.58	65.5	22	45	8
400	115	2.92	2.57	65.3	18	45	6	140	3.56	2.70	68.6	22	45	8
450	115	2.92	2.66	67.6	18	45	6	140	3.56	2.85	72.4	22	45	8
500	115	2.92	2.75	69.9	18	45	6	140	3.56	2.93	74.4	22	45	8

*The actual operating voltage shall not exceed the rated circuit voltage by more than (a) 5 percent during continuous operation or (b) 10 percent during emergencies lasting not more than 15 minutes.

(Continued)

Not for Resale

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS

Table 7.1-3
(Continued)

Conductor Size, AWG or kcmil	100 Percent Insulation Level							133 Percent Insulation Level						
	Insulation Thickness		Outside Diameter		Test Voltage, kV		Minimum Partial-discharge Extinction Level, kV	Insulation Thickness		Outside Diameter		Test Voltage, kV		Minimum Partial-discharge Extinction Level, kV
	mils	mm	inches	mm	AC	DC		mils	mm	inches	mm	AC	DC	
8001 to 15000 Volts*														
2	175	4.44	1.88	47.8	27	70	11	...	...	...	...	...	...	...
1	175	4.44	1.98	50.3	27	70	11	215	5.46	2.20	55.9	33	80	15
1/0	175	4.44	2.05	52.0	27	70	11	215	5.46	2.30	58.4	33	80	15
2/0	175	4.44	2.15	54.6	27	70	11	215	5.46	2.42	61.5	33	80	15
3/0	175	4.44	2.26	57.4	27	70	11	215	5.46	2.53	64.3	33	80	15
4/0	175	4.44	2.40	61.0	27	70	11	215	5.46	2.65	67.3	33	80	15
250	175	4.44	2.50	63.5	27	70	11	...	...	...	...	...	...	...
300	175	4.44	2.64	67.0	27	70	11	...	...	...	...	...	...	...
350	175	4.44	2.75	69.9	27	70	11	...	...	...	...	...	...	...
400	175	4.44	2.92	74.2	27	70	11	...	...	...	...	...	...	...
450	175	4.44	3.00	76.2	27	70	11	...	...	...	...	...	...	...
500	175	4.44	3.10	78.4	27	70	11	...	...	...	...	...	...	...

*The actual operating voltage shall not exceed the rated circuit voltages by more than (a) 5 percent during continuous operation or (b) 10 percent during emergencies lasting not more than 15 minutes.

Table 7.1-4
Overall Jacket Thickness

Calculated Diameter of Cable Under Jacket		Jacket Thickness	
inches	mm	mils	mm
1.500 or less	38.10 or less	110	2.79
1.501–2.500	38.13–63.50	140	3.56
2.501–3.500	63.53–88.90	170	4.32

Not for Resale

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

Table 7.1-5

Nominal DC Resistance of Medium Hard-drawn Coated and Uncoated Copper Conductors Concentric Stranded, Class B and C

Conductor Size, AWG or kcmil	Class of Stranding	Coated Copper				Uncoated Copper			
		20°C		25°C		20°C		25°C	
		ohms per 1000 feet	ohms per km	ohms per 1000 feet	ohms per km	ohms per 1000 feet	ohms per km	ohms per 1000 feet	ohms per km
6	B and C	0.436	1.43	0.444	1.46	0.417	1.37	0.425	1.40
4	B and C	0.274	0.899	0.279	0.917	0.262	0.860	0.267	0.877
2	B and C	0.172	0.565	0.176	0.577	0.165	0.541	0.168	0.552
1	B and C	0.137	0.448	0.139	0.457	0.131	0.429	0.133	0.437
1/0	B and C	0.108	0.355	0.110	0.362	0.104	0.340	0.106	0.347
2/0	B and C	0.859	0.282	0.0876	0.287	0.0822	0.270	0.0838	0.275
3/0	B and C	0.0681	0.224	0.0695	0.228	0.0652	0.214	0.0665	0.218
4/0	B	0.536	0.176	0.0547	0.179	0.517	0.170	0.0527	0.173
4/0	C	0.0540	0.177	0.0551	0.181	0.517	0.170	0.0527	0.173
250	B and C	0.0457	0.150	0.0466	0.153	0.0438	0.144	0.0446	0.146
300	B and C	0.0381	0.125	0.0389	0.128	0.0365	0.120	0.0372	0.122
350	B and C	0.0327	0.107	0.0333	0.109	0.0313	0.103	0.0319	0.105
400	B	0.0284	0.0931	0.0289	0.0949	0.0274	0.0898	0.0279	0.0915
400	C	0.0286	0.0938	0.0292	0.0956	0.0274	0.0898	0.0279	0.0915
450	B	0.0252	0.0827	0.0257	0.0844	0.0243	0.0798	0.0248	0.0813
450	C	0.0254	0.0834	0.0259	0.0850	0.0243	0.0798	0.0248	0.0813
500	B	0.0227	0.0745	0.0231	0.0759	0.0219	0.0718	0.0223	0.0732
500	C	0.0229	0.0750	0.0233	0.0765	0.0219	0.0718	0.0223	0.0732

GENERAL DESCRIPTION OF COMPLETED CABLE

7.2.2 Single-conductor Cables, Nonshielded, 0–2000 Volts

These cables shall consist of an insulated conductor with a jacket that meets the requirements of 7.2.18 and shall be in accordance with Table 7.2-2. Normal-service cables shall have a heavy-duty jacket, and hard-service cables shall have an extra-heavy-duty jacket.

7.2.3 Type W and G Two-conductor Cables, 0–2000 Volts

These cables shall be one of two types (1) flat twin or (2) two-conductor round.

7.2.3.1 Two-Conductor Flat Twin Cables

7.2.3.1.1 Type W, Without Grounding Conductor

These cables shall consist of two conductors that are separately covered with insulation and, in addition, may be separately covered with a tape, braid, or serving, and then laid parallel under a jacket that meets the requirements of 7.2.18. The conductor shall be separated by a web of the jacket or other material. If the protective covering on the individual conductors is omitted, a reinforcement shall be applied either over the parallel conductors or within the jacket. The cables shall be in accordance with Table 7.2-3.

7.2.3.1.2 Type G, with Grounding Conductor

These cables shall consist of two power conductors that are separately covered with insulation and, in addition, may be separately covered with a tape, braid, or serving. The two power conductors shall then be laid parallel with a grounding conductor (see 7.2.12) between them under a jacket that meets the requirements of 7.2.18. If the protective covering on the power conductors is omitted, a reinforcement shall be applied either over the parallel conductors and grounding conductor or within the jacket. The cables shall be in accordance with Table 7.2-3.

7.2.3.2 Two-Conductor Round Cables

7.2.3.2.1 Type W, Without Grounding Conductors

These cables shall consist of two conductors that are separately covered with insulation, in addition, each conductor shall be separately covered with a colored tape or braid, which may be omitted if colored insulation is used (see 7.2.15). The conductors, together with any necessary fillers, shall be cabled with a left-hand lay in accordance with Table 7.2-1 and covered with a jacket that meets the requirements of 7.2.18. The cables shall be in accordance with Table 7.2-4.

7.2.3.2.2 Type G, with Grounding Conductors

These cables shall consist of two power conductors that are separately covered with insulation. Each power conductor shall be separately covered with a colored tape or braid, which may be omitted if colored insulation is used (see 7.2.15). The power conductors, together with two grounding conductors (see 7.2.12) and any necessary fillers, shall be cabled with a left-hand lay in accordance with Table 7.2-1 and covered with a jacket that meets the requirements of 7.2.18. The cables shall be in accordance with Table 7.2-4.

7.2.4 Type W, G, and G-GC Three- and Four-conductor Cables, 0–2000 Volts

Three-conductor cables shall be one of five types: (1) Type W, round construction, without grounding conductors, (2) Type G, round construction, with grounding conductors, (3) Type G, flat construction, with grounding conductors, (4) Type G-GC, round construction, with grounding conductors and a ground check conductor, and (5) Type G-GC, flat construction, with a grounding conductor. Four-conductor cables shall be one of two types: (1) Type W, round construction, without grounding conductors and (2) Type G, round construction, with grounding conductors.

7.2.4.1 Type W, Round, Without Grounding Conductors

These cables shall consist of three or four conductors that are separately covered with insulation. Each conductor shall be separately covered with a colored tape or braid, which may be omitted if colored insulation is used (see 7.2.15). The conductors, together with any necessary fillers, shall be cabled with a left-hand lay in accordance with Table 7.2-1 and covered with a jacket that meets the requirements of 7.2.18. Three-conductor cables shall be in accordance with Table 7.2-5, and four-conductor cables shall be in accordance with Table 7.2-6.

7.2.4.2 Type G, Round, with Grounding Conductors

These cables shall consist of three or four power conductors that are separately covered with insulation. Each power conductor shall be separately covered with a colored tape or braid, which may be omitted if colored insulation is used (see 7.2.15). The power conductors, together with the grounding conductors (see 7.2.12) and

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

any necessary fillers, shall be cabled with a left-hand lay in accordance with Table 7.2-1 and covered with a jacket that meets the requirements of 7.2.18. Three-conductor cables shall be in accordance with Table 7.2-5, and four-conductor cables shall be in accordance with Table 7.2-6.

7.2.4.3 Type G, Three-Conductor Flat, with Grounding Conductors

These cables shall consist of three power conductors that are separately covered with insulation and may be separately covered with a tape, braid, or serving. The three power conductors shall then be laid parallel with one of two flat grounding conductors (see 7.2.12) in a vertical position between each of them and under a jacket that meets the requirements of 7.2.18. If the protective covering on the individual power conductors is omitted, a reinforcement shall be applied either over the parallel conductors and grounding conductors or within the jacket. The cables shall be in accordance with Table 7.2-7.

7.2.4.4 Type G-GC, Three-Conductor Round, with Grounding Conductors and Ground Check Conductor

These cables shall consist of three power conductors that are separately covered with insulation, two grounding conductors (see 7.2.12) and one ground check conductor (see 7.2.11). Each power and ground check conductor shall be separately covered with a colored tape or braid, which may be omitted if colored insulation is used (see 7.2.15). All power grounding and ground check conductors and any necessary fillers shall be cabled with a left-hand lay in accordance with Table 7.2-1 and covered with a jacket that meets the requirements of 7.2.18. The ground check conductor shall be laid between the black and white power conductors. These cables shall be in accordance with Table 7.2-8.

7.2.4.5 Type G-GC, Three-Conductor Flat, with Grounding Conductor and Ground Check Conductor

These cables shall consist of three power conductors that are separately covered with a tape, braid, or serving. The three power conductors shall be laid parallel with the flat ground check conductor (see 7.2.11) in a vertical position between the black and white power conductors and with the flat grounding conductor (see 7.2.12) in a vertical position between the white and red power conductors under a jacket that meets the requirements of 7.2.18. If the protective covering on the individual conductors is omitted, a reinforcement shall be applied either over the parallel conductors, grounding conductor and ground check conductor or within the jacket. The cables shall be in accordance with Table 7.2-9.

7.2.5 Type W and G, Five- and Six-conductor, 0–2000 Volts

Five-conductor cables shall be one of two types: (1) Type W, without a grounding conductor and (2) Type G, with a grounding conductor. Six-conductor cables shall be Type W only.

7.2.5.1 Type W, Without Grounding Conductor

These cables shall consist of five or six conductors that are separately covered with insulation. Each conductor shall be separately covered with a colored tape or braid, which may be omitted if colored insulation is used (see 7.2.15). The conductors, together with any necessary fillers, shall be cabled with a left-hand lay in accordance with Table 7.2-1 and covered with a jacket that meets the requirements of 7.2.18. The cables shall be in accordance with Table 7.2-10.

7.2.5.2 Type G, with Grounding Conductor (Five-Conductor Cables Only)

These cables shall consist of five power conductors that are separately covered with insulation. Each power conductor shall be separately covered with a colored tape or braid, which may be omitted if colored insulation is used (see 7.2.15). The power conductors, together with any necessary fillers, shall be cabled with a left-hand lay in accordance with Table 7.2-1 around a single grounding conductor and covered with a jacket that meets the requirements of 7.2.18. These cables shall be in accordance with Table 7.2-10. These cables shall be used for the internal wiring of equipment only.

7.2.6 Type PG, Two and Three Power Conductor With Single Grounding Conductor, 0–2000 Volts

These cables shall consist of two or three power conductors that are separately covered with insulation. Each power conductor shall be separately covered with a colored tape or braid, which may be omitted if colored insulation is used (see 7.2.15). The power conductors, together with a single grounding conductor (see 7.2.12) and any necessary fillers, shall be cabled with a left-hand lay in accordance with Table 7.2-1 and covered with a jacket that meets the requirements of 7.2.18. These cables shall be in accordance with Table 7.2-11.

7.2.7 Type PCG, Two and Three Power Conductor With Control Conductors and Single Grounding Conductor, 0–2000 Volts

These cables shall consist of two or three power conductors and two No. 10 AWG control conductors all of which are separately covered with insulation. Each

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

power and control conductor shall be separately covered with a tape or braid, except that on power conductors this tape or braid may be omitted if colored insulation is used (see 7.2.15). The power conductors, together with two control conductors and a single grounding conductor, shall be cabled together with a left-hand lay in accordance with Table 7.2-1. Each control conductor shall be in a separate interstice between the power conductors; the black control conductor shall be between the black and white power conductors, and the white control conductor adjacent to the white power conductor. The assembly shall be covered with a jacket that meets the requirements of 7.2.18. These cables shall be in accordance with Table 7.2-12.

7.2.8 Type G, Three-conductor Round With Grounding Conductors, 2001–5000 Volts

These cables shall consist of three power conductors that are separately covered with insulation. Each power conductor shall be separately covered with a colored tape (see 7.2.15). The power conductor, together with the grounding conductors (see 7.2.12) and any necessary fillers, shall be cabled with a left-hand lay in accordance with Table 7.2-1 and covered with a jacket that meets the requirements of 7.2.18. The cables shall be in accordance with Table 7.2-13.

7.2.9 Type SH, SHC-GC, SHD, and SHD-GC, Shielded Cables, 0–25000 Volts at 100 Percent Insulation Level Only

7.2.9.1 Type SH Single-Conductor Cables, 2001–25000 Volts

These cables shall consist of an insulated conductor covered with a tape, a shield that meets the requirements of 7.2.16 with or without a tape over the shield, and a jacket that meets the requirements of 7.2.18. The cables shall be in accordance with Table 7.2-14.

7.2.9.2 Type SHC-GC Three-Conductor Cables, 0–2000 Volts

These cables shall consist of three power conductors that are separately covered with insulation. Each power conductor shall be separately covered with a colored tape or braid that may be omitted if colored insulation is used (see 7.2.15). The power conductors, together with two grounding conductors (see 7.2.12), one ground check conductor (see 7.2.11), and any necessary fillers, shall be cabled with a left-hand lay in accordance with Table 7.2-1. The ground check conductor shall be laid between the black and white power conductors. The assembly shall be covered with a shield that meets the requirements of 7.2.16 and a jacket that meets the requirements of 7.2.18. These cables shall be in accordance with Table 7.2-15.

7.2.9.3 Type SHD Three-Conductor Cables, 0–25000 Volts

These cables shall consist of three power conductors that are separately covered with insulation, a colored tape (see 7.2.15) and a shield that meets the requirements of 7.2.16, and three grounding conductors (see 7.2-18), one in each interstice.

All power and grounding conductors and any necessary fillers shall be cabled together with a left-hand lay in accordance with Table 7.2-1 and covered with a jacket that meets the requirements of 7.2.18. These cables shall be in accordance with Table 7.2-16.

7.2.9.4 Type SHD-GC Three-Conductor Cables, 0–25000 Volts

These cables shall consist of three power conductors that are separately covered with insulation, a colored tape (see 7.2.15) and a shield that meets the requirements of 7.2.16 and two grounding conductors (see Table 7.2-18) and one ground check conductor (see 7.2.11).

All power conductors, grounding conductors, the ground check conductor, and any necessary fillers shall be cabled with a left-hand lay in accordance with Table 7.2-1 and covered with a jacket that meets the requirements of 7.2.18. The ground check conductors shall be laid between the black and white power conductors. These cables shall be in accordance with Table 7.2-16.

7.2.10 Power Conductors

7.2.10.1 Power conductors shall be made of annealed coated or uncoated copper wires in accordance with Part 2. A nonconducting separator may be used for cables rated 0–2000 volts.

7.2.10.2 The sizes, strandings, and nominal diameters of the conductors shall be in accordance with Table 7.2-18.

7.2.10.3 A conductor stress control layer shall be in accordance with 2.7.

7.2.11 Control and Ground Check Conductors

The control conductors for Type PCG shall be not smaller than 10 AWG. The ground check conductor for Types G-GC, SHC-GC, and SHD-GC shall be as given in Tables 7.2-8, 7.2-9, 7.2-15, and 7.2-16. A minimum of 49 strands of annealed coated or uncoated copper wire shall be used. A separator may be used. In all other characteristics, the conductors shall meet the requirements of 7.2.10.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

7.2.12 Grounding Conductors

7.2.12.1 The grounding conductors for two, three and four conductor round Type G, SHC-GC, SHD, and SHD-GC shall be annealed copper of not less than the size and number of wires in Table 7.2-18 for the corresponding power conductor sizes. In all other characteristics, they shall meet the requirements of 7.2.10.

7.2.12.2 The single grounding conductor for flat twin Type G cables shall be composed of either coated or uncoated copper and shall have a minimum cross-sectional area of 50 percent of the power conductor but not less than the cross-sectional area for a No. 8 AWG conductor as given in Table 7.2-3. A separator may be used. The grounding conductor wires shall meet the requirements of 2.1.1.

7.2.12.3 The two grounding conductors for flat three-conductor Type G cables shall be flat, rectangular, or oval in shape, composed of either coated or uncoated copper and of the size given in Table 7.2-7. The grounding conductor wires shall meet the requirements of 2.1.1. A separator may be used.

7.2.12.4 The grounding conductors for three-conductor round Type G-GC shall meet the requirements of 7.2.10 and shall be of the size and stranding given in Table 7.2-8.

7.2.12.5 The grounding conductor for flat three-conductor Type G-GC cables shall be flat, rectangular, or oval in shape, composed of either coated or uncoated copper and of the size given in Table 7.2-9. The grounding conductor wires shall meet the requirements of 2.1.1. A separator may be used.

7.2.12.6 The single grounding conductor for five-conductor Type G and for Type PG and PCG cables shall meet the requirements of 7.2.10 and shall be of the size and stranding given in Tables 7.2.10, 7.2.11, and 7.2.12.

7.2.12.7 The grounding conductors for Types G, G-GC, PG, PCG, and SHC-GC cables shall be covered or uncovered. The grounding conductors for Types SHD and SHD-GC shall be uncovered. When used, the outer covering over the grounding conductor shall be green in color.

7.2.13 Insulation

The insulation shall meet the requirements given in Part 3. The average thickness of the insulation on the power conductors shall be not less than that given in Tables 7.2-2 through 7.2-16. In these tables, the highest rated circuit voltage given in the titles represents the maximum operating voltage recommended for that thickness of insulation. The average thickness of insulation shall be not less than 30 mils (0.76 mm) on the 10 AWG control and ground check conductors and not less than 45 mils (1.14 mm) on 8 AWG ground check conductors. The minimum thickness shall be not less than 90 percent of the specified average values.

7.2.14 Tapes and Braids

Tapes and braids if used over the insulation shall be suitable for the intended purpose.

7.2.15 Conductor Identification

Identification shall be by any suitable means in accordance with the color sequence given in 7.2.15.1 and 7.2.15.2. If a conducting nonmetallic tape is used over the insulated conductor, it shall be plainly identified as being conducting.

7.2.15.1 Power Conductors

Two-conductor cables	
All types	black, white
Three-conductor cables	
Type G (round and flat)	black, white, red
Types PCG, PG, G-GC, SHD*, SHD-GC*, and SHC-GC	black, white, red
Type W	black, white, green
Four-conductor cables	
Type G	black, white, red, orange
Type W	black, white, red, green
Five-conductor cables	
Type G	black, white, red, orange, blue
Type W	black, white, red, green, orange
Six-conductor cables	
Type W	black, white, red, green, orange, blue

*If conducting nonmetallic tapes are used, identification may be by means of stripes or printing in a contrasting color.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

7.2.15.2 Control and Ground Check Conductors

Control conductors, Type PCG	black, white
Ground check conductors, Type G-GC (round or flat), Type SHD-GC, and Type SHC-GC	yellow

7.2.16 Shielding

7.2.16.1 The shielding for Types SH, SHD, SHC-GC, and SHD-GC cables shall consist of nonmagnetic wires.

If copper or copper alloy wires are used, they shall be coated in accordance with 2.1.1.

7.2.16.2 Metal Braid Shields

If shielding is applied in the form of a metal braid, the coverage shall be not less than 84 percent as determined by the following formula:

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

Where—

$$F = \frac{NP\,d}{\sin a}$$

a = Angle of braid with axis of cable

$$\text{Tan } a = \frac{2\pi\,DP}{C}$$

d = Diameter of individual braid wires in inches.
C = Number of carriers.
D = Diameter under shield in inches.
N = Number of wires per carrier.
P = Picks per inch.

7.2.16.3 Metal Wire Shields

If the shielding is applied in the form of a serving or wrap, the coverage shall be not less than 60 percent as determined by the following formula:

$$\text{Percent coverage} = \frac{Nd}{W} \times 100$$

Where—

N = Number of parallel wires
d = Diameter of individual wires in inches
$W = \pi\,D \cos a$
D = Diameter under shield in inches
a = Angle between serving wires and axis of cable

$$\text{Tan } a = \pi\frac{D}{C}$$

C = Pitch of serving in inches

7.2.17 Conductor Assembly

For round cables, the insulated conductors, together with grounding conductors and ground check conductor when required and any necessary fillers, shall be cabled with a left-hand lay. For Type SHD and SHD-GC cables, the grounding conductors shall be in contact with the metallic shields. Suitable fillers shall be used to produce an essentially round cross-section in the completed cable. A binder tape and/or threads may be used over the assembly.

7.2.18 Jackets

7.2.18.1 General

The jacket shall be applied in one or two layers. If applied in two layers, the outer jacket shall constitute at least 50 percent of the total thickness of jacket. The single layer jacket and the outer layer of a two layer jacket shall meet the requirements of 7.2.18.1.1, 7.2.18.1.2, 7.2.18.1.3, 7.2.18.1.4, 7.2.18.1.5, 7.2.18.1.6, 7.2.18.1.7, or 7.2.18.1.8.

Single- or two-layer jackets shall be reinforced by two servings or a braid of a suitable natural or synthetic material. The diameter of the reinforcing material shall be not greater than 35 mils (0.89 mm). If two servings are used, they shall be applied in opposite directions of lay. The reinforcing shall be under the single-layer jacket and under or between the layers of the two-layer construction.

7.2.18.1.1 Extra-Heavy-Duty Neoprene Jacket

Physical requirements	
Tensile strength, minimum	
psi	2400
MPa	16.5
Tensile stress at 200 percent elongation, minimum	
psi	700
MPa	4.83
Elongation at rupture, minimum, percent	300
Set, maximum, percent	20
Tear, minimum	
pounds per inch	40
kN/m	7.01
Aging requirements	
After air oven test at 100°C±1°C for 168 hours—tensile strength and elongation at rupture, minimum, percentage of unaged value	50
After oil immersion test at 121°C±1°C for 18 hours—tensile strength and elongation, minimum, percentage of unaged value	60

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

7.2.18.1.2 HEAVY-DUTY NEOPRENE JACKET

Physical Requirements	
Tensile strength, minimum	
psi	1800
MPa	12.4
Tensile stress at 200 percent elongation, minimum	
psi	500
MPa	3.45
Elongation at rupture, minimum, percent	300
Set, maximum, percent	20
Aging Requirements	
After air oven test at 100°C±1°C for 168 hours – tensile strength and elongation at rupture, minimum, percentage of unaged value	50
After oil immersion test at 121°C±1°C for 18 hours – tensile strengthand elongation, minimum, percentage of unaged value	60

7.2.18.1.3 EXTRA-HEAVY-DUTY NITRILE-BUTADIENE/ POLYVINYL-CHLORIDE JACKET*

Physical Requirements	
Tensile strength, minimum	
psi	2400
kgf/mm^2	1.69
Tensile stress at 200 percent elongation, minimum	
psi	700
kgf/mm^2	0.49
Elongation at rupture, minimum, percent	300
Set, maximum, percent	30
Tear, minimum	
pounds per inch	40
mm	0.71
Aging Requirements	
After air oven test at 100°C±1°C for 168 hours – tensile strength and elongation at rupture, minimum, percentage of unaged value	50
After oil immersion test at 121°C±1°C for 18 hours – tensile strengthand elongation, minimum, percentage of unaged value	60

*Suitable for a minimum temperature of –10°C (14°F).

7.2.18.1.4 HEAVY-DUTY NITRILE-BUTADIENE/ POLYVINYL-CHLORIDE JACKET*

Physical Requirements	
Tensile strength, minimum	
psi	1800
kgf/mm^2	1.27
Tensile stress at 200 percent elongation, minimum	
psi	500
kgf/mm^2	0.35
Elongation at rupture, minimum, percent	300
Set, maximum, percent	30
Aging Requirements	
After air oven test at 100°C±1°C for 168 hours – tensile strength and elongation at rupture, minimum, percentage of unaged value	50
After oil immersion test at 121°C±1°C for 18 hours – tensile strength and elongation, minimum, percentage of unaged value	60

*Suitable for a minimum temperature of –10°C (14°F).

7.2.18.1.5 HEAVY-DUTY CHLOROSULFONATED POLYETHYLENE JACKET

Physical Requirements	
Tensile strength, minimum	
psi	1800
kgf/mm^2	1.27
Tensile stress at 200 percent elongation, minimum	
psi	500
kgf/mm^2	0.35
Elongation at rupture, minimum, percent	300
Set, maximum, percent	30
Aging Requirements	
After air oven test at 100°C±1°C for 168 hours – tensile strength and elongation at rupture, minimum, percentage of unaged value	85
Elongation at rupture, minimum, percentage of unaged value	65
After oil immersion test at 121°C±1°C for 18 hours – tensile strengthand elongation, minimum, percentage of unaged value	60

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS

Not for Resale

7.2.18.1.6 EXTRA-HEAVY-DUTY CHLOROSULFONATED POLYETHYLENE

Physical Requirements	
Tensile strength, minimum	
psi	2400
MPa	16.55
Tensile stress at 200 percent elongation, minimum	
psi	700
MPa	4.83
Elongation at rupture, minimum, percent	300
Set, maximum, percent	30
Tear, minimum	
pounds per inch	40
kN/m	7.01
Aging Requirements	
After air oven test at 100°C±1°C for 168 hours – tensile strength and elongation at rupture, minimum, percentage of unaged value	70
Elongation at rupture, minimum, percentage of unaged value	60
After oil immersion test at 121°C±1°C for 18 hours – tensile strength and elongation, minimum, percentage of unaged value	60

7.2.18.1.7 HEAVY-DUTY CHLORINATED POLYETHYLENE, CROSS-LINKED

Physical Requirements	
Tensile strength, minimum	
psi	1800
MPa	12.41
Tensile stress at 200 percent elongation, minimum	
psi	500
MPa	3.45
Elongation at rupture, minimum, percent	300
Set, maximum, percent	30
Aging Requirements	
After air oven test at 100°C±1°C for 168 hours	
Tensile strength and elongation at rupture, minimum, percentage of unaged value	85
Elongation at rupture, minimum, percentage of unaged value	55
After oil immersion test at 121°C±1°C for 18 hours – tensile strength and elongation, minimum, percentage of unaged value	60

7.2.18.1.8 EXTRA-HEAVY-DUTY CHLORINATED POLYETHYLENE, CROSS-LINKED

Physical Requirements	
Tensile strength, minimum	
psi	2400
MPa	16.55
Tensile stress at 200 percent elongation, minimum	
psi	700
MPa	4.83
Elongation at rupture, minimum, percent	300
Set, maximum, percent	30
Tear, minimum	
pounds per inch	40
kN/m	7.01
Aging Requirements	
After air oven test at 100°C±1°C for 168 hours	
Tensile strength and elongation at rupture, minimum, percentage of unaged value	70
Elongation at rupture, minimum, percentage of unaged value	55
After oil immersion test at 121°C±1°C for 18 hours – tensile strength and elongation, minimum, percentage of unaged value	60

7.2.18.2 THICKNESS OF JACKET

The average thickness of the jacket shall be not less than that given in Tables 7.2-13 through 7.2-17. The minimum thickness shall be not less than 80 percent of the values given in the tables. The reinforcing specified in 7.2.18.1 shall be included in the measurement of the jacket thickness.

7.2.19 Completed Cable

7.2.19.1 OUTSIDE DIAMETERS

Nominal outside diameters of the completed cables shall be in accordance with Tables 7.2-2 through 7.2-16.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

7.2.19.2 Diameter Tolerances

The tolerance for outside diameters shall be plus 8 percent and minus 5 percent, except for 0–2000 volt SHD and SHD-GC cables, and 0–2000 volt non-shielded cables. For 0–2000 volt SHD and SHD-GC cables, the tolerance for outside diameters shall be ±5 percent. For 0–2000 volt flat twin cables, the tolerance shall be ±0.04 inch for the major and ±0.03 inch for the minor diameter. For 0-2000 volt flat three-conductor cables, the tolerance shall be ±0.08 inch for the major and ±0.05 inch for the minor diameter. For all other 0–2000 volt non-shielded cables, the tolerances shall be as follows:

Size, AWG or kcmil	Outside Diameter Tolerances, Plus and Minus, Inches
8–1	0.03
1/0–2/0	0.04
3/0–4/0	0.05
250–1000	0.06

7.2.20 Marking

The cable shall be identified throughout its length to indicate the manufacturer.

7.2.21 Tests

The cable shall be tested in accordance with Part 6 and shall meet the requirements specified in 7.2.

The insulated power conductors shall meet the test voltage requirements given in Table 7.2-2 through 7.2-16. The partial-discharge extinction level test is not required.

The insulated ground check conductor shall withstand for 15 seconds an ac voltage of 3000 volts. The insulation resistance test is not required.

Table 7.2-1
Maximum Length of Lay

Number of Power Conductors	Factors for Maximum Length of Lay*
2	20 × d
3	21 × d
4	23 × d
5	27 × d
6	30 × d

*d = diameter of individual power conductor.

Table 7.2-2
0 to 2000 Volts
Single-conductor Portable Power Cable

Power Conductor Size, AWG or kcmil†	Insulation Thickness		Outside Diameter				Test Voltage, kV	
			Normal Service		Hard Service			
	mils	mm	inches	mm	inches	mm	AC	DC
8	60	1.52	0.44	11.2	0.51	13.0	7.0	21.0
6	60	1.52	0.51	13.0	0.59	15.0	7.0	21.0
4	60	1.52	0.57	14.5	0.64	16.3	7.0	21.0
3	60	1.52	0.63	16.0	0.68	17.3	7.0	21.0
2	60	1.52	0.66	16.8	0.71	18.0	7.0	21.0
1	80	2.03	0.74	18.8	0.82	20.8	8.0	24.0
1/0	80	2.03	0.77	19.6	0.87	22.1	8.0	24.0
2/0	80	2.03	0.82	20.8	0.95	24.1	8.0	24.0
3/0	80	2.03	0.87	22.1	1.04	26.4	8.0	24.0
4/0	80	2.03	0.93	23.6	1.11	28.2	8.0	24.0
250	95	2.41	1.03	25.2	1.18	29.5	9.5	28.5
300	95	2.41	1.09	27.7	1.25	31.0	9.5	28.5
350	95	2.41	1.15	29.2	1.30	32.5	9.5	28.5
400	95	2.41	1.20	30.5	1.36	33.8	9.5	28.5
450	95	2.41	1.26	32.0	1.41	34.8	9.5	28.5
500	95	2.41	1.31	33.3	1.45	35.8	9.5	28.5
550	110	2.79	1.42	36.1	...	...	11.5	34.5
600	110	2.79	1.46	37.1	...	...	11.5	34.5
650	110	2.79	1.50	38.1	...	...	11.5	34.5
700	110	2.79	1.54	39.1	...	...	11.5	34.5
750	110	2.79	1.58	40.1	...	...	11.5	34.5
800	110	2.79	1.62	41.0	...	...	11.5	34.5
900	110	2.79	1.69	43.0	...	...	11.5	34.5
1000	110	2.79	1.76	44.7	...	...	11.5	34.5

†See Table 7.2-18.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS

Not for Resale

Table 7.2-3
0 to 2000 Volts
Type W and G Two-Conductor Flat Twin Portable Power Cables

Power Conductor Size, AWG or kcmil†	Power Conductor Insulation Thickness		Grounding Conductor Size, AWG	Outside Diameter				Test Voltage, kV	
				Minor		Major			
	mils	mm		inches	mm	inches	mm	AC	DC
Type W (Without Grounding Conductor)									
8	60	1.52	...	0.51	12.9	0.84	21.3	7.0	21.0
6	60	1.52	...	0.56	14.2	0.93	23.6	7.0	21.0
4	60	1.52	...	0.61	15.5	1.05	26.7	7.0	21.0
3	60	1.52	...	0.68	17.3	1.14	28.9	7.0	21.0
2	60	1.52	...	0.73	18.5	1.24	31.5	7.0	21.0
1	80	2.03	...	0.81	20.6	1.40	35.6	8.0	24.0
1/0	80	2.03	...	0.93	23.6	1.51	38.3	8.0	24.0
2/0	80	2.03	...	0.99	25.1	1.63	41.4	8.0	24.0
3/0	80	2.03	...	1.03	26.1	1.77	45.0	8.0	24.0
4/0	80	2.03	...	1.10	27.9	1.89	48.0	8.0	24.0
Type G (With Grounding Conductors)									
6	60	1.52	8	0.56	14.2	1.02	25.9	7.0	21.0
4	60	1.52	7	0.61	15.5	1.15	29.2	7.0	21.0
3	60	1.52	6	0.68	17.3	1.26	32.0	7.0	21.0
2	60	1.52	5	0.73	18.5	1.35	34.3	7.0	21.0
1	80	2.03	4	0.81	20.6	1.55	39.4	8.0	24.0
1/0	80	2.03	3	0.93	23.6	1.67	42.4	8.0	24.0
2/0	80	2.03	2	0.99	25.1	1.85	47.5	8.0	24.0
3/0	80	2.03	1	1.03	26.1	2.00	50.8	8.0	24.0
4/0	80	2.03	1/0	1.10	27.9	2.10*	53.3*	8.0	24.0

*This cable requires extra-heavy-duty jackets (see 7.2.1).

†See Table 7.2-18.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS

Not for Resale

Table 7.2-4
0 to 2000 Volts
Type W and G Two-conductor Round Portable Power Cables

Power Conductor Size, AWG or kcmil†	Insulation Thickness		Outside Diameter		Test Voltage, kV	
	mils	mm	inches	mm	AC	DC
8	60	1.52	0.81	20.5	7.0	21.0
6	60	1.52	0.93	23.6	7.0	21.0
4	60	1.52	1.08	27.4	7.0	21.0
3	60	1.52	1.17	29.7	7.0	21.0
2	60	1.52	1.27	32.3	7.0	21.0
1	80	2.03	1.44	36.6	8.0	24.0
1/0	80	2.03	1.52	38.6	8.0	24.0
2/0	80	2.03	1.65	41.9	8.0	24.0
3/0	80	2.03	1.77	45.0	8.0	24.0
4/0	80	2.03	1.92	48.8	8.0	24.0
250	95	2.41	2.10*	53.3*	9.5	28.5
300	95	2.41	2.22*	56.3*	9.5	28.5
350	95	2.41	2.36*	59.9*	9.5	28.5
400	95	2.41	2.47*	62.7*	9.5	28.5
450	95	2.41	2.60*	66.0*	9.5	28.5
500	95	2.41	2.70*	68.5*	9.5	28.5

Table 7.2-5
0 to 2000 Volts
Type W and G Three-conductor Round Portable Power Cables

Power Conductor Size, AWG or kcmil†	Insulation Thickness		Outside Diameter		Test Voltage, kV	
	mils	mm	inches	mm	AC	DC
8	60	1.52	0.91	23.1	7.0	21.0
6	60	1.52	1.01	25.7	7.0	21.0
4	60	1.52	1.17	29.7	7.0	21.0
3	60	1.52	1.24	31.5	7.0	21.0
2	60	1.52	1.34	34.3	7.0	21.0
1	80	2.03	1.51	38.4	8.0	24.0
1/0	80	2.03	1.65	42.0	8.0	24.0
2/0	80	2.03	1.75	44.0	8.0	24.0
3/0	80	2.03	1.89	48.0	8.0	24.0
4/0	80	2.03	2.04*	51.8*	8.0	24.0
250	95	2.41	2.39*	60.7*	9.5	28.5
300	95	2.41	2.56*	65.0*	9.5	28.5
350	95	2.41	2.68*	68.1*	9.5	28.5
400	95	2.41	2.82*	71.6*	9.5	28.5
450	95	2.41	2.94*	74.7*	9.5	28.5
500	95	2.41	3.03*	77.7*	9.5	28.5

*These cables require extra-heavy-duty jackets (see 7.2.1).

†See Table 7.2-18.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

Table 7.2-6
0 to 2000 Volts
Type W and G Four-conductor Portable Power Cables

Power Conductor Size, AWG or kcmil†	Insulation Thickness		Outside Diameter		Test Voltage, kV	
	mils	mm	inches	mm	AC	DC
8	60	1.52	0.99	25.1	7.0	21.0
6	60	1.52	1.10	27.9	7.0	21.0
4	60	1.52	1.27	32.3	7.0	21.0
3	60	1.52	1.34	34.0	7.0	21.0
2	60	1.52	1.48	37.6	7.0	21.0
1	80	2.03	1.68	42.7	8.0	24.0
1/0	80	2.03	1.79	45.5	8.0	24.0
2/0	80	2.03	1.93	49.0	8.0	24.0
3/0	80	2.03	2.07*	52.6*	8.0	24.0
4/0	80	2.03	2.26*	57.4*	8.0	24.0
250	95	2.41	2.66*	67.6*	9.5	28.5
300	95	2.41	2.84*	72.1*	9.5	28.5
350	95	2.41	2.98*	75.7*	9.5	28.5
400	95	2.41	3.14*	79.8*	9.5	28.5
450	95	2.41	3.26*	82.8*	9.5	28.5
500	95	2.41	3.40*	86.4*	9.5	28.5

*These cables require extra-heavy-duty jackets (see 7.2.1).

†See Table 7.2-18.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

Table 7.2-7
0 to 2000 Volts
Type G Three-conductor Flat Portable Power Cables With Two Grounding Conductors

Power Conductor Size, AWG†	Power Conductor Insulation Thickness		Grounding Conductor Size, AWG	Nominal Outside Diameter				Test Voltage, kV	
				Minor		Major			
	mils	mm	(each)	inches	mm	inches	mm	AC	DC
6	60	1.52	8	0.67	17.0	1.65	41.9	7.0	21.0
4	60	1.52	8	0.75	19.0	1.85	47.0	7.0	21.0
3	60	1.52	7	0.77	19.6	1.99	50.5	7.0	21.0
2	60	1.52	6	0.81	20.6	2.10*	53.3*	7.0	21.0
1	80	2.03	5	0.97	24.6	2.43*	61.7*	8.0	24.0
1/0	80	2.03	4	1.01	25.6	2.61*	66.3*	8.0	24.0
2/0	80	2.03	3	1.10	27.9	2.86*	72.6*	8.0	24.0
3/0	80	2.03	2	1.18	29.9	3.12*	79.2*	8.0	24.0
4/0	80	2.03	1	1.24	31.5	3.30*	83.8*	8.0	24.0

*These cables require extra-heavy-duty jackets (see 7.2.1).

†See Table 7.2-18.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS

Not for Resale

Table 7.2-8
0 to 2000 Volts
Type G-GC Three-conductor Round Portable Power Cables with Two Grounding Conductors and One Ground-check Conductor

Power Conductor Size, AWG or kcmil†	Power Conductor Insulation Thickness		Each Grounding Conductor		Ground Check Conductor		Outside Diameter		Test Voltage, kV	
	mils	mm	Size, AWG	Number of Wires per Conductor	Minimum Size, AWG	Insulation Thickness, mils	inches	mm	AC	DC
8	60	1.52	10	49	10	30	0.97	24.6	7.0	21.0
6	60	1.52	10	49	10	30	1.05	26.6	7.0	21.0
4	60	1.52	8	49	10	30	1.19	30.2	7.0	21.0
3	60	1.52	8	49	10	30	1.25	31.7	7.0	21.0
2	60	1.52	7	49	10	30	1.34	34.3	7.0	21.0
1	80	2.03	6	133	8	45	1.51	38.4	8.0	24.0
1/0	80	2.03	5	133	8	45	1.65	42.0	8.0	24.0
2/0	80	2.03	4	133	8	45	1.75	44.0	8.0	24.0
3/0	80	2.03	3	133	8	45	1.89	48.0	8.0	24.0
4/0	80	2.03	2	133	8	45	2.04*	51.8*	8.0	24.0
250	95	2.41	2	133	8	45	2.39*	60.7*	9.5	28.5
300	95	2.41	1	133	8	45	2.56*	65.0*	9.5	28.5
350	95	2.41	1/0	259	8	45	2.68*	68.1*	9.5	28.5
400	95	2.41	1/0	259	8	45	2.82*	71.6*	9.5	28.5
450	95	2.41	2/0	259	8	45	2.94*	74.7*	9.5	28.5
500	95	2.41	2/0	259	8	45	3.03*	77.7*	9.5	28.5

*These cables require extra-heavy-duty jackets (see 7.2.1).

†See Table 7.2-18

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS

Not for Resale

Table 7.2-9
0 to 2000 Volts
Type G-GC Three-conductor Flat Portable Power Cables with One Grounding Conductor and One Ground Check Conductor

Power Conductor Size, AWG†	Power Conductor Insulation Thickness		Grounding Conductor Size, AWG	Ground Check Conductor, Minimum Size, AWG	Nominal Outside Diameter				Test Voltage, kV	
					Minor		Major			
	mils	mm			inches	mm	inches	mm	AC	DC
6	60	1.52	8	8	0.67	17.0	1.69	42.9	7.0	21.0
4	60	1.52	7	8	0.75	19.0	1.89	48.0	7.0	21.0
3	60	1.52	6	8	0.77	19.5	2.08*	52.8*	7.0	21.0
2	60	1.52	5	8	0.81	20.5	2.23*	56.6*	7.0	21.0
1	80	2.03	4	8	0.97	24.6	2.48*	62.9*	8.0	24.0
1/0	80	2.03	3	8	1.01	25.6	2.67*	67.8*	8.0	24.0
2/0	80	2.03	2	8	1.10	27.9	2.86*	72.6*	8.0	24.0
3/0	80	2.03	1	8	1.18	29.9	3.12*	79.2*	8.0	24.0
4/0	80	2.03	1/0	8	1.24	31.5	3.30*	83.8*	8.0	24.0

Table 7.2-10
0 to 2000 Volts
Type W and G, Five- and Six-conductor Portable Power Cables

Power Conductor Size, AWG†	Insulation Thickness		Grounding Conductor (Type G)		Outside Diameter				Test Voltage, kV	
			Size, AWG	Minimum Number of Strands	Five-conductor Type W and G		Six-conductor Type W			
	mils	mm			inches	mm	inches	mm	AC	DC
8	60	1.52	8	49	1.07	27.2	1.18	30.0	7.0	21.0
6	60	1.52	7	49	1.21	30.7	1.31	33.3	7.0	21.0
4	60	1.52	5	133	1.40	35.6	1.52	38.6	7.0	21.0
3	60	1.52	4	133	1.48	37.6	1.61	40.9	7.0	21.0
2	60	1.52	3	133	1.61	40.9	1.75	44.4	7.0	21.0
1	80	2.03	2	133	1.88	47.8	2.05*	52.1*	8.0	24.0

*These cables require extra-heavy-duty jacket (see 7.2.1).

†See Table 7.2-18.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

Table 7.2-11
0 to 2000 Volts
Type PG Two- and Three-conductor Power Cables

Power Conductor Size, AWG or kcmil†	Power Conductor Insulation Thickness		Grounding Conductor		Outside Diameter				Test Voltage, kV	
			Size, AWG	Minimum Number of Strands	Two-conductor Cables		Three-Conductor Cables			
	mils	mm			inches	mm	inches	mm	AC	DC
8	60	1.52	8	49	0.84	21.3	0.93	23.6	7.0	21.0
6	60	1.52	8	49	0.93	23.6	1.03	26.2	7.0	21.0
4	60	1.52	6	49	1.08	27.4	1.20	30.5	7.0	21.0
3	60	1.52	6	49	1.17	29.7	1.27	32.3	7.0	21.0
2	60	1.52	5	133	1.27	32.3	1.34	34.0	7.0	21.0
1	80	2.03	4	133	1.44	36.6	1.52	38.6	8.0	24.0
1/0	80	3.03	3	133	1.52	38.6	1.68	42.7	8.0	24.0
2/0	80	2.03	2	133	1.65	41.9	1.79	45.5	8.0	24.0
3/0	80	2.03	1	133	1.77	45.0	1.93	49.0	8.0	24.0
4/0	80	2.03	1/0	259	1.92	48.8	2.13*	54.1*	8.0	24.0
250	95	2.41	2/0	259	2.16*	54.9*	2.39*	60.7*	9.5	28.5

*These cables require extra-heavy-duty jackets (see 7.2.1).

†See Table 7.2-18.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS

Not for Resale

Table 7.2-12
0 to 2000 Volts
Type PCG‡ Two- and Three-conductor Portable Power Cables

Power Conductor Size, AWG or kcmil†	Power Conductor Insulation Thickness		Grounding Conductor		Outside Diameter				Test Voltage, kV	
			Size, AWG	Minimum Number of Strands	Two-conductor Cables		Three-Conductor Cables			
	mils	mm			inches	mm	inches	mm	AC	DC
8	60	1.52	8	49	0.94	23.9	1.03	26.2	7.0	21.0
6	60	1.52	8	49	0.98	24.9	1.18	30.0	7.0	21.0
4	60	1.52	6	49	1.10	27.9	1.29	32.8	7.0	21.0
3	60	1.52	6	49	1.20	30.5	1.31	33.3	7.0	21.0
2	60	1.52	5	133	1.29	32.8	1.39	35.0	7.0	21.0
1	80	2.03	4	133	1.44	36.6	1.52	38.6	8.0	24.0
1/0	80	3.03	3	133	1.52	38.6	1.68	42.7	8.0	24.0
2/0	80	2.03	2	133	1.65	41.9	1.79	45.5	8.0	24.0
3/0	80	2.03	1	133	1.77	45.0	1.93	49.0	8.0	24.0
4/0	80	2.03	1/0	259	1.92	48.8	2.13*	54.1*	8.0	24.0
250	95	2.41	2/0	259	2.16*	54.9*	2.39*	60.7*	9.5	28.5

*These cables require extra-heavy-duty jackets (see 7.2.1).

†See Table 7.2-18.

‡Control conductors for all PCG cables shall be size 10 AWG, with a minimum of 49 strands and 30 mils (0.76 mm) insulation and, if necessary, a braid covering. The ac test voltage shall be 3.0 kV for 15 seconds.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

Table 7.2-13
2001 to 5000 Volts
Type G Three-conductor Portable Power Cables

Power Conductor Size, AWG or kcmil†	Insulation Thickness		Jacket Thickness		Outside Diameter		Test Voltage, kV	
	mils	mm	mils	mm	inches	mm	AC	DC
6	110	2.79	155	3.94	1.37	34.8	13.0	35.0
4	110	2.79	170	4.32	1.55	39.3	13.0	35.0
3	110	2.79	170	4.32	1.62	41.1	13.0	35.0
2	110	2.79	190	4.83	1.75	44.4	13.0	35.0
1	110	2.79	190	4.83	1.84	46.7	13.0	35.0
1/0	110	2.79	205	5.21	1.96	49.7	13.0	35.0
2/0	110	2.79	205	5.21	2.08*	52.8*	13.0	35.0
3/0	110	2.79	205	5.21	2.20*	55.9*	13.0	35.0
4/0	110	2.79	220	5.59	2.38*	60.4*	13.0	35.0

*These cables require extra-heavy-duty jackets (see 7.2.1).

†See Table 7.2-18.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS

Not for Resale

Table 7.2-14
Type SH Single-conductor Portable Power Cables*
For 100 Percent Insulation Level Only

Power Conductor Size, AWG or kcmil†	Insulation Thickness		Jacket Thickness		Outside Diameter		Test Voltage, kV	
	mils	mm	mils	mm	inches	mm	AC	DC
2001 to 5000 Volts								
6	110	2.79	110	2.79	0.77	19.5	13.0	...
4	110	2.79	110	2.79	0.82	20.8	13.0	...
3	110	2.79	110	2.79	0.85	21.5	13.0	...
2	110	2.79	125	3.18	0.92	23.3	13.0	...
1	110	2.79	125	3.18	0.96	24.3	13.0	...
1/0	110	2.79	140	3.56	1.04	26.4	13.0	...
2/0	110	2.79	140	3.56	1.07	27.1	13.0	...
3/0	110	2.79	155	3.94	1.18	29.9	13.0	...
4/0	110	2.79	155	3.94	1.24	31.5	13.0	...
250	120	3.05	155	3.94	1.32	33.5	13.0	...
300	120	3.05	170	4.32	1.37	34.8	13.0	...
350	120	3.05	170	4.32	1.47	37.3	13.0	...
500	120	3.05	190	4.83	1.62	41.1	13.0	...
5001 to 8000 Volts								
4	150	3.81	125	3.18	0.97	24.6	18.0	45.0
3	150	3.81	140	3.56	1.03	26.1	18.0	45.0
2	150	3.81	140	3.56	1.07	27.1	18.0	45.0
1	150	3.81	140	3.56	1.12	28.4	18.0	45.0
1/0	150	3.81	155	3.94	1.19	30.2	18.0	45.0
2/0	150	3.81	155	3.94	1.24	31.5	18.0	45.0
3/0	150	3.81	155	3.94	1.30	33.0	18.0	45.0
4/0	150	3.81	155	3.94	1.37	34.8	18.0	45.0
250	150	3.81	170	4.32	1.45	36.8	18.0	45.0
300	150	3.81	170	4.32	1.52	38.6	18.0	45.0
350	150	3.81	170	4.32	1.57	39.9	18.0	45.0
500	150	3.81	190	4.83	1.76	44.7	18.0	45.0
8001 to 15000 Volts								
2	210	5.33	155	3.94	1.22	30.9	27.0	70.0
1	210	5.33	155	3.94	1.26	32.0	27.0	70.0
1/0	210	5.33	155	3.94	1.31	33.2	27.0	70.0
2/0	210	5.33	155	3.94	1.36	34.5	27.0	70.0
3/0	210	5.33	170	4.32	1.46	37.0	27.0	70.0
4/0	210	5.33	170	4.32	1.52	38.6	27.0	70.0
250	210	5.33	170	4.32	1.57	39.9	27.0	70.0
300	210	5.33	170	4.32	1.64	41.6	27.0	70.0
350	210	5.33	190	4.83	1.73	43.9	27.0	70.0
500	210	5.33	190	4.83	1.88	47.7	27.0	70.0
15001 to 25000 Volts								
1	295	7.49	170	4.32	1.49	37.8	38.0	100.0
1/0	295	7.49	170	4.32	1.54	39.1	38.0	100.0
2/0	295	7.49	170	4.32	1.59	40.4	38.0	100.0
3/0	295	7.49	170	4.32	1.64	41.6	38.0	100.0
4/0	295	7.49	190	4.83	1.74	44.2	38.0	100.0
250	295	7.49	190	4.83	1.79	45.5	38.0	100.0
300	295	7.49	190	4.83	1.86	47.2	38.0	100.0
350	295	7.49	190	4.83	1.91	48.5	38.0	100.0
500	295	7.49	205	5.21	2.10	53.3	38.0	100.0

*These cables require extra-heavy-duty jackets (see 7.2.1).

†See Table 7.2-18.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS

Not for Resale

Table 7.2-15
0 to 2000 Volts
Type SHC-GC Three-conductor Portable Power Cables*
For 100 Percent Insulation Level Only

Power Conductor Size, AWG or kcmil†	Power Conductor Insulation Thickness		Ground Check Conductor Size, AWG	Jacket Thickness		Outside Diameter		AC Test Voltage, kV
	mils	mm		mils	mm	inches	mm	
6	70	1.78	10	155	3.94	1.27	32.2	7.0
4	70	1.78	10	155	3.94	1.39	35.3	7.0
3	70	1.78	10	170	4.32	1.49	37.8	7.0
2	70	1.78	10	170	4.32	1.57	39.9	7.0
1	80	2.03	8	190	4.83	1.75	44.4	8.0
1/0	80	2.03	8	190	4.83	1.85	47.0	8.0
2/0	80	2.03	8	205	5.21	1.99	50.5	8.0
3/0	80	2.03	8	205	5.21	2.11	53.6	8.0
4/0	80	2.03	8	220	5.59	2.29	58.2	8.0
250	95	2.41	8	220	5.59	2.46	62.5	9.5
300	95	2.41	8	235	5.97	2.63	66.8	9.5
350	95	2.41	8	235	5.97	2.75	69.8	9.5
500	95	2.41	8	265	6.73	3.14	79.8	9.5

*These cables require extra-heavy-duty jackets (see 7.2.1).

†See Table 7.2-18.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS

Not for Resale

Table 7.2-16
Type SHD and SHD-GC Three-conductor Portable Power Cables*
For 100 Percent Insulation Level Only

Power Conductor Size, AWG or kcmil†	Power Conductor Insulation Thickness		Ground Check Conductor Size, AWG (Type SHD-GC)	Jacket Thickness		Outside Diameter		Test Voltage, kV	
	mils	mm		mils	mm	inches	mm	AC	DC
0 to 2000 Volts									
6	70	1.78	10	155	3.94	1.29	32.8	7.0	...
4	70	1.78	10	155	3.94	1.40	35.6	7.0	...
3	70	1.78	10	170	4.32	1.51	38.3	7.0	...
2	70	1.78	8	170	4.32	1.59	40.4	7.0	...
1	80	2.03	8	190	4.83	1.76	44.7	8.0	...
1/0	80	2.03	8	190	4.83	1.86	47.2	8.0	...
2/0	80	2.03	8	205	5.21	2.00	50.8	8.0	...
3/0	80	2.03	8	205	5.21	2.13	54.1	8.0	...
4/0	80	2.03	8	220	5.59	2.31	58.7	8.0	...
250	95	2.41	8	220	5.59	2.51	63.8	9.5	...
300	95	2.41	8	235	5.97	2.68	68.1	9.5	...
350	95	2.41	8	235	5.97	2.81	71.4	9.5	...
500	95	2.41	8	265	6.73	3.19	81.0	9.5	...
2001 to 5000 Volts									
6	110	2.79	8	185	4.70	1.56	39.6	13.0	...
4	110	2.79	8	185	4.70	1.68	42.6	13.0	...
3	110	2.79	8	205	5.21	1.78	45.2	13.0	...
2	110	2.79	8	205	5.21	1.87	47.5	13.0	...
1	110	2.79	8	205	5.21	1.95	49.5	13.0	...
1/0	110	2.79	8	220	5.59	2.08	52.8	13.0	...
2/0	110	2.79	8	220	5.59	2.20	55.8	13.0	...
3/0	110	2.79	8	235	5.97	2.36	59.9	13.0	...
4/0	110	2.79	8	235	5.97	2.50	63.5	13.0	...
250	120	3.05	8	250	6.35	2.69	68.3	13.0	...
300	120	3.05	8	250	6.35	2.81	71.4	13.0	...
350	120	3.05	8	265	6.73	2.95	74.9	13.0	...
500	120	3.05	8	280	7.11	3.31	84.0	13.0	...
5001 to 8000 Volts									
4	150	3.81	8	205	5.21	1.94	49.3	18.0	45.0
3	150	3.81	8	205	5.21	2.02	51.3	18.0	45.0
2	150	3.81	8	220	5.59	2.12	53.8	18.0	45.0
1	150	3.81	8	220	5.59	2.21	56.1	18.0	45.0
1/0	150	3.81	8	220	5.59	2.32	58.9	18.0	45.0
2/0	150	3.81	8	235	5.97	2.46	62.5	18.0	45.0
3/0	150	3.81	8	250	6.35	2.62	66.5	18.0	45.0
4/0	150	3.81	8	250	6.35	2.75	69.8	18.0	45.0
250	150	3.81	8	250	6.35	2.89	73.4	18.0	45.0
300	150	3.81	8	265	6.73	3.04	77.2	18.0	45.0
350	150	3.81	8	280	7.11	3.20	81.3	18.0	45.0
500	150	3.81	8	295	7.49	3.56	90.4	18.0	45.0
8001 to 15000 Volts									
2	210	5.33	8	235	5.97	2.41	61.2	27.0	70.0
1	210	5.33	8	235	5.97	2.52	64.0	27.0	70.0
1/0	210	5.33	8	250	6.35	2.64	67.0	27.0	70.0
2/0	210	5.33	8	250	6.35	2.73	69.8	27.0	70.0
3/0	210	5.33	8	265	6.73	2.90	73.6	27.0	70.0
4/0	210	5.33	8	265	6.73	3.05	77.4	27.0	70.0
15001 to 25000 Volts									
1	295	7.49	8	265	6.62	2.95	74.9	38.0	100.0
1/0	295	7.49	8	265	6.62	3.05	77.4	38.0	100.0
2/0	295	7.49	8	280	6.90	3.20	81.2	38.0	100.0
3/0	295	7.49	8	280	6.90	3.33	84.5	38.0	100.0
4/0	295	7.49	8	295	7.49	3.50	88.9	38.0	100.0

*These cables require extra-heavy-duty jackets (see 7.2.1). †See Table 7.2-18.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

Table 7.2-17
Jacket Thicknesses for Types and Sizes of Portable Cables not Covered by Tables 7.2-2 through 7.2-16

Calculated Diameter Under Jacket		Jacket Thickness	
inches	mm	mils	mm
0.325 and less	8.26 and less	60	1.52
0.326–0.430	8.28–10.92	80	2.03
0.431–0.540	10.95–13.72	95	2.41
0.541–0.640	13.74–16.26	110	2.79
0.641–0.740	16.28–18.80	125	3.18
0.741–0.850	18.82–21.59	140	3.56
0.851–1.000	21.62–27.94	155	3.94
1.101–1.320	27.97–33.53	170	4.32
1.321–1.550	33.55–39.37	190	4.82
1.551–1.820	39.40–46.23	205	5.21
1.821–2.050	46.25–52.07	220	5.59
2.051–2.300	52.10–58.42	235	5.97
2.301–2.550	58.45–64.77	250	6.35
2.551–2.800	64.80–71.12	265	6.73
2.801–3.100	71.15–78.74	280	7.11
3.101–3.500	78.77–88.90	295	7.49
3.501–3.950	88.93–100.33	310	7.87
3.951–4.450	100.36–113.03	330	8.38
4.451–5.000	113.06–127.00	345	8.76

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS

Not for Resale

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

WC 8-88
6470247 0008423 3

Table 7.2-18
Conductors

Power Conductors						Grounding Conductors (Round Cables)							
		Diameter of Each Wire		Conductor Diameter		Two-Conductor Type G Cables		Three-Conductor Type SHD-GC and Type SHC-GC Cables		All Other Three-Conductor Type G Cables		Four-Conductor Type G Cables	
Conductor Size, AWG or kcmil	Minimum Number of Wires per Conductor	mils	mm	inches	mm	Size of Grounding Conductors, AWG	Minimum Number of Wires per Conductor	Size of Grounding Conductors, AWG	Minimum Number of Wires per Conductor	Size of Grounding Conductors, AWG	Minimum Number of Wires per Conductor	Size of Grounding Conductors, AWG	Minimum Number of Wires per Conductor
8	49	18.4	0.467	0.166	4.22	10	19	...	...	12	19	12	19
6	49	23.1	0.587	0.208	5.28	10	19	10	19	10	19	12	19
4	49	29.2	0.742	0.263	6.68	8	49	8	49	8	49	10	19
3	49	32.8	0.833	0.295	7.49	6	49	7	49	8	49	10	19
2	133	22.3	0.566	0.335	8.51	6	133	6	133	7	49	9	49
1	133	25.1	0.638	0.377	9.58	5	133	5	133	6	49	8	49
1/0	133	28.2	0.716	0.423	10.74	4	133	4	133	6	133	7	49
2/0	133	31.6	0.803	0.474	12.04	3	133	3	133	5	133	6	133
3/0	259	25.5	0.648	0.536	13.61	2	259	2	133	4	133	5	133
4/0	259	28.6	0.726	0.601	15.27	1	259	1	133	3	133	4	133
250	259	31.1	0.790	0.653	16.59	1/0	259	2	259	2	259	3	133
300	259	34.0	0.864	0.714	18.14	1/0	259	1	259	1	259	3	133
350	259	36.8	0.934	0.773	19.63	2/0	259	1	259	1	259	2	259
400	259	39.3	0.998	0.825	20.96	3/0	259	1/0	259	1/0	259	1	259
450	259	41.7	1.060	0.876	22.25	3/0	259	1/0	259	1/0	259	1	259
500	259	43.9	1.115	0.922	23.42	4/0	259	4/0	259	2/0	259	1/0	259
550	427	35.9	0.912	0.969	24.61	...	...	...	...	...	...	...	...
600	427	37.5	0.952	1.013	25.73	...	...	...	...	...	...	...	...
650	427	39.0	0.991	1.053	26.75	...	...	...	...	...	...	...	...
700	427	40.5	1.029	1.094	27.79	...	...	...	...	...	...	...	...
750	427	41.9	1.064	1.131	28.73	...	...	...	...	...	...	...	...
800	427	43.3	1.100	1.169	29.69	...	...	...	...	...	...	...	...
900	427	45.9	1.166	1.239	31.47	...	...	...	...	...	...	...	...
1000	427	48.4	1.229	1.307	33.20	...	...	...	...	...	...	...	...

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

Table 7.2-18 (Continued)
Conductors

Power Conductors						Grounding Conductors (Round Cables)							
		Diameter of Each Wire		Conductor Diameter		Two-Conductor Type G Cables		Three-Conductor Type SHD-GC and Type SHC-GC Cables		All Other Three-Conductor Type G Cables		Four-Conductor Type G Cables	
Conductor Size, AWG or kcmil	Minimum Number of Wires per Conductor	mils	mm	inches	mm	*Size of* Grounding Conductors, AWG	*Minimum* Number of Wires per Conductor	*Size of* Grounding Conductors, AWG	*Minimum* Number of Wires per Conductor	*Size of* Grounding Conductors, AWG	*Minimum* Number of Wires per Conductor	*Size of* Grounding Conductors, AWG	*Minimum* Number of Wires per Conductor
250	259	31.1	0.790	0.653	16.59	1/0	259	1/0	259	2	259	3	133
250	427	24.2	0.615	0.653	16.59	1/0	259	1/0	259	2	259	3	133
300	259	34.0	0.864	0.714	18.14	1/0	259	1/0	259	1	259	3	133
300	427	26.5	0.673	0.716	18.19	1/0	259	1/0	259	1	259	3	133
350	259	36.8	0.934	0.773	19.63	2/0	259	2/0	259	1	259	2	259
350	427	28.6	0.726	0.772	19.61	2/0	259	2/0	259	1	259	2	259
400	259	39.3	0.998	0.825	20.96	3/0	427	3/0	427	1/0	259	1	259
400	427	30.6	0.777	0.826	20.98	3/0	427	3/0	427	1/0	259	1	259
450	259	41.7	1.060	0.876	22.25	3/0	427	3/0	427	1/0	259	1	259
450	427	32.5	0.826	0.878	22.30	3/0	427	3/0	427	1/0	259	1	259
500	259	43.9	1.115	0.922	23.42	4/0	427	4/0	427	2/0	259	1/0	259
500	427	34.2	0.869	0.923	23.44	4/0	427	4/0	427	2/0	259	1/0	259
550	427	35.9	0.912	0.969	24.61	...	...	...	...	...	...	...	...
550	703	28.0	0.711	0.980	24.89	...	...	...	...	...	...	...	...
600	427	37.5	0.952	1.013	25.73	...	...	...	...	...	...	...	...
600	703	29.2	0.742	1.022	25.96	...	...	...	...	...	...	...	...
650	427	39.0	0.991	1.053	26.75	...	...	...	...	...	...	...	...
650	703	30.4	0.772	1.064	27.03	...	...	...	...	...	...	...	...
700	427	40.5	1.029	1.094	27.79	...	...	...	...	...	...	...	...
700	703	31.6	0.803	1.106	28.09	...	...	...	...	...	...	...	...
750	427	41.9	1.064	1.131	28.73	...	...	...	...	...	...	...	...
750	703	32.7	0.831	1.145	29.08	...	...	...	...	...	...	...	...
800	427	43.3	1.100	1.169	29.69	...	...	...	...	...	...	...	...
800	703	33.7	0.856	1.180	29.97	...	...	...	...	...	...	...	...
900	427	45.9	1.166	1.239	31.47	...	...	...	...	...	...	...	...
900	703	35.8	0.909	1.253	31.83	...	...	...	...	...	...	...	...
1000	427	48.4	1.229	1.307	33.20	...	...	...	...	...	...	...	...
1000	703	37.7	0.958	1.320	33.53	...	...	...	...	...	...	...	...

WC 8-88
6470247 0008424 5

7.3 PREASSEMBLED AERIAL CABLES

7.3.1 Scope

This section covers preassembled aerial cables with one or more individually insulated ethylene-propylene-rubber conductors that are attached to a messenger to form self-supporting aerial cables for use on power transmission and distribution systems operating at 35 kV or less phase-to-phase.

The characteristics of the completed assembly shall be such that the cable can be installed at a minimum temperature of –10°C (14°F).

For ampacities see Appendix M.

7.3.2 Conductors shall be either copper or aluminum in accordance with Part 2.

7.3.2.1 COPPER

Copper conductors shall be sizes 6 AWG to 750 kcmil. The stranding will be Class B, Class C, or compact except that, when required, size 6 AWG may be solid.

7.3.2.2 ALUMINUM

Aluminum conductors shall be sizes 6 AWG to 750 kcmil. The stranding shall be Class B, Class C, or compact.

7.3.2.3 CONDUCTOR STRESS CONTROL LAYER

The conductor stress control layer shall be in accordance with 2.7.

7.3.3 Insulation

The insulation shall meet the requirements given in Part 3, except that, for Type I cable, the average insulation thickness shall be not less than that given in Table 7.3-1, and the minimum thickness shall be not less than 90 percent of this value.

7.3.4 Cable Types

The cable shall be one of the types given in Table 7.3-2.

7.3.4.1 TYPE I—NONSHIELDED, JACKETED, OR NONJACKETED

Type I cables shall be in accordance with Tables 7.3-1 and 7.3-2, and cables rated 2001–5000 volts shall meet the requirements of 7.9.6.2.

7.3.4.2 TYPE II—SHIELDED, NONJACKETED

Type II cables shall be in accordance with Table 7.3-2. The insulation shield shall be in accordance with 4.1.1 except that the metallic component shall be a helically wrapped nonmagnetic shielding tape having a thickness of at least 4.5 mils (0.114 mm) and shall be applied with a lap of not less than 15 percent of its width.

7.3.4.3 TYPE III—SHIELDED, JACKETED

Type III cables shall be in accordance with Table 7.3-2. The insulation shield shall be in accordance with 4.1.1. A separator tape may be applied over the shielding.

Table 7.3-1
Type I Cables Only

Rated Circuit Voltage, Phase-to-Phase	Conductor Size, AWG or kcmil	Jacketed Cable				Nonjacketed Cable		Test Voltage	
		Insulation Thickness at 100 and 133 Percent Insulation Level		Jacket Thickness		Insulation Thickness			
		mils	mm	mils	mm	mils	mm	AC	DC
0–600	6–2	45	1.14	30	0.76	60	1.52	5.5	16.5
	1–4/0	55	1.40	45	1.14	80	2.03	7	21
	225–500	65	1.65	65	1.65	95	2.41	8	24
	525–750	80	2.03	65	1.65	110	2.79	10	30
601–2000	6–2	55	1.40	30	0.76	70	1.78	7	21
	1–4/0	65	1.65	45	1.14	90	2.29	8	24
	225–500	75	1.90	65	1.65	105	2.67	9.5	28.5
	525–750	90	2.29	65	1.65	120	3.05	11.5	34.5
100 Percent Insulation Level Only									
2001–5000	6	90	2.29	30	0.76	110	2.79	13	35
	4–2/0	90	2.29	45	1.14	110	2.79	13	35
	3/0–4/0	90	2.29	65	1.65	110	2.79	13	35
	225–500	90	2.29	65	1.65	120	3.05	13	35
	525–750	90	2.29	65	1.65	130	3.30	13	35

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

7.3.5 Jacket

Jackets for Type I and III cables shall be one of the following:

	See par.
Neoprene, heavy-duty black	4.4.3
Polyvinyl chloride	4.4.5
Polyethylene, black	4.4.6
Chlorinated Polyethylene, Thermoplastic	4.4.7
Nitrile-butadiene/polyvinyl-chloride, heavy duty	4.4.8
Chlorosulfonated polyethylene, heavy duty	4.4.10
Chlorinated Polyethylene, Heavy Duty, Cross-Linked	4.4.11

The average thickness of the jacket for Type I cables shall be not less than that given in Table 7.3-1 and, for Type III cables, not less than that given in Table 4-3. The minimum thickness shall be not less that 80 percent of these values.

7.3.6 Identification

Each insulated conductor of multiple-conductor cables shall be permanently marked so that circuit identification can be made without exposing the insulation. Single-conductor cables need not have circuit identification. Cables shall be identified to indicate the manufacturer.

7.3.7 Assembly

The insulated conductors shall be cabled together with a suitable lay. The messenger shall be laid parallel to the axis of a single conductor or the cabled conductors. The cabled conductors shall be bound to a copper type messenger by means of a copper binding strap or to an aluminum binding strap. The binding strap shall have a pitch of from 3 to 8 inches (76.2 to 203.2 mm), shall be rectangular with rounded edges, and shall have nominal dimensions not less than those shown in Table 7.3-3.

The messenger shall extend 5 feet (1.52 meters) beyond each end of the conductors for use in installing the cable.

7.3.8 Messenger Sizes

The messenger shall be either composite stranded copper and copper-clad steel in accordance with ASTM B 229, Grade 30 EHS stranded copper-clad steel in accordance with ASTM B 228, stranded aluminum-clad steel in accordance with ASTM B 416, stranded aluminum-alloy conductors (AAAC) in accordance with ASTM B 399, or composite stranded aluminum and aluminum-clad steel (ACSR/AW) in accordance with ASTM B 549. The 9/16-inch copper-clad steel size is based on the use of 19-wire construction rather than the 7-wire for added strength and flexibility.

The messenger sizes for copper-clad steel shall be as given in Table 7.3-4 and for ACSR/AW shall be as given in Table 7.3-5. For other types of messenger, consult the manufacturer.

Table 7.3-2

Type	Description	Type of Insulation, See	Maximum Rated Circuit Voltage, Phase-to-Phase	
			100 Percent Insulation Level	133 Percent Insulation Level
I	Nonshielded			
	Jacketed	3.6 or 3.7	5	2
	Nonjacketed	3.7	5	2
II	Shielded, nonjacketed	3.6 or 3.7	35	25
III	Shielded, jacketed	3.6 or 3.7	35	25

Table 7.3-3

Diameter of Cable Assembly Excluding Messenger		Binding Strap							
		Copper				Aluminum			
		Thickness		Width		Thickness		Width	
inches	mm	mils	mm	mils	mm	mils	mm	mils	mm
0–1.000	0–25.40	25	0.64	250	6.35	30	0.76	250	6.35
1.001 and Over	25.43 and Over	30	0.76	375	9.53	40	1.02	375	9.53

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

7.3.9 Design Criteria

The messenger size should be based on a normal stringing tension of 15.6°C (60°F) not exceeding 30 percent of the ultimate strength and a maximum tension not exceeding 50 percent of the ultimate strength at a heavy loading condition. For further information, see the *National Electrical Safety Code*, ANSI Standards Publication No. C2. (This paragraph is approved by NEMA as Authorized Engineering Information.)

The messenger sizes given in Tables 7.3-4 and 7.3-5 are of sufficient strength, except for the 750 kcmil copper cable, to permit installation of the cables on the basis of a 150-foot (45.7-meter) ruling span with a maximum normal sag of 2.5 feet (0.76 meter) at 15.6°C (60°F) no ice, no wind, and without exceeding the tension limits given in Table 7.3-6.

For the 750 kcmil copper cable, the span should be limited to 125 feet (38.1 meters) to satisfy this design criteria.

For single-phase circuits using the messenger as the grounded neutral conductor, the resistance of the messenger should be not greater than that of the conductor.

7.3.10 Tests

The cable shall be tested in accordance with Part 6 and shall meet the requirements specified in 7.3.

7.4 SINGLE- AND MULTIPLE-CONDUCTOR FLEXIBLE CORDS

7.4.1 Scope

This section covers single, two-, three-, and four-conductor flexible cords with conductor sizes 18 to 10 AWG, inclusive, with ethylene-propylene-rubber insulation and with heavy-duty or medium-duty jackets.

Multiple-conductor cords are intended for hard service (300 volts maximum) or extra hard service (600 volts maximum).

Single-conductor cords do not have a service designation. For single-conductor cords, sizes 18 and 16 AWG, the maximum voltage rating is 300 volts. For single-conductor cords, sizes 14, 12, and 10 AWG, the maximum voltage rating is 600 volts.

Ampacities, type designations, and voltage ratings are given in Appendix N.

Remote control and drill cords for use in underground coal mines in accordance with U.S. Bureau of Mines requirements for Electric Motor-Driven Mine Equip-

Table 7.3-4
Messenger Size (Copper-clad Steel) (ASTM B 228 or B 229)

Conductor Size, AWG or kcmil	Cable Voltage Rating and Power Conductor Material					
	Up through 5kV 100 and 133 Percent Insulation Level		Over 5 through 15 kV 100 and 133 Percent Insulation Level		Over 15 through 35 kV 100 Percent Insulation Level	
	Copper	Aluminum	Copper	Aluminum	Copper	Aluminum
SINGLE CONDUCTOR						
6*	6D	6D	6D	6D	...	...
4*	4D	6D	4D	6D	...	...
2*	2J	4D	2J	4D	...	...
TWO AND THREE CONDUCTOR						
6*	5/16	5/16	5/16	5/16	...	...
4*	5/16	5/16	5/16	5/16	...	...
2*	5/16	5/16	5/16	5/16	...	...
1*	5/16	5/16	3/8	5/16	3/8	3/8
1/0	5/16	5/16	3/8	3/8	1/2	3/8
2/0	5/16	5/16	3/8	3/8	1/2	1/2
3/0	3/8	5/16	1/2	3/8	1/2	1/2
4/0	3/8	5/16	1/2	3/8	9/16	1/2
350	3/8	3/8	1/2	1/2	...	...
500	1/2	3/8	9/16	1/2	...	...
750	1/2†	3/8	...	...	...	...

*See limitations on conductor size in Tables 3-1 and 7.3-1.

†See 7.3.9

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

Table 7.3-5
Messenger Size (ACSR/AW) (ASTM B 549)

Conductor Size, AWG or kcmil	Cable Voltage Rating and Power Conductor Material					
	Up through 5kV 100 and 133 Percent Insulation Level		Over 5 through 15 kV 100 and 133 Percent Insulation Level		Over 15 through 35 kV 100 Percent Insulation Level	
	Copper	Aluminum	Copper	Aluminum	Copper	Aluminum
			SINGLE CONDUCTOR			
6*	4–4/3	4–4/3	4–4/3	4–4/3	...	...
4*	2–4/3	4–4/3	2–4/3	4–4/3	...	...
2*	1/0–5/2	2–4/3	1/0–5/2	2–4/3	...	...
			TWO AND THREE CONDUCTOR			
6*	4–2/5	4–2/5	4–2/5	4–2/5	...	...
4*	4–2/5	4–2/5	4–2/5	4–2/5	...	...
2*	4–2/5	4–2/5	4–2/5	4–2/5	...	...
1*	4–2/5	4–2/5	2–2/5	4–2/5	1/0–2/5	2–2/5
1/0	4–2/5	4–2/5	2–2/5	2–2/5	1/0–2/5	2–2/5
2/0	4–2/5	4–2/5	2–2/5	2–2/5	1/0–2/5	1/0–2/5
3/0	2–2/5	4–2/5	1/0–2/5	2–2/5	19 No.9	1/0–2/5
4/0	2–2/5	4–2/5	1/0–2/5	2–2/5	19 No.9	1/0–2/5
350	2–2/5	2–2/5	1/0–2/5	1/0–2/5	...	...
500	1/0–2/5	2–2/5	19 No.9	1/0–2/5	...	...
750	1/0–2/5†	2–2/5	...	...	...	...

*See limitations on conductor size in Tables 3-1 and 7.3-1.

†See 7.3.9

Table 7.3-6

Loading Condition	Maximum Tension, Percent of Ultimate Strength
Heavy Loading	
½ inch (12.7 mm) ice, 4 lb/sq ft (192 Pa) wind force, 17.8°C (0°F)	50
Normal loading	
No ice, no wind, 15.6°C (60°F)	30

Table 7.4-1

Conductor Size, AWG	Cross-sectional Area, cmil	Maximum Lay of Twist			
		Bunch Stranded (Lay of Strands)		Rope Stranded (Lay of Ropes)	
		inches	mm	inches	mm
18	1620	1.00	25.4	1.88	47.8
16	2580	1.25	31.8	2.13	54.1
14	4110	1.63	41.4	2.50	63.5
12	6530	2.00	50.8	3.13	79.5
10	10380	2.50	63.5	3.13	79.5

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS

Not for Resale

ment and Accessories (Schedule 2G) are covered in Appendix N.

7.4.2 Conductors

7.4.2.1 The conductors shall be annealed uncoated or coated copper wire and shall meet the requirements given in Part 2 except the conductor resistance, as specified in paragraph 2.5, is not required.

The conductor size shall be determined by the method in paragraph 6.3.2.1, which specifies cross-sectional area by diameter measurement, or by paragraph 6.3.2.2 which specifies cross-sectional area by weight.

7.4.2.2 Sizes

The conductors shall be sizes 18 through 10 AWG. The cross-sectional area of the conductors shall be not more than 2.0 percent below the values given in Table 7.4-1, except that if only No. 30 AWG strands are employed on 18 AWG conductors, the cross-sectional area shall be not less than 3 percent below the values given in the table.

7.4.2.3 Stranding

The strands in the conductors shall be no smaller than 36 AWG and no larger than 30 AWG. The individual strands of the conductors shall be bunch stranded (twisted together) or rope stranded. The lay of twist shall not exceed the values given in Table 7.4-1.

7.4.2.4 Separator

A separator, if used, shall consist of a close covering of cotton, paper, or other material. Where a separator is not used, the individual strands of the conductor shall be separately coated in accordance with 2.1.1.2.

7.4.3 Insulation

The insulation shall meet the requirements given in Part 3, except that the thickness shall be in accordance with Table 7.4-2 and shall be measured as follows:

7.4.3.1 Average Thickness

The average thickness of the insulation shall be determined in accordance with 6.4.2.1.

7.4.3.2 Minimum Thickness

The minimum thickness of the insulation shall be determined by a pin-gauge dial micrometer which exerts a force of 25±2 grams on the specimen. The pin shall

Table 7.4-2
Insulation Thicknesses

Conductor Size, AWG	Hard Service Multiple-conductor Cords				Extra Hard Service Multiple-conductor Cords and Single-conductor Cords			
	Average		Minimum		Average		Minimum	
	mils	mm	mils	mm	mils	mm	mils	mm
18–16	30	0.76	27*	0.69	30	0.76	27*	0.69
14	30	0.76	27*	0.69	45	1.14	41†	1.04
12	30	0.76	27*	0.69	45	1.14	41†	1.04
10	45	1.14	41†	1.04	45	1.14	41†	1.04

*The minimum thickness at the line of contact between conductors shall be not less than 25 mils (0.64 mm).

†The minimum thickness at the line of contact between conductors shall be not less than 39 mils (0.99 mm).

Table 7.4-3
Maximum Length of Lay

Conductor Size, AWG	Two Conductor		Three Conductor		Four Conductor	
	inches	mm	inches	mm	inches	mm
18	2.00	50.8	2.25	57.2	2.50	63.5
16	2.25	57.2	2.50	63.5	2.75	69.8
14	2.50	63.5	3.25	82.6	3.75	95.2
12	3.00	76.2	3.50	88.9	4.25	108.0
10	3.50	88.9	4.00	101.6	4.75	120.6

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

be 0.437 inch (11.1 mm) long and 0.043 inch (1.09 mm) in diameter, and the end of the presser foot which makes contact with the specimen shall be a flat rectangle 0.043 inch (1.09 mm) wide by 0.312 inch (7.92 mm) long.

The conductor and the separator, if any, shall be removed carefully. The specimen of insulation shall be placed carefully on the pin. The specimen shall be so located that the entire length of the presser foot will make contact with it. The presser foot shall be permitted to come to rest gently on the specimen, and the reading shall be taken immediately. The specimen shall be rotated and several measurements taken in order to determine the actual minimum thickness. The presser foot shall not be in contact with the specimen when the latter is rotated.

Table 7.4-4
Heavy-duty Jackets

	Natural Rubber	SBR	Neoprene	Nitrile butadiene/ polyvinyl-chloride*	Chloro-sulfon-ated Poly-ethylene	Chlori-nated Polyethylene, Cross-linked
Physical requirements						
Tensile strength, minimum						
psi	3500	1800	1800	1800	1800	1800
MPa	24.1	12.4	12.4	12.4	12.4	12.4
Tensile strength at 200 percent elongation, minimum						
psi	500	...	500	500	500	500
MPa	3.45	...	3.45	3.45	3.45	3.45
Elongation at rupture, minimum, percent	500	300	300	300	300	300
Set, maximum, percent	15	20	20	30	30	30
Tear resistance, minimum						
pounds per inch	40	...	...	...	...	...
kN/m	7.01	...	...	...	...	...
Aging Requirements						
After air oven test at 100°C±1°C for 168 hours						
Tensile strength, minimum, percentage of unaged value	...	...	50	50	85	85
Elongation at rupture, minimum, percent	...	...	50	50	65	55
After air oven test at 70°C±1°C for 168 hours						
Tensile strength, minimum						
psi	...	1600	...	...	...	...
MPa	...	11.0	...	...	...	...
Elongation at rupture, minimum, percent	...	250	...	...	...	...
After oxygen pressure test at 70°C±1°C for 96 hours						
Tensile strength, minimum						
psi	2500	1600	...	...	...	...
MPa	17.2	11.0	...	...	...	...
Elongation at rupture, minimum, percent	400	250	...	...	...	...
After oil immersion test at 121°C±1°C for 18 hours—tensile strength and elongation, minimum, percentage of unaged value	...	...	60	60	60	60

*Suitable for a minimum temperature of –10°C (14°F).

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

7.4.4 Conductor Assembly

7.4.4.1 Circuit Identification

Circuit identification shall be obtained by means of colored insulating compounds, braids, or tapes in the following sequence:

Two conductors – black, white

Three conductors – black, white, green, or black, white red

Four conductors – black, white, red, green

7.4.4.2 Length of Lay

The length of lay of insulated conductors shall not exceed the values given in Table 7.4-3.

7.4.4.3 Fillers

Fillers shall be placed in the interstices of the assembly (see 5.2).

7.4.4.4 Binder

A binder, if used, shall be a tape braid, wrap of multiple ends of thread, or a combination of these, and shall be applied over the assembly conductors.

7.4.5 Jackets

7.4.5.1 Heavy-Duty Jackets

The jackets shall be a black compound of natural rubber, SBR synthetic rubber, or neoprene or a black or colored compound of nitrile-butadiene/polyvinyl-chloride, chlorosulfunated polyethylene, or cross-linked chlorinated polyethylene that meets the applicable requirements of Table 7.4-4.

7.4.5.2 Medium-Duty Jackets

The jacket shall be a black or colored compound of natural rubber, SBR synthetic rubber, neoprene, nitrile-butadiene/polyvinyl-chloride, chlorosulphonated

Table 7.4-6
Average and Minimum Thicknesses of Jackets

Conductor Size, AWG	Single-conductor Cords				Multiple-conductor Cords: Hard Service Two to Four Conductors				Multiple-conductor Cords: Extra Hard Service Two to Four Conductors			
	Average		Minimum		Average		Minimum		Average		Minimum	
	mils	mm	mils	mm	mils	mm	mils	mm	mils	mm	mils	mm
18	30	0.76	23	0.58	30	0.76	23	0.58	60	1.53	48	1.22
16	30	0.76	23	0.58	30	0.76	23	0.58	60	1.53	48	1.22
14	30	0.76	23	0.58	30	0.76	23	0.58	80	2.04	64	1.63
12	30	0.76	23	0.58	45	1.14	36	0.91	95	2.42	76	1.94
10	30	0.76	23	0.58	60	1.55	48	1.22	95	2.42	76	1.94

Table 7.4-7
Overall Diameters

Type of Cord	Conductor Size, AWG	Two Conductor		Three Conductor		Four Conductor	
		Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
		inches	inches	inches	inches	inches	inches
Hard Service	18	0.280	0.315	0.300	0.335	0.325	0.365
	16	0.305	0.340	0.325	0.360	0.350	0.395
	14	0.335	0.375	0.360	0.395	0.390	0.435
	12	0.405	0.455	0.425	0.475	0.465	0.520
	10	0.540	0.606	0.565	0.635	0.625	0.700
Extra Hard Service	18	0.340	0.385	0.360	0.400	0.385	0.430
	16	0.365	0.410	0.385	0.430	0.410	0.460
	14	0.495	0.550	0.520	0.575	0.560	0.620
	12	0.565	0.625	0.590	0.655	0.640	0.710
	10	0.615	0.685	0.650	0.720	0.700	0.775

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS

Not for Resale

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

Table 7.4-5 Medium-duty Jackets

	Natural Rubber or SBR	Neoprene	Nitrile-butadiene/ polyvinyl chloride*	Chlorosul-phonated Polyethylene	Ethylene Propylene Rubber	Chlorinated Polyethylene Cross-linked	Polyvinyl Chloride*	Chlorinated Polyethylene Ther-moplastic
Physical requirements								
Tensile strength, minimum								
psi	1500	1500	1500	1500	1500	1500	1600	1400
MPa	10.3	10.3	10.3	10.3	10.3	10.3	11.0	9.6
Elongation at rupture, minimum, percent	300	300	250	300	300	300	250	150
Set, maximum, percent	20	20	30	30	...	35	...	...
Aging requirements								
After air-oven test at 121°C for 168 hours								
Tensile strength, minimum, percentage of unaged value	...	...	...	...	...	...	...	85
Elongation at rupture, minimum, percentage of unaged value	...	...	...	...	...	...	...	50
After air oven test at 100°C ±1°C for 168 hours – tensile strength and elongation at rupture, minimum, percentage of unaged value	...	50	50	...	...	55	50	...
After oxygen pressure test at 70°C ±1°C for 96 hours – tensile strength and elongation at rupture, minimum, percentage of unaged value	70	...	...	70	...	...	...	...
After oxygen pressure test at 80°C ±1°C for 168 hours – tensile strength and elongation at rupture, minimum, percentage of unaged value	...	...	...	...	50	...	...	...
After air pressure heat test at 127°C ±1°C for 20 hours – tensile strength and elongation at rupture, minimum, percentage of unaged value	...	...	...	...	50	...	...	...
After oil immersion test at 121°C ±1°C for 18 hours – tensile strength and elongation, minimum, percentage of unaged value	...	60	60	...	...	60	50	...
After oil immersion test at 100°C ± 1° C for 18 hours – tensile strength and elongation, minimum, percentage of unaged value	...	...	...	...	...	...	...	60
After air oven test at 70°C ±1°C for 168 hours – tensile strength and elongation at rupture, minimum, percentage of unaged value	...	...	...	70	...	...	...	...

*Suitable for a minimum temperature of –10°C (14°F).

WC 8-88
6470247 0008432 4

polyethylene, ethylene propylene rubber or polyvinyl-chloride, or thermoplastic chlorinated polyethylene that meets the applicable requirements of Table 7.4-5.

7.4.5.3 Oil Resistance

The jacket of an oil resistant cord shall be one of those meeting the requirements of 121°C oil immersion test given in Table 7.4-4 or 7.4-5.

7.4.5.4 Application

The jacket shall be applied over the insulation of a single-conductor cord or over the assembled conductors or binder of multiple-conductor cords.

7.4.5.5 Reinforcement

Reinforcement, if used, shall consist of a braid or a serving of fibrous material under the entire jacket or completely embedded in the jacket.

7.4.5.6 Thickness

The thickness of the jacket shall be in accordance with Table 7.4-6 and shall be determined in accordance with 7.4.3.1 and 7.4.3.2.

7.4.6 Overall Diameters

The minimum average overall diameter of the completed cord shall be in accordance with Table 7.4-7.

7.4.7 Strength of Completed Cord

The mechanical strength of completed two- and three-conductor cord, sizes 16 and 18 AWG, shall be determined by means of a freely hanging weight or a suitable testing machine and shall be such that no conductor will break when the test force given in Table 7.4-8 is applied for 1 minute.

7.4.8 Tests

The cord shall be tested in accordance with Part 6 and shall meet the requirements specified in 7.4 except as otherwise specified in 7.4.8.1.

7.4.8.1 Electrical Tests

Each length of completed single-conductor cord shall withstand either the dc or the ac spark test voltage given in Table 7.4-9. Each length of completed multiple-conductor cord shall withstand an ac voltage test unless each individual insulated conductor, prior to assembly, has withstood either an ac spark test or a dc spark test. The ac voltage shall be applied for 15 seconds between conductors without immersing the cord in any liquid.

The ac test and the ac spark test shall be in accordance with Underwriters' Laboratories, Inc., "Standards for Flexible Cord and Fixture Wire," UL 62.

The dc spark test shall be in accordance with 6.27.4b.

The test voltages shall be in accordance with Table 7.4-9.

Table 7.4-8
Strength of Completed Cord

		Test Force	
		Two and Three Conductor	
Type of Cord	Conductor Size, AWG	Pounds	kg
Hard Service	18	175	79.4
	16	200	90.7
Extra Hard Service	18	200	90.7
	16	225	102

Table 7.4-9
Test Voltages

Conductor Size, AWG	Test Voltages, kV		
	AC Voltage Test	AC Spark Test	DC Spark Test
18	2.0	6.0	...
16	2.0	6.0	...
14	3.0	7.0	16.0
12	3.0	7.0	16.0
10	3.0	7.0	16.0

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

7.5 CONTROL CABLES

See NEMA Pub. No. WC 57, ICEA Pub. No. S-73-532.

7.5.1 Scope

Paragraph deleted.

7.5.2 Conductors

Paragraph deleted.

7.5.3 Insulation

Paragraph deleted.

7.5.4 Jacket Over Insulation

Paragraph deleted.

7.5.5 Conductor Identification

Paragraph deleted.

7.5.6 Assembly

Paragraph deleted.

7.5.7 Overall Jacket

Paragraph deleted.

7.5.8 Type D Cables

Paragraph deleted.

7.5.9 Tests

Paragraph deleted.

7.5.10 Optional Flame Test Requirements

Paragraph deleted.

7.6 CONCENTRIC-NEUTRAL UNDERGROUND DISTRIBUTION CABLES

7.6.1 Scope

This section covers two-conductor concentric neutral power cables consisting of one ethylene-propylene-rubber-insulated central conductor and one copper concentirc neutral conductor applied hlically overall. These cables are intednded for use on single-phase and three-phase primary underground distribution systems operating at 2001 to 35,000 volts phase-to-phase at 100 percent insulation level. For amapacities, see Appendix F.

7.6.2 Central Conductor

Central conductors shall be annealed copper or aluminum. The minimum conductor size shall be in accordance with Table 7.6-1.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS

Not for Resale

Table 7.6-1
Minimum Conductor Size

Rated Circuit Voltage, Phase-to-Phase, Volts	Minimum Conductor Size, AWG
2001–15000	4
15001–28000	1
28001–35000	1/0

7.6.2.1 COPPER

Conductors shall be (1) annealed uncoated copper or annealed coated copper either Class B or C stranded or (2) uncoated copper, compact stranded, and shall meet the requirements of Part 2.

7.6.2.2 ALUMINUM

The conductor shall be aluminum 1350 either solid (through 4/0 AWG), Class B or C stranded, or compact stranded in accordance with Part 2.

7.6.2.3 CONDUCTOR STRESS CONTROL LAYER

The conductors shall be aluminum 1350 either solid through 4/0 AWG, Class B or C stranded, or compact stranded in accordance with Part 2.

7.6.3 Insulation

The shielded central conductor shall be insulated with an ethylene-propylene-rubber compound that meets the requirements given in Part 3. The average thickness of the insulation shall be not less than that given in Table 3-1 for the 100 percent insulation level. The minimum thickness shall be not less than 90 percent of the values given in that table.

7.6.4 Insulation Shielding and Protective Covering

A layer of conducting nonmetallic material meeting the requirements of 4.1.1 shall be extruded directly over the insulation to serve both an electrostatic shield and a protective covering. The thickness of the extruded insulation shielding at any location when measured on completed cable shall be in accordance with Table 7.6-2.

The conducting layer shall be compatible with the insulation and shall be legibly identified as being conducting.

Temperatures lower than 130°C (266°F) may be required for emergency overload conditions because of the type of material used in the cable, joints, and terminations or because of cable environmental conditions. (This paragraph is approved by NEMA as Authorized Engineering Information.)

7.6.5 Concentric Conductor

The overall concentric conductor shall consist of a number of copper wires meeting the chemical requirements of ASTM B 5 and the resistivity, tensile, and elongation requirements of ASTM B 3 for uncoated wires, ASTM B 33 for tin coated wires or ASTM B 189 for lead-alloy-coated wires. The number of wires of a specified size shall be not less than that given in Table 7.6-3 for cables used in single phase systems and in either Table 7.6-5 or Table 7.6-6 for three phase system.

The nominal diameters and circular mil areas of the wires in Tables 7.6-3, 7.6-5, and 7.6-6 shall be as follows:

AWG Size	Diameter inch	Area kcmil
14	0.0641	4.11
12	0.0808	6.53
10	0.1019	10.38
9	0.1144	13.09
8	0.1285	16.51

The individual wires comprising a given concentric conductor may vary ±5 percent in diameter from the appropriate nominal value given above, but the total circular mil area of the specified concentric conductor shall be as follows:

1. For single-phase systems, at least 98 percent of the product of the appropriate number of wires given in Table 7.6-3 times the appropriate nominal circular mil area tabulated above.
2. For three-phase systems at least 98 percent of the product of the appropriate number of wires given in Table 7.6-5 or 7.6-6 times the appropriate nominal circular mil area tabulated above.

NOTE: This is for a one-third neutral.

The wires of the concentric conductor shall be applied directly over the conducting material given in 7.6.4 with a lay not less than six nor more than ten times the diameter over the concentric wires.

Table 7.6-2
For Cables with or without an Overall Jacket

Calculated Insulation Diameter	Insulation Shield Thickness		
	Minimum Point	Maximum Point	Maximum Indent
Inches	Inch	Inch	Inch
1.000 or less	0.030	0.070	0.015
1.001–1.500	0.040	0.085	0.015
1.501–2.000	0.055	0.100	0.020
2.001 and larger	0.055	0.115	0.020

Note: The minimum point does not apply to locations under the metallic shield indent.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

7.6.6 Optional Jackets Applied Over a Concentric Conductor

The jackets shall be either nonconducting or conducting depending upon installation requirements. If nonconducting compound is used, it shall meet the physical and aging requirements of 4.4.3 through 4.4.11 as applicable.

If conducting compound is used, it shall be either Type I or II compound meeting the physical and aging requirements of Table 7.6-7.

A Type II jacket provides more heat and deformation resistance than Type I.

CAUTION: Cable users should be aware that some types of jackets may alter the physical and electrical characteristics of the cable components. (This sentence is approved by NEMA as Authorized Engineering Information.)

7.6.6.1 Extruded To Fill Type Jacket

The jacket material shall cover the concentric conductor and fill the spaces between wires. The jacket material shall be in contact with the insulation shielding, but shall strip freely.

When measured over the wires, the average jacket thickness shall be not less than the appropriate value stated in Table 7.6-4A.

Table 7.6-4A
Jacket Thickness and Test Voltage

Calculated Diameter of Concentric Conductor	Average Jacket Thickness	AC Spark-Test Voltage (kV) for Nonconducting	
Inches	Inch	Cross-linked Jackets	Thermoplastic Jackets
1.500 or less	0.050	2.0	4.5
Over 1.500	0.080	3.0	7.0

The minimum thickness over the wires shall be not less than 80 percent of the specified average thickness.

After a jacket has been applied, the indent of the extruded insulation shield caused by the metallic shield shall not be more than the specified maximum indent value found in Table 7.6-2.

7.6.6.2 Overlaying Type Jacket

If a nonmetallic tape is applied over the concentric conductors of the cable and the jacket is conducting, then the tape shall be conducting. When the jacket is nonconducting, the tape shall be either conducting or nonconducting. A conducting tape shall be clearly identified as being conducting.

The average jacket thickness when measured over the wires shall be not less than specified in Table 4-6. The minimum thickness at any point shall be not less than 80 percent of the specified average thickness.

Table 7.6-3

Insulated Conductor Size, AWG or kcmil		Concentric Conductor, Minimum Number of Wires			
Copper	Aluminum	14 AWG	12 AWG	10 AWG	9 AWG
...	4	6	...	...	...
4	2	10	...	...	...
3	1	13	...	...	...
2	1/0	16	10*	...	...
1	2/0	20*	13	...	...
1/0	3/0	25*	16	10*	...
2/0	4/0	32*	20*	13	10*
3/0	250	...	25*	16	13*
4/0	350	...	32*	20*	16

*Alternate constructions.

Table 7.6-4

Rated Circuit Voltage, Phase-to-Phase, Volts	Minimum Partial-discharge Extinction Level, kV
2001–5000	5
5001–8000	7
8001–15000	13
15001–25000	22
25001–28000	25
28001–35000	31

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

Table 7.6-5
Copper Central Conductor

Copper Insulated Conductor Size, AWG or kcmil	Minimum Number of Concentric Wires				
	14 AWG	12 AWG	10 AWG	9 AWG	8 AWG
4–2	6	...	...	...	...
1	7	6*	...	...	...
1/0	9	6*	...	...	...
2/0	11	7*	6*	...	...
3/0	14	9*	6*	6*	...
4/0	18	11*	7*	6*	...
250	21*	13	9*	7*	...
350	...	18	12*	9*	...
500	...	26*	17	13*	10*
750	...	...	25*	20*	15
1000	...	...	...	26*	20

Table 7.6-6
Aluminum Central Conductor

Aluminum Insulated Conductor Size, AWG or kcmil	Minimum Number of Concentric Wires				
	14 AWG	12 AWG	10 AWG	9 AWG	8 AWG
4–1/0	6	...	...	...	...
2/0	7	6*	...	...	...
3/0	9	6*	...	...	...
4/0	11	7*	6*	...	...
250	13	8*	6*	6*	...
300	15	10*	6*	6*	...
350	18	11*	7*	6*	...
					...
500	25*	16	10*	8*	...
750	...	24*	15	12*	...
1000	...	...	20*	16	12*

*Alternate constructions.

After a jacket has been applied, the indent of the extruded insulation shield caused by the metallic shield shall not be more than the specified maximum indent value found in Table 7.6-2.

7.6.6.3 IDENTIFICATION

When a conducting material is used for the overall jacket, the cable legend shall identify the material as being conducting.

7.6.6.4 SPARK TEST FOR NONCONDUCTING JACKETS

A nonconducting jacket over the concentric neutral conductors shall withstand an ac spark test voltage. The voltage for extruded-to-fill type jackets is given in Table 7.6-4A. The voltage for overlaying type jackets is in accordance with 4.4.15. The voltage shall be applied between an electrode at the outside surface of the jacket and the concentric neutral conductor. The neutral conductor shall be connected to ground during the test. The spark test shall be conducted in accordance with 6.27.4a.3 and 6.27.4a.4.

7.6.7 Tests

The cable shall be tested in accordance with Part 6 and shall meet the requirements specified in 7.6. The partial-discharge extinction level shall be in accordance with Table 7.6-4. The electrical requirement tests shall be made without immersion in water.

7.7 CONCENTRIC-NEUTRAL UNDERGROUND DISTRIBUTION CABLES

Section deleted and material was combined with 7.6 on 5-12-1982.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

Table 7.6-7
Properties of Thermoplastic Conducting Jackets

	Type I	Type II
Physical Requirements		
Tensile strength, minimum		
psi	1200	1500
Elongation at rupture, minimum percent	100	150
Aging Requirements		
After air oven aging at 100°C±1°C for 48 hours		
Tensile strength, minimum percentage of unaged value	75	
Elongation at rupture, minimum percent	100	
After air oven aging at 121°C ±1°C for 168 hours		
Tensile strength, minimum percentage of unaged value		75
Elongation at rupture, minimum percentage of unaged value		75
Heat distortion, maximum, percent		
Air Oven at 90°C±1°C	25	
Air Oven at 121°C±1°C		25
Volume Resistivity		
At room temperature (23°C±2°C) and 90°C±1°C, max. meter-ohms	100	100
Brittleness Temperature. °C not warmer than	–10	–15

7.8 METAL-CLAD CABLES WITH GROUNDING CONDUCTOR

7.8.1 Scope

This section covers two-, three-, and four-conductor ethylene-propylene-rubber-insulated interlocked armored metal-clad cables with a grounding conductor. Power conductors shall be size 14 AWG through 1000 kcmil if of copper, and size 12 AWG through 1000 kcmil if of aluminum.

7.8.2 Conductors

Insulated power conductors and insulated or uninsulated grounding conductors shall be made of copper or aluminum and shall meet the requirements given in Part 2. The grounding conductor shall be cabled with the insulated power conductors in one or more sections.

7.8.2.1 CABLES RATED 2000 VOLTS OR LESS

The minimum size of the grounding conductor shall be as given in Table 7.8-1.

7.8.2.2 CABLES RATED 2001 VOLTS AND ABOVE

The minimum size of the grounding conductor shall be in accordance with Table 7.8-2.

7.8.3 Conductor Stress Control Layer

A conductor stress control layer shall be used on conductors having rated circuit voltages above 2000 volts.

7.8.4 Insulation

The insulation shall meet the requirements given in Part 3.

7.8.5 Insulation Shielding

Insulation shielding shall comply with 4.1 and 4.2.

7.8.6 Covering

If a nonmetallic covering is used over the individual insulated conductor, it shall be a tape, braid, or jacket. The jacket shall comply with 4.4.

7.8.7 Assembly

The insulated power conductors and the grounding conductor shall be cabled together with or without fillers. The direction of lay shall be left-hand. The maximum length of lay shall be in accordance with Part 5 and shall be based on the calculated diameter of the individual power conductor. A suitable binder shall be applied over the assembly.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

Table 7.8-1 ▲
Grounding Conductor Size for Cables Rated 2000 Volts or Less

Power Conductor Size AWG or kcmil		Minimum Grounding Conductor Size AWG	
Copper	Aluminum	Copper	Aluminum
14	12	14	12
12	10	12	10
10-8	8-6	10	8
6-4	4-2	8	6
3-2/0	1-3/0	6	4
3/0-250	4/0-350	4	2
300-400	400-600	3	1
450-650	700-1000	2	1/0
700-900	———	1	2/0
1000	———	1/0	3/0

7.8.8 Armor

An interlocked metal tape armor meeting the requirements of 4.5.7 shall be applied over the assembly.

7.8.9 Tests

The cable shall be tested in accordance with Part 6 and shall meet the requirements specified in 7.8.

7.9 NONSHIELDED SINGLE-CONDUCTOR POWER CABLE

7.9.1 Scope

This section covers nonshielded single-conductor power cable with ethylene-propylene-rubber insulation intended for use at 2001 to 5000 volts at 100 percent insulation level and 2001 to 3000 volts at 133 percent insulation level under conditions where shields cannot be adequately grounded or where space is adequately grounded or where space is inadequate for proper termination of the shielding, as follows (see 4.2 and Appendix G):

a. Single Conductors
   1. Unspliced cables in random lay in grounded metal conduit indoors above grade in dry locations.
   2. Mounted on insulators in free air.
b. Triplexed Single Conductors (Factory Assembled)—In conduit or cable trays indoors above grade in dry locations.
c. Single and triplexed conductors—Aerially, field spun to a grounded messenger.

NOTE 1—Care must be taken at joint and terminal locations to have a minimum length of separated conductors. Where field splices are permitted, they should be bound together to keep the phase conductors in contact with each other.*

NOTE 2—Pulling compounds should be nonconducting.*

*These notes approved by as Authorized Engineering Information.

Table 7.8-2
Grounding Conductor Size for Cables Rated 2001 Volts and Above

Power Conductor Size, AWG or kcmil		Minimum Grounding Conductor Size, AWG	
Copper	Aluminum	Copper	Aluminum
8 AWG	8–6 AWG	8	6
6–2	4–1/0	6	4
1–2/0	2/0–250 kcmil	4	2
3/0 AWG–250 kcmil	300–400	3	1
300–400	450–600	2	1/0
450–600	750–900	1	2/0
750–1000	1000	1/0	3/0

7.9.2 Conductors

The conductors shall be copper or aluminum in accordance with Part 2. The conductor sizes shall be as given in Table 7.9-1.

Table 7.9-1

Conductor Size, AWG or kcmil	Jacket Thickness	
	mils	mm
8–6	30	0.76
4–2/0	45	1.14
3/0–1000	65	1.65

▲ Revised 1-30-1991.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

7.9.3 Insulation

The insulation shall meet the requirements given in Part 3. The average thickness of the insulation shall be not less than 90 mils (2.29 mm) and the minimum thickness shall be not less than 81 mils (2.06 mm).

7.9.4 Jacket

A jacket that meets the requirements of 4.4.3 neoprene, 4.4.5 polyvinyl chloride, 4.4.7 thermoplastic chlorinated polyethylene, 4.4.8 nitrile butadiene/polyvinyl chloride, 4.4.10 chlorosulfonated polyethylene, or 4.4.11 cross-linked chlorinated polyethylene shall be applied over the insulation. The average thickness of the jacket shall be not less than that given in Table 7.9-1, and the minimum thickness shall be not less than 80 percent of this value.

7.9.5 Length of Lay

Triplexed cables shall have a maximum length of lay of 35 times the diameter of the single-conductor cable.

7.9.6 Tests

The cable shall be tested in accordance with Part 6 and shall meet the requirements specified in 7.9, except as otherwise specified in 7.9.6.1 and 7.9.6.2.

7.9.6.1 Electrical Requirements

Each insulated and jacketed conductor in the completed cable shall be tested in accordance with 6.27 and 6.28 and shall meet the following requirements.

7.9.6.1.1 AC Voltage Test

(See 6.27.2.) The conductor shall withstand an ac test voltage of 13 kV, except that the dc voltage test may be substituted.

7.9.6.1.2 Insulation Resistance

(See 6.28.) The conductor shall have an insulation resistance not less than that corresponding to a constant of 12000 at 15.6°C (60°F).

7.9.6.1.3 DC Voltage Test

(See 6.27.3.) Upon completion of the insulation resistance test, each conductor shall withstand a dc test voltage of 35 kV, unless the ac voltage test is performed.

7.9.6.2 Tests for Discharge Resistance

The samples shall be taken in accordance with 6.23.1.

7.9.6.2.1 Surface Resistivity

The surface resistivity shall be measured in accordance with 6.23.2 and shall be not less than 200,000 megohms.

7.9.6.2.2 U-Bend Discharge

The sample shall be tested in accordance with 6.23.3 with an ac potential of 13 kV. There shall be no voltage breakdown or surface cracking.

7.10 NONSHIELDED SINGLE-CONDUCTOR CABLES FOR SERIES-LIGHTING CIRCUITS

7.10.1 Scope

This section covers nonshielded single-conductor cable with ethylene-propylene rubber insulation intended for use in series lighting circuits, as follows:

a. Nonjacketed—2000 volts or less
b. Jacketed—5000 volts or less

7.10.2 Conductors

The conductors shall be copper in accordance with Part 2 and of the sizes given in Table 7.10-1 or 7.10-2.

7.10.3 Insulation

7.10.3.1 Nonjacketed Cable

The insulation for nonjacketed cable shall meet the requirements of 3.7. The average thickness of the insulation shall be not less than that given in Table 7.10-1, and the minimum thickness at any point shall be not less than 90 percent of this value.

7.10.3.2 Jacketed Cable

The insulation for jacketed cables shall meet the requirements of 3.6 or 3.7. The average thickness of the insulation shall be not less than that given in Table 7.10-2, and the minimum thickness at any point shall be not less than 90 percent of this value.

Table 7.10-1
Nonjacketed Cable

Circuit Voltage, Volts*	Conductor Size, AWG	Insulation Thickness†		Test Voltage, kV		DC Spark Test Voltage, kV
		mils	mm	AC	DC	
1000 or less	12–4	60	1.52	5.0	15.0	21.0
1001–2000	8–4	75	1.91	7.5	22.5	26.5

* The highest circuit voltage at each step represents the maximum operating voltage recommended for the thickness of insulation.

† If protectors are employed, the thickness shall be determined by the full-load voltage. If the circuit is to be operated without protectors, the thickness shall be determined by the open-circuit voltage.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

7.10.4 Jacket

For jacketed cables, a jacket that meets the requirements of 4.4.3 neoprene, 4.4.5 polyvinyl chloride, 4.4.7 thermoplastic chlorinated polyethylene, 4.4.8 nitrile butadiene/polyvinyl chloride, 4.4.10 chlorosulfonated polyethylene, or 4.4.11 cross-linked chlorinated polyethylene shall be applied over the insulation. The average thickness of the jacket shall be not less than that given in Table 7.10-2, and the minimum thickness shall be not less than 80 percent of this value.

7.10.5 Tests

The cable shall be tested in accordance with Part 6 and shall meet the requirements specified with Part 6 and shall meet the requirements specified in 7.10, except as otherwise specified in 7.10.5.1 through 7.10.5.3.

7.10.5.1 Voltage Tests

(See 6.27.) The completed cable shall be tested at the test voltages specified in Table 7.10-1 or 7.10-2 in accordance with the following:

2000 volts or less—6.27.2 or 6.27.3 or 6.27.4
2001 to 5000 volts—6.27.2 or 6.27.3

7.10.5.2 Insulation Resistance

(See 6.28.) The completed cable shall have an insulation resistance not less than that corresponding to the following at 15.6°C (60°F).

Circuit Voltage, Volts	Insulation Resistance Constant	
	Nonjacketed	Jacketed
0–2000	10000	6000
2001–5000	...	12000

7.10.5.3 Tests for Discharge Resistance

These tests shall be made on cable rated 2001 volts and higher; and the samples shall be taken in accordance with 6.23.1.

7.10.5.3.1 Surface Resistivity

The surface resistivity shall be measured in accordance with 6.23.2 and shall be not less than 20000 megohms.

7.10.5.3.2 U-Bend Discharge

The sample shall be tested in accordance with 6.23.3 with an ac potential of 13 kV. There shall be no voltage breakdown or surface cracking.

Table 7.10-2
Jacketed Cable

Circuit Voltage, Volts*	Conductor Size, AWG	Insulation Thickness**		Jacket Thickness		Test Voltage, kV		DC Spark Test Voltage, kV
		mils	mm	mils	mm	AC	DC	
0–1000	12–4	45	1.14	30	0.76	5.0	15.0	16.0
1001–2000	8–4	60	1.52	30	0.76	7.5	22.5	22.5
2001–5000	8–6	60	1.52	30	0.76	13.0	35.0	...
	4	90	2.29	45	1.14	13.0	35.0	...

The following tabulation of series lighting transformer ratings is representative of those in current use†:

Rating, kV	6.6 Ampere Secondary		20 Ampere Secondary	
	Full-load Voltage, Volts, With Protectors	Open-circuit Voltage, Volts, Without Protectors	Full-load Voltage, Volts, With Protectors	Open-circuit Voltage, Volts, Without Protectors
10	1515	2090	500	690
15	2272	3090	750	1020
20	3030	4115	1000	1360
25	3787	5110	1250	1685
30	4545	6130	1500	2020
40	6060	8180	2000	2700

* The highest circuit voltage at each step represents the maximum operating voltage recommended for the thickness of insulation.

** If protectors are employed, the thickness shall be determined by the full-load voltage. If the circuit is to be operated without protectors, the thickness shall be determined by the open-circuit voltage.

† This paragraph is approved as Authorized Engineering Information.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

Part 8*
APPENDICES

APPENDIX A
ABBREVIATIONS AND SYMBOLS

AC—alternating current
AWG—American wire gauge
BWG—Birmingham wire gauge
C—Celsius (centigrade)
DC—direct current
F—Fahrenheit
g/m—grams per meter
Hz—hertz (electrical frequency in cycles per second)
kcmil—thousands of circular mils (formerly MCM)
kg—kilogram(s)
km —kilometer(s)
kN/m—kilonewtons per meter
kV—kilovolt(s)
MPa—megapascals
mm—millimeter(s)
psi—pounds per square inch
%—percent
±—plus or minus

*Part 8 is approved by NEMA as Authorized Engineering Information.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

APPENDIX B
REPRESENTATIVE TENSILE STRENGTH AND ELONGATION OF NONMAGNETIC METALS

Metal	Tensile Strength		Elongation 2-inch (50.8) Length, Percent
	psi	MPa	
Aluminum	13000–45000	90–310	15–45
Ambrac	50000–70000	345–482	20–40
Low Brass	40000–50000	276–345	40–50
Commercial Bronze	35000–42000	241–289	40
Copper	35000–50000	241–345	1–35
Monel	75000	517	45
Stainless	82000–90000	565–620	50
Zinc	20000	138	60

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

APPENDIX C
DEFINITIONS FOR MAXIMUM TEMPERATURE OF CONDUCTORS IN INSULATED WIRE AND CABLE

C1.1 MAXIMUM CONDUCTOR TEMPERATURE – OPERATING

The highest conductor temperature attained by any part of the cable line under operating current load.

C1.2 MAXIMUM CONDUCTOR TEMPERATURE – EMERGENCY OVERLOAD

The highest conductor temperature attained by any part of the cable line during emergency overload of specified time, magnitude, and frequency of application.

C1.3 MAXIMUM CONDUCTOR TEMPERATURE – SHORT CIRCUIT

The highest conductor temperature attained by any part of the cable line during a short circuit of specified time and magnitude.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS

Not for Resale

APPENDIX D
EMERGENCY OVERLOADS

Operations at the emergency overload temperature of 130°C for insulations rated 90°C continuous and 140°C for insulations rated 105°C continuous shall not exceed 100 hours in any twelve consecutive months nor more than 500 hours during the lifetime of the cable.

Lower temperatures for emergency overload conditions may be required because of the type of material used in the cable, joints, and terminations or because of cable environmental conditions.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

Appendix E
REFERENCED PUBLICATIONS AND STANDARDS

E1.1 ICEA PUBLICATIONS

T-24-380, rev. 12/80	*Guide for Partial-Discharge Test Procedure**
P-46-426/IEEE #S-135 (SH007096)	Power Cable Ampacities‡
P-53-426, 2nd Ed./NEMA WC 50-1976	*Ampacities, Including Effect of Shield Losses for Single-Conductor Solid-Dielectric Power Cable, 15 kV through 69 kV*†

E2 ASTM STANDARDS**

E2.1.1 ASTM Standards to which reference is made in this standard, but not in all of the other three: ICEA S-19-81, WC 3; S-61-402, WC 5; and S-66-524, WC 7.

B 233-85	*Aluminum-Alloy 1350 Drawing Stock for Electrical Purposes, Specifications for*
B 246-88	*Tinned Hard-Drawn and Medium-Hard Drawn Copper Wire for Electrical Purposes, Specifications for*
B 557-84	*Tension Testing Wrought and Cast Aluminum- and Magnesium-Alloy Products*
D 1248-84	*Polyethylene Plastics Molding and Extrusion Materials, Specification for*
B 228-88	*Concentric-Lay, Stranded Copper-Clad Steel Conductors, Specifications for*
B 416-88	*Concentric-Lay-Stranded Aluminum-Clad Steel Conductors, Specification for*
B 549-88	*Concentric-Lay-Stranded Aluminum Conductors, Aluminum-Clad Steel Reinforced (ACSR/AW), Specification for*

E2.1.2 ASTM Standards to which reference is made in each of the following four standards: ICEA S-19-81, WC 3; S-61-402, WC 5, S-66-524, WC 7; and S-68-516, WC 8.

A 90-81 (R 1987)	*Weight of Coating on Zinc Coating (Galvanized) Iron or Steel Articles, Test Method for*
B 1-85	*Hard-Drawn Copper Wire, Specification for*
B 2-88	*Medium-Hard Drawn Copper Wire, Specification for*
B 3-74 (R 1980, 1985)	*Soft or Annealed Copper Wire, Specification for*
B 5-83	*Tough-Pitch Electrolytic Copper Refinery Shapes, Specification for*
B 8-86	*Concentric-Lay Stranded Copper Conductors, Hard, Medium-Hard, or Soft, Specification for*
B 29-79 (R 1984)	*Pig Lead. Specification for*
B 33-81 (R 1985)	*Tinned Soft or Annealed Copper Wire for Electrical Purposes, Specification for*

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS

Not for Resale

B 172-71 (R 1980, 1985)	*Rope-Lay-Stranded Copper Conductors Having Bunch-Stranded Members, for Electrical Conductors, Specification for*
B 173-71 (R 1980, 1985)	*Standard Specification for Rope-Lay-Stranded Copper Conductors Having Concentric-Stranded Members, for Electrical Conductors*
B 174-71 (R 1980, 1985)	*Standard Specification for Bunch-Stranded Copper Conductors for Electrical Conductors*
B 189-81 (R 1985)	*Standard Specification for Lead-Coated and Lead-Alloy-Coated Soft Copper Wire for Electrical Purposes*
B 193-87	*Standard Test Method for Resistivity of Electrical Conductor Materials*
B 229-85	*Standard Specification for Concentric-Lay-Stranded Copper and Copper-Clad Steel Composite Conductors*
B 230-85	*Standard Specification for Aluminum-Alloy 1350-H19 Wire, for Electrical Purposes*
B 231-85	*Standard Specification for Concentric Lay-Stranded Aluminum Alloy 1350 Conductors*
B 243-88	*Cross-Sectional Area of Stranded Conductors, Determination of*
B 399-86	*Concentric-Lay-Stranded Aluminum-Alloy 6201-T81 Conductors*
B 400-86	*Compact-Round Concentric-Lay-Stranded Aluminum 1350 Conductors*
B 496-85	*Compact-Round Concentric-Lay-Stranded Copper Conductors*
B 609-81 (R 1985)	*Aluminum 1350 Round Wire, Annealed and Intermediate Tempers, for Electrical Purposes*
D 257-78 (R 1983)	*Standard Test Method for DC Resistance or Conductance of Insulating Materials*
D 412-87	*Standard Test Method for Rubber Properties in Tension*
D 471-79	*Standard Test Method for Rubber Property—Effect of Liquids*
D 746-79 (R 1987)	*Standard Test Method for Brittleness Temperature of Plastics and Elastomers by Impact*
D 1693-70 (R 1980, 1988)	*Standard Test Method for Environmental Stress-Cracking of Ethylene Plastics*
D 3349-86	*Standard Test Method for Absorption Coefficient of Carbon Black Pigmented Ethylene Plastic Film*
E 8-88	*Standard Methods of Tension Testing of Metallic Materials*

* Copies may be obtained from the Insulated Cable Engineers Association, Inc., PO Box 440, South Yarmouth, MA 02664 USA

† Copies may be obtained from National Electrical Manufacturers Association, 1300 North 17th Street, Suite 1847, Rosslyn, VA 22209 USA.

‡ Copies may be obtained from IEEE Service Center, 445 Hoes Lane, Piscataway, NJ 08854, USA.

** Copies may be obtained from the American Society for Testing and Materials (ASTM), 1916 Race Street, Philadelphia, PA 19103 USA

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS

Not for Resale

APPENDIX F
AMPACITIES FOR TWO-CONDUCTOR CONCENTRIC-NEUTRAL SINGLE-PHASE PRIMARY UNDERGROUND RESIDENTIAL DISTRIBUTION CABLES (SEE PART 7)

Conductor Size, AWG or kcmil	Copper				Aluminum			
	Direct Buried*	In Buried Duct*	In Air†	In Duct in Air†	Direct Buried*	In Buried Duct*	In Air†	In Duct in Air†
Cables Rated 5 kV 90°C								
4	169	111	114	97	132	88	90	76
3	193	128	132	111	...	...	...	...
2	219	144	152	126	174	115	120	100
1	249	165	174	144	199	132	139	116
1/0	284	188	200	163	226	150	160	131
2/0	324	217	233	189	256	172	186	149
3/0	368	247	268	215	291	195	211	170
4/0	425	288	316	250	335	226	247	197
250	...	...	...	...	370	252	278	219
300	...	...	...	...	418	287	319	250
Cables Rated 15 kV 90°C								
4	162	116	120	100	128	91	95	79
3	186	132	138	114	...	...	...	...
2	210	150	158	131	168	119	125	103
1	240	171	181	148	193	137	145	119
1/0	273	194	208	169	218	155	166	135
2/0	313	224	240	196	248	177	190	154
3/0	358	255	278	222	284	201	218	176
4/0	410	293	324	257	324	230	253	201
250	...	...	...	...	360	257	285	225
300	...	...	...	...	403	291	324	254

*Ambient temperature of 20°C; 100 percent load factor; thermal resistivity RHO-90

The multiplying correction factors for load factors of 75 and 50 percent shall be:

	Correction Factors			
	75 Percent Load Factor		50 Percent Load Factor	
Rating of Cable, kV	Cable Only	In Duct	Cable Only	In Duct
5	1.09	1.04	1.16	1.07
15	1.08	1.04	1.16	1.07

Continuous loading at maximum rating may result in moisture migration away from cables and increased thermal resistivity. See **Power Cable Ampacities,** ICEA Publication No. P-46-426 (IEEE Publication No. S-135), Section 5, Page XIII.

†Ambient temperature of 40°C; 30 to 100 percent load factor.

Appendix F-1
AMPACITIES FOR THREE-PHASE UNDERGROUND DISTRIBUTION CABLES

For ampacities see the ICEA-NEMA Standards Publication *Ampacities Including Effect of Shield Losses for Single-Conductor Solid-Dielectric Power Cable 15 kV through 69 kV,* ICEA P-53-426, NEMA WC 50-1976 (R 1982,1988).

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

APPENDIX G
SHIELDING

G1.1 DEFINITION OF SHIELDING

Shielding of an electric power cable is the practice of confining the dielectric field of the cable to the insulation of the conductor or conductors. It is accomplished by means of a conductor stress control layer and an insulation shield.

G2.1 FUNCTIONS OF SHIELDING

G2.1.1 A conductor stress control layer is employed to preclude excessive voltage stress on voids between conductor and insulation. To be effective, it must adhere to or remain in intimate contact with the insulation under all conditions.

G2.1.2 An insulation shield has a number of functions:

1. To confine to dielectric field within the cable.
2. To obtain symmetrical radial distribution of voltage stress within the dielectric, thereby minimizing the possibility of surface discharges by precluding excessive tangential and longitudinal stresses.
3. To protect cable connected to overhead lines or otherwise subject to induced potentials.
4. To limit radio interference.
5. To reduce the hazard of shock. This advantage is obtained only if the shield is grounded. If not grounded, the hazard of shock may be increased.

G3.1 USE OF INSULATION SHIELDING

G3.1.1 The use of shielding involves consideration of installation and operating conditions. Definite rules cannot be established on a practical basis for all cases, but the following features should be considered as a working basis for the use of shielding.

G3.1.2 Where there is no metallic covering or shield over the insulation, the electric field will be partly in the insulation and partly in whatever lies between the insulation and ground. The external field, if sufficiently intense in air, will generate surface discharge and convert atmospheric oxygen into ozone, which may be destructive to insulations and to protective jackets. If the surface of the cable is separated from ground by a thin layer of air and the air gap is subjected to a voltage stress that exceeds the dielectric strength of air, a discharge will occur, causing ozone formation.

G3.1.3 The ground may be either a metallic conduit, a damp nonmetallic conduit, or a metallic binding tape or rings on an aerial cable, a loose metallic sheath, etc. Likewise, damage to nonshielded cable may result when the surface of the cable is moist or covered with soot, soapy grease or other conducting film and the external field is partly confined by such conducting film so that the charging current is carried by the film to some spot where it can discharge to ground. The resultant intensity of discharge may be sufficient to cause burning of the insulation or jacket.

G3.1.4 Where nonshielded cables are used in underground ducts containing several circuits that must be worked on independently, the external field, if sufficiently intense, can cause shocks to those who handle or contact energized cable. In cases of this kind, it may be advisable to use shielded cable. Shielding used to reduce hazards of shock should have a resistance low enough to operate protective equipment in case of fault. In some cases, the efficiency of protective equipment may require proper size ground wires as a supplement to shielding. The same considerations apply to exposed installations where cables may be handled by personnel who may not be acquainted with the hazards involved. (This paragraph is approved by NEMA as Authorized Engineering Information.)

G4.1 GROUNDING OF THE INSULATION SHIELD

G4.1.1 The insulation shield must be grounded at least at one end and preferably at two or more locations. It is recommended that the shield be grounded at cable terminations and at splices and taps. Stress cones should be made at all shield terminations.

G4.1.2 The shield should operate at or near ground potential at all times. Frequent grounding of shields reduces the possibility of open sections on nonmetallic covered cable. Multiple grounding of shields is desirable in order to improve the reliability and safety of the circuit. All grounding connections should be made to the shield in such a way as to provide a permanent low resistance bond. Shielding that does not have adequate ground connection due to discontinuity of the shield or to improper termination may be more dangerous than nonshielded nonmetallic cable and hazardous to life.

G5.1 SHIELD MATERIALS

G5.1.1 Two distinct types of materials are employed in constructing cable shields.

G5.1.1.1 Nonmetallic shields may consist of a con-

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

ducting tape or a layer of conducting compound. The tape may be conducting compound, fibrous tape faced, or filled with conducting compound or conducting fibrous tape.

G5.1.1.2 Metallic shields should be nonmagnetic and may consist of tape, braid, concentric serving of wires, or a sheath. (This paragraph is approved by NEMA as Authorized Engineering Information.)

G6.1 SPLICES AND TERMINATIONS

G6.1.1 To prevent excessive leakage current and flashover, metallic and nonmetallic insulation shields, including any conducting residue on the insulation surface, must be removed completely at splices and terminations.

G6.1.2 An outer extruded insulation shield shall be removable without damaging or imparting conductivity to the underlying insulation. This may be accomplished by the aid of heat (air or flame) or by the use of a suitable solvent.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS

Not for Resale

NEMA WC*8 88 ■ 6470247 0501467 270 ■

Appendix H ■
RECOMMENDED BENDING RADII FOR CABLES

H1.1 SCOPE

This appendix contains the minimum values for the radii to which insulated cables may be bent for permanent training during installation. These limits do not apply to conduit bends, sheaves or other curved surfaces around which the cable may be pulled under tension while being installed. In all cases the minimum radii specified refers to the inner surface of the cable and not to the axis of the cable.

H2.1 POWER CABLES WITHOUT METALLIC SHEATH, SHIELDING OR ARMOR

The minimum bending radii for both single-and multiple-conductor cable without metallic sheath and without metallic shielding or armor are shown in Table H-1.

H3.1 POWER CABLES WITH METALLIC SHIELDING SHEATHS OR ARMOR

H3.1.1 Interlocked Armored and Metallic Sheathed Cables

The minimum bending radius for interlocked armored cables smooth or corrugated aluminum sheath or lead sheath shall be in accordance with Table H-2.

H3.1.2 Flat Tape Armored or Wire Armored Cables

The minimum bending radius for all flat tape armored and all wire armored cables is twelve times the overall diameter of cable.

H3.1.3 Shielded Cables, Without Armor

H3.1.3.1 Tape Shielded Cables

The minimum bending radius for tape shielded cables given below applies to helically applied flat or corrugated tape or longitudinally applied corrugated tape shielded cables.

The minimum bending radius for a single conductor cable is twelve times the overall diameter.

For multiple-conductor or multiplexed single conductor cables having individually taped shielded conductors, the minimum bending radius is twelve times the diameter of the individual conductors or seven times the overall diameter, whichever is greater.

For multiple-conductor cables having an overall tape shield over the assembly, the minimum bending radius is twelve times the overall diameter of the cable.

H3.1.3.2 Wire Shielded Cables

The minimum bending radius for a single conductor cable is eight times the overall diameter.

For multiple-conductor or multiplexed single conductor cables having wire shielded individual conductors, the minimum bending radius is eight times the diameter of the individual conductors or five times the overall diameter, whichever is greater.

For multiple-conductor cables having a wire shield over the assembly, the minimum bending radius is eight times the overall diameter of the cable.

H4.1 DRUM DIAMETERS OF REELS

See NEMA Pub. No. WC26-1984,* *Wire and Cable Packaging*, which is quoted in Table H-3.

Table H-1
MINIMUM BENDING RADII FOR POWER CABLE
SINGLE & MULTIPLE CONDUCTOR CABLES
WITHOUT METALLIC SHEATH, METALLIC SHIELDING OR ARMOR

Thickness of Conductor Insulation		Overall Diameter of Cable					
		inches	mm	inches	mm	inches	mm
		1.000 and less	25.4 and less	1.001–2.000	25.4–50.8	2.001 and more	50.8 and more
inches	mm	Minimum Bending Radius as a Multiple of Cable Diameter					
0.169 and less	4.31 and less	4		5		6	
0.170–0.310	4.32–7.87	5		6		7	
0.311 and over	7.88 and over	...		7		8	

* Editorially revised on July 22, 1987.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

Table H-2 ■
MINIMUM RADII FOR POWER CABLE
SINGLE & MULTIPLE CONDUCTOR CABLES WITH INTERLOCKED ARMOR, SMOOTH OR CORRUGATED ALUMINUM SHEATH OR LEAD SHEATH

	Overall Diameter of Cable					
	inches	mm	inches	mm	inches	mm
	0.75 & less	190 & less	0.76 to 1.50	191 to 381	1.51 & larger	382 & larger
	Minimum Bending Radius as a Multiple of Cable Diameter					
Smooth Aluminum Sheath						
Single Conductor Nonshielded, Multiple Conductor or Multiplexed, with Individually Shielded Conductors	10		12		15	
Single Conductor Shielded	12		12		15	
Multiple Conductor or Multiplexed, with Overall Shield	12		12		15	
Interlocked Armor or Corrugated Aluminum Sheath						
Nonshielded	7		7		7	
Multiple Conductor with Individually Shielded Conductor	12/7*		12/7*		12/7*	
Multiple Conductor with Overall Shield	12		12		12	
Lead Sheath	12		12		12	

*12 x individual shielded conductor diameter, or 7 x overall cable diameter, whichever is the greater.

■ Table added 1-30-1991.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

Table H-3
EXCERPT FROM NEMA STANDARDS PUBLICATION WC 26-1984, *WIRE AND CABLE PACKAGING* *

Type of Cable	Minimum Drum Diameter as a Multiple of Outside Diameter† of Cable
A. Single- and multiple-conductor nonmetallic-covered cable	
1. Nonshielded and wire shielded, including cables with concentric wires	
a. 0–2000 Volts	10
b. More than 2000 Volts	
1. Nonjacked with concentric wires	14
2. All others	12
2. Tape Shielded	14
B. Single- and multiple-conductor metallic-covered cable	
1. Tubular metallic sheathed	
a. Lead	14
b. Aluminum	
1. Outside diameter—1.750" and less	25
2. Outside diameter—1.751" and larger	30
2. Wire armored	16
3. Flat tape armored	16
4. Corrugated metallic sheathed	14
5. Interlocked armor	14
C. Multiple single conductors cabled together without common covering, including self-supporting cables—The circumscribing overall diameter shall be multiplied by the factor given in item A or B and then by the reduction factor of 0.75.	
D. Combinations—For combinations of the types described in items A, B, and C, the highest factor for any component type shall be used.	
E. Single- and multiple-conductor cable in coilable nonmetallic duct	
Outside diameter of duct, inches— 0.0–0.5026	26
0.51–1.0024	24
1.01–1.2522	22
1.26–1.5021	21
More than1.5021	20

†Outside Diameter—

1. When metallic-sheathed cables are covered only by a thermosetting or thermoplastic jacket, the "outside diameter" is the diameter over the metallic sheath itself. In all other cases, the outside diameter is the diameter outside of all the material on the cable in the state in which it is to be wound upon the reel.

2. For "flat-twin" cables (where the cable is placed upon the reel with its flat side against the drum), the minor outside diameter shall be multiplied by the appropriate factor to determine the minimum drum diameter.

3. The multiplying factors given for item E refer to the outside diameter of the duct.

* Editorially revised on 7-22-1987.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

Appendix I
AMPACITIES FOR THREE-CONDUCTOR MINE POWER CABLES

2001 TO 15000 VOLTS
COPPER AND ALUMINUM

Conductor Size, AWG or kcmil		Ampacities*			
		2001 to 8000 Volts		8001 to 15000 Volts	
Copper	Aluminum	Copper	Aluminum	Copper	Aluminum
6	4	93	95	...	...
4	2	122	124	...	...
2	1/0	159	165	164	168
1	2/0	184	189	187	192
1/0	3/0	211	218	215	221
2/0	4/0	243	251	246	254
3/0	250	279	278	283	281
4/0	350	321	342	325	344
250	400	355	360	359	367
300	450	398	395	401	393
350	500	435	425	438	424
400	...	470	...	473	...
450	...	502	...	504	...
500	...	536	...	536	...

*Ampacities are based on an ambient temperature of 40°C and a conductor temperature of 90°C taken from **Power Cable Ampacities**, ICEA Publication No. P-46-426 (IEEE Publication No. S-135), Vol. for Copper Conductors and Vol.2 for Aluminum Conductors, page 309.

Correction factors for ampacities at various ambient temperatures are as follows:

Ambient Temperature, Degrees C	Correction Factors
10	1.26
20	1.18
30	1.10
40	1.00
50	0.90

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS

Not for Resale

Appendix J
AMPACITIES AND VOLTAGE RATINGS OF PORTABLE CABLES

Deleted in its entirety.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

Deleted in its entirety.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

Appendix K

Deleted in its entirety.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS

Not for Resale

APPENDIX L
ADDITIONAL CONDUCTOR INFORMATION

Table L-1
Solid Aluminum and Copper Conductors

Conductor Size, AWG or kcmil	Approximate Weight			
	Aluminum		Copper	
	Pounds per 1000 Feet	g/m	Pounds per 1000 Feet	g/m
22	...	...	1.94	2.88
20	...	...	3.10	4.61
19	...	...	3.90	5.81
18	...	...	4.92	7.32
17	...	...	6.21	9.24
16	...	...	7.81	11.6
15	...	...	9.87	14.7
14	...	...	12.4	18.5
13	...	...	15.7	23.4
12	6.01	8.94	19.8	29.4
11	7.57	11.3	24.9	37.1
10	9.56	14.22	31.43	46.77
9	12.04	17.92	39.62	58.95
8	15.20	22.62	49.98	74.38
7	19.16	28.52	63.03	93.80
6	24.15	35.94	79.44	118.2
5	30.45	45.32	100.2	149.0
4	38.41	57.17	126.3	188.0
3	48.43	72.08	159.3	237.1
2	61.07	90.89	200.9	298.9
1	77.03	114.6	253.3	377.0
1/0	97.15	144.6	319.5	475.5
2/0	122.5	182.3	402.8	599.5
3/0	154.4	229.8	507.8	755.8
4/0	194.7	289.8	640.5	953.2
250	230.1	342.4	...	...
300	276.1	410.9	...	...
350	322.1	479.4	...	...
400	368.2	547.9	...	...
450	414.4	616.3	...	...
500	460.2	648.8	...	...

Authorized Engineering Information 7-14-1982.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS

Not for Resale

WC 8-88 6470247 0008464 6

Table L-2
Concentric Stranded Class B Aluminum and Copper Conductors

Conductor Size, AWG or kcmil	Number of Strands	Approximate Diameter of Each Strand		Approximate Outside Diameter		Approximate Weight			
						Aluminum		Copper	
		mils	mm	inches	mm	Pounds per 1000 ft.	g/m	Pounds per 1000 ft.	g/m
22	7	9.6	0.244	0.029	0.737	...	...	1.975	2.941
20	7	12.1	0.307	0.036	0.914	...	...	3.154	4.705
19	7	13.6	0.345	0.041	1.04	...	...	3.974	5.922
18	7	15.2	0.386	0.046	1.17	...	...	5.015	7.462
17	7	17.2	0.437	0.052	1.32	...	...	6.324	9.429
16	7	19.2	0.488	0.058	1.47	...	...	7.974	11.86
15	7	21.6	0.549	...	...	...	...	9.959	14.98
14	7	24.2	0.615	...	...	...	...	12.68	18.88
13	7	27.2	0.691	...	...	...	...	16.01	23.82
12	7	30.5	0.775	...	...	6.13	9.12	20.16	30.00
11	7	34.3	0.871	...	...	7.72	11.5	25.49	37.80
10	7	38.5	0.978	...	...	9.75	14.5	32.06	47.71
9	7	43.2	1.10	...	...	12.3	18.3	40.42	60.14
8	7	48.6	1.23	...	...	15.5	23.1	51.0	75.9
7	7	54.5	1.39	...	...	19.5	29.1	64.2	95.7
6	7	61.2	1.56	...	...	24.6	36.7	80.9	121
5	7	68.8	1.75	...	...	31.1	46.2	102	152
4	7	77.2	1.96	...	...	39.2	58.3	129	192
3	7	86.7	2.20	...	...	49.4	73.5	162	242
2	7	97.4	2.47	...	...	62.3	92.7	205	305
1	19	66.4	1.69	...	...	78.6	117	259	385
1/0	19	74.5	1.89	...	...	99.1	147	326	485
2/0	19	83.7	2.13	...	...	125	186	411	611
3/0	19	94.0	2.39	...	...	157	234	518	771
4/0	19	105.5	2.68	...	...	199	296	653	972
250	37	82.2	2.09	...	...	235	349	772	1150
300	37	90.0	2.29	...	...	282	419	925	1380
350	37	97.3	2.47	...	...	329	489	1080	1610
400	37	104.0	2.64	...	...	376	559	1236	1840
450	37	110.3	2.80	...	...	422	629	1390	2070
500	37	116.2	2.95	...	...	469	699	1542	2300
550	61	95.0	2.41	...	...	517	768	1700	2530
600	61	99.2	2.52	...	...	563	838	1850	2760
650	61	103.2	2.62	...	...	610	908	2006	2990
700	61	107.1	2.72	...	...	657	978	2160	3220
750	61	110.9	2.82	...	...	704	1050	2316	3450
800	61	114.5	2.91	...	...	751	1120	2469	3680
900	61	121.5	3.09	...	...	845	1260	2780	4140
1000	61	128.0	3.25	...	...	939	1400	3086	4590
1100	91	109.9	2.79	...	...	1032	1540	3394	5050
1200	91	114.8	2.92	...	...	1126	1680	3703	5510
1250	91	117.2	2.98	...	...	1173	1750	3859	5740
1300	91	119.5	3.04	...	...	1220	1820	4012	5970
1400	91	124.0	3.15	...	...	1313	1960	4320	6430
1500	91	128.4	3.26	...	...	1408	2100	4632	6890
1600	127	112.2	2.85	...	...	1501	2240	4936	7350
1700	127	115.7	2.94	...	...	1596	2370	5249	7810
1750	127	117.4	2.98	...	...	1643	2440	5403	8040
1800	127	119.1	3.02	...	...	1691	2510	5562	8270
1900	127	122.3	3.11	...	...	1783	2650	5865	8730
2000	127	125.5	3.19	...	...	1877	2790	6176	9190

Authorized Engineering Information 7-14-1982.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS

Not for Resale

Table L-3
Concentric Stranded Class C and D Aluminum and Copper Conductors

Conductor Size, AWG or kcmil	Class C			Class D		
	Number of Strands	Approximate Diameter of Each Strand		Number of Strands	Approximate Diameter of Each Strand	
		mils	mm		mils	mm
22	...	...	...	...	...	...
20	...	...	...	...	...	...
19	...	...	...	...	...	...
18	...	...	...	...	...	...
17	...	...	...	...	...	...
16	...	...	...	...	...	...
15	...	...	...	...	...	...
14	19	14.7	0.373	37	10.5	0.267
13	19	16.5	0.419	37	11.8	0.300
12	19	18.5	0.470	37	13.3	0.338
11	19	20.8	0.528	37	14.9	0.378
10	19	23.4	0.594	37	16.7	0.424
9	19	26.2	0.665	37	18.8	0.478
8	19	29.5	0.749	37	21.1	0.536
7	19	33.1	0.841	37	23.7	0.602
6	19	37.2	0.945	37	26.6	0.676
5	19	41.7	1.06	37	29.9	0.759
4	19	46.9	1.19	37	33.6	0.853
3	19	52.6	1.34	37	37.7	0.958
2	19	59.1	1.50	37	42.4	1.08
1	37	47.6	1.21	61	37.0	0.940
1/0	37	53.4	1.36	61	41.6	1.06
2/0	37	60.0	1.52	61	46.7	1.19
3/0	37	67.3	1.71	61	52.4	1.33
4/0	37	75.6	1.92	61	58.9	1.50
250	61	64.0	1.63	91	52.3	1.33
300	61	70.1	1.78	91	57.4	1.46
350	61	75.7	1.92	91	62.0	1.57
400	61	81.0	2.06	91	66.3	1.68
450	61	85.9	2.18	91	70.3	1.79
500	61	90.5	2.30	91	74.1	1.88
550	91	77.7	1.97	127	65.8	1.67
600	91	81.2	2.06	127	68.7	1.74
650	91	84.5	2.15	127	71.5	1.82
700	91	87.7	2.23	127	74.2	1.88
750	91	90.8	2.31	127	76.8	1.95
800	91	93.8	2.38	127	79.4	2.02
900	91	99.4	2.53	127	84.2	2.14
1000	91	104.8	2.66	127	88.7	2.25
1100	127	93.1	2.36	169	80.7	2.05
1200	127	97.2	2.47	169	84.3	2.14
1250	127	99.2	2.52	169	86.0	2.18
1300	127	101.2	2.57	169	87.7	2.23
1400	127	105.0	2.67	169	91.0	2.31
1500	127	108.7	2.76	169	94.2	2.39
1600	169	97.3	2.47	217	85.9	2.18
1700	169	100.3	2.55	217	88.5	2.25
1750	169	101.8	2.59	217	89.8	2.28
1800	169	103.2	2.62	217	91.1	2.31
1900	169	106.0	2.69	217	93.6	2.38
2000	169	108.8	2.76	217	96.0	2.44

NOTE: The weights of Class C and Class D conductors are the same as for the equivalent Class B conductor (see Table N-2).

Authorized Engineering Information 7-14-1982.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS

Not for Resale

Table L-4
Rope-Lay Aluminum and Copper Conductors, Class G

Conductor Size, AWG or kcmil	Number of Strands	Suggested Construction	Approximate Diameter of Each Strand		Approximate Outside Diameter		Approximate Weight			
							Aluminum		Copper	
			mils	mm	inches	mm	Pounds per 1000 ft.	g/m	Pounds per 1000 ft.	g/m
14	49	7×7	9.2	0.23	0.83	2.11	...	...	12.8	19.1
12	49	7×7	11.6	0.29	0.104	2.64	...	...	20.3	30.3
10	49	7×7	14.6	0.37	0.131	3.33	...	...	32.3	48.2
9	49	7×7	16.4	0.42	0.148	3.76	...	...	40.8	60.7
8	49	7×7	18.4	0.47	0.166	4.22	...	...	51	76.6
7	49	7×7	20.6	0.52	0.185	4.70	20	29.4	65	96.6
6	49	7×7	23.1	0.59	0.208	5.28	25	37.0	82	122
5	49	7×7	26.0	0.66	0.234	5.94	31	46.7	103	154
4	49	7×7	29.2	0.74	0.263	6.68	40	58.9	130	194
3	49	7×7	32.8	0.83	0.295	7.49	50	74.2	164	244
2	49	7×7	36.8	0.93	0.331	8.41	63	93.6	207	308
1	133	19×7	25.1	0.64	0.377	9.58	80	119	264	392
1/0	133	19×7	28.2	0.72	0.423	10.7	102	150	334	495
2/0	133	19×7	31.6	0.80	0.474	12.0	127	190	419	623
3/0	133	19×7	35.5	0.90	0.533	13.5	161	239	529	786
4/0	133	19×7	39.9	1.01	0.599	15.2	203	301	668	991
250	259	37×7	31.1	0.79	0.653	16.6	242	358	795	1175
300	259	37×7	34.0	0.86	0.714	18.1	287	429	945	1410
350	259	37×7	36.8	0.93	0.773	19.6	337	501	1110	1650
400	259	37×7	39.3	1.00	0.825	21.0	385	573	1265	1885
450	259	37×7	41.7	1.06	0.876	22.3	433	644	1425	2120
500	259	37×7	43.9	1.12	0.922	23.4	482	716	1585	2355
550	427	61×7	35.9	0.91	0.969	24.6	532	791	1750	2600
600	427	61×7	37.5	0.95	1.013	25.7	581	863	1910	2840
650	427	61×7	39.0	0.99	1.053	26.7	629	935	2070	3075
700	427	61×7	40.5	1.03	1.094	27.8	678	1005	2230	3310
750	427	61×7	41.9	1.06	1.131	28.7	725	1080	2385	3545
800	427	61×7	43.3	1.10	1.169	29.7	774	1150	2545	3785
900	427	61×7	45.9	1.17	1.239	31.5	869	1295	2860	4255
1000	427	61×7	48.4	1.23	1.307	33.2	967	1440	3180	4730
1100	427	61×7	50.8	1.29	1.372	34.8	1064	1580	3500	5205
1200	427	61×7	53.0	1.35	1.431	36.3	1158	1725	3810	5675
1250	427	61×7	54.1	1.37	1.461	37.1	1208	1800	3975	5910
1300	427	61×7	55.2	1.40	1.490	37.8	1257	1870	4135	6150
1400	427	61×7	57.3	1.46	1.547	39.3	1356	2015	4460	6620
1500	427	61×7	59.3	1.51	1.601	40.7	1452	2155	4775	7095
1600	703	37×19	47.7	1.21	1.670	42.4	1560	2325	5130	7640
1700	703	37×19	49.2	1.25	1.722	43.7	1660	2470	5460	8115
1750	703	37×19	49.9	1.27	1.747	44.4	1709	2540	5620	8355
1800	703	37×19	50.6	1.29	1.771	45.0	1756	2615	5775	8595
1900	703	37×19	52.0	1.32	1.820	46.2	1854	2760	6100	9070
2000	703	37×19	53.3	1.35	1.866	47.4	1950	2905	6415	9550

NOTE: Rope-lay aluminum Class G conductors are not recommended in sizes 8 AWG and smaller and individual aluminum wires in stranded conductors should not be smaller than 24 AWG.

Authorized Engineering Information 7-14-1982.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS

Not for Resale

Table L-5
Rope-Lay Aluminum and Copper Conductors, Class H

Conductor Size, AWG or kcmil	Number of Strands	Suggested Construction	Approximate Diameter of Each Strand		Approximate Outside Diameter		Approximate Weight			
							Aluminum		Copper	
			mils	mm	inches	mm	Pounds per 1000 ft.	g/m	Pounds per 1000 ft.	g/m
8	133	19×7	11.1	0.28	0.167	4.24	...	...	52	77.4
7	133	19×7	12.5	0.32	0.188	4.78	...	...	65	97.5
6	133	19×7	14.0	0.36	0.210	5.33	...	...	82	123
5	133	19×7	15.8	0.40	0.237	6.02	...	...	105	155
4	133	19×7	17.7	0.45	0.266	6.76	...	...	132	196
3	133	19×7	19.9	0.51	0.299	7.59	...	...	167	247
2	133	19×7	22.3	0.57	0.335	8.51	63	94.5	208	311
2	259	37×7	16.0	0.41	0.336	8.53	...	...	210	312
1	259	37×7	18.0	0.46	0.378	9.60	...	...	266	394
1/0	259	37×7	20.2	0.51	0.424	10.8	102	151	334	497
2/0	259	37×7	22.7	0.58	0.477	12.1	128	190	422	626
3/0	259	37×7	25.5	0.65	0.536	13.6	162	240	533	790
3/0	427	61×7	19.8	0.50	0.535	13.6	...	...	532	794
4/0	259	37×7	28.6	0.73	0.601	15.3	204	303	670	996
4/0	427	61×7	22.3	0.57	0.602	15.3	205	304	675	1000
250	427	61×7	24.2	0.61	0.653	16.6	242	360	795	1180
300	427	61×7	26.5	0.67	0.716	18.2	290	431	953	1420
350	427	61×7	28.6	0.73	0.772	19.6	337	503	1110	1655
400	427	61×7	30.6	0.78	0.826	21.0	386	575	1270	1890
450	427	61×7	32.5	0.83	0.878	22.3	436	647	1435	2130
500	427	61×7	34.2	0.87	0.923	23.4	483	719	1590	2365
550	703	37×19	28.0	0.71	0.980	24.9	538	798	1770	2625
600	703	37×19	29.2	0.74	1.022	26.0	584	871	1920	2865
650	703	37×19	30.4	0.77	1.064	27.0	634	944	2085	3105
700	703	37×19	31.6	0.80	1.106	28.1	686	1015	2255	3340
750	703	37×19	32.7	0.83	1.145	29.1	733	1090	2410	3580
800	703	37×19	33.7	0.86	1.180	30.0	778	1160	2560	3820
900	703	37×19	35.8	0.91	1.253	31.8	880	1305	2895	4295
1000	703	37×19	37.7	0.96	1.320	33.5	974	1450	3205	4775
1100	703	37×19	39.6	1.01	1.386	35.2	1075	1595	3535	5250
1200	703	37×19	41.3	1.05	1.446	36.7	1169	1740	3845	5730
1250	703	37×19	42.2	1.07	1.477	37.5	1221	1815	4015	5970
1300	703	37×19	43.0	1.09	1.505	38.2	1268	1885	4170	6205
1400	703	37×19	44.6	1.13	1.561	39.6	1363	2035	4485	6685
1500	703	37×19	46.2	1.17	1.617	41.1	1464	2180	4815	7160
1600	1159	61×19	37.2	0.94	1.674	42.5	1564	2325	5145	7640
1700	1159	61×19	38.3	0.97	1.724	43.8	1658	2470	5455	8115
1750	1159	61×19	38.9	0.99	1.751	44.5	1710	2540	5625	8355
1800	1159	61×19	39.4	1.00	1.773	45.0	1754	2615	5770	8595
1900	1159	61×19	40.5	1.03	1.823	46.3	1854	2760	6100	9070
2000	1159	61×19	41.5	1.05	1.868	47.4	1946	2905	6400	9550

NOTE: Individual aluminum wires in stranded conductors should not be smaller than 24 AWG.

Authorized Engineering Information 7-14-1982.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS

Not for Resale

Table L-6
Aluminum and Copper Conductors, Class I
Each Individual Strand 24 AWG, 0.0201 Inch (0.511 mm)

Conductor Size, AWG or kcmil	Suggested Construction	Approximate Number of Strands	Approximate Outside Diameter		Approximate Weight			
					Aluminum		Copper	
			inches	mm	Pounds per 1000 ft.	g/m	Pounds per 1000 ft.	g/m
10	1×26	26	0.125	3.18	...	...	32.5	48.3
9	1×33	33	0.138	3.51	...	...	41	61.3
8	1×41	41	0.156	3.96	16	23.1	51	76.1
7	1×52	52	0.185	4.70	20	29.3	65	96.5
6	7×9	63	0.207	5.26	24	36.3	80	119
5	7×12	84	0.235	5.97	32	48.3	105	159
4	7×15	105	0.263	6.68	41	60.4	134	199
3	7×19	133	0.291	7.39	51	76.5	169	252
2	7×23	161	0.319	8.10	62	92.7	205	305
1	7×30	210	0.367	9.32	81	121	167	397
1/0	19×14	266	0.441	11.2	104	155	342	508
2/0	19×18	342	0.500	12.7	133	199	439	654
3/0	19×22	418	0.549	13.9	163	243	537	799
4/0	19×28	532	0.613	15.6	208	309	683	1015
250	7×7×13	637	0.682	17.3	251	374	825	1230
300	7×7×15	735	0.737	18.7	290	431	955	1420
350	7×7×18	882	0.800	20.3	348	517	1145	1700
400	7×7×20	980	0.831	21.1	386	575	1270	1890
450	7×7×23	1127	0.894	22.7	444	661	1460	2175
500	7×7×25	1225	0.941	23.9	483	719	1590	2365
550	7×7×28	1372	0.980	24.9	541	805	1780	2645
600	7×7×30	1470	1.027	26.1	579	862	1905	2835
650	19×7×12	1596	1.152	29.3	635	945	2090	3110
700	19×7×13	1729	1.194	30.3	687	1025	2260	3365
750	19×7×14	1862	1.235	31.4	740	1100	2435	3625
800	19×7×15	1995	1.290	32.8	793	1180	2610	3885
900	19×7×17	2261	1.372	34.8	901	1340	2965	4405
1000	19×7×19	2527	1.427	36.2	1005	1495	3305	4920
1100	19×7×21	2793	1.495	38.0	1111	1655	3655	5440
1200	19×7×22	2926	1.537	39.0	1164	1730	3830	5700
1250	19×7×23	3059	1.564	39.7	1216	1810	4000	5955
1300	19×7×24	3192	1.605	40.8	1269	1890	4175	6215
1400	19×7×26	3458	1.674	42.5	1386	2045	4560	6735
1500	19×7×28	3724	1.715	43.6	1482	2205	4875	7250
1600	19×7×30	3990	1.797	45.6	1587	2360	5220	7770
1700	19×7×32	4256	1.852	47.0	1693	2520	5570	8290
1750	19×7×33	4389	1.880	47.8	1746	2600	5745	8545
1800	19×7×34	4522	1.921	48.8	1800	2675	5920	8805
1900	19×7×36	4788	1.976	50.2	1905	2835	6265	9325
2000	19×7×37	4921	2.003	50.9	1958	2915	6440	9585

NOTE: Aluminum Class I conductors are not recommended in sizes 8 AWG and smaller.

Authorized Engineering Information 7-14-1982.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS

Not for Resale

Table L-7
Copper Conductors, Class K
Each Individual Strand 30 AWG, 0.0100 Inch (0.254 mm)

Conductor Size, AWG or kcmil	Suggested Construction	Approximate Number of Strands	Approximate Outside Diameter		Approximate Weight	
			inches	mm	Pounds per 1000 ft.	g/m
20	1×10	10	0.038	0.97	3.2	4.59
18	1×16	16	0.048	1.22	5.0	7.35
16	1×26	26	0.060	1.52	8.0	11.9
14	1×41	41	0.078	1.98	12.8	18.8
12	1×65	65	0.101	2.57	20.3	29.9
10	1×104	104	0.126	3.20	32.5	47.8
9	7×19	133	0.150	3.81	42	62.3
8	7×24	168	0.157	3.99	53	78.7
7	7×30	210	0.179	4.55	66	98.4
6	7×38	266	0.210	5.33	84	125
5	7×48	336	0.235	5.97	106	157
4	7×60	420	0.272	6.91	132	197
3	19×28	532	0.304	7.72	169	252
2	19×35	665	0.338	8.59	211	315
1	19×44	836	0.397	10.1	266	395
1/0	19×56	1064	0.451	11.5	338	503
2/0	7×7×27	1323	0.470	11.9	425	632
3/0	7×7×34	1666	0.533	13.5	535	795
4/0	7×7×43	2107	0.627	15.9	676	1005
250	7×7×51	2499	0.682	17.3	802	1195
300	7×7×61	2989	0.768	19.5	960	1425
350	19×7×26	3458	0.809	20.5	1120	1665
400	19×7×30	3990	0.878	22.3	1290	1925
450	19×7×34	4522	0.933	23.7	1465	2180
500	19×7×38	5054	0.988	25.1	1635	2435
550	19×7×41	5453	1.056	26.8	1765	2630
600	19×7×45	5985	1.125	28.6	1940	2885
650	19×7×49	6517	1.166	29.6	2110	3140
700	19×7×52	6916	1.207	30.7	2240	3335
750	19×7×57	7581	1.276	32.4	2455	3655
800	19×7×60	7980	1.305	33.1	2585	3845
900	37×7×35	9065	1.323	33.6	2935	4370
1000	37×7×39	10101	1.419	36.0	3270	4870

Authorized Engineering Information 7-14-1982.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS

Not for Resale

WC 8-88 6470247 0008470 1

Table L-8
Copper Conductors, Class M
Each Individual Strand 34 AWG, 0.0063 Inch (0.160 mm)

Conductor Size, AWG or kcmil	Suggested Construction	Approximate Number of Strands	Approximate Outside Diameter		Approximate Weight	
			inches	mm	Pounds per 1000 ft.	g/m
20	1×26	26	0.038	0.97	3.2	4.74
18	1×41	41	0.048	1.22	5.0	7.48
16	1×65	65	0.060	1.52	8.0	11.9
14	1×104	104	0.078	1.98	12.8	19.0
12	7×24	168	0.101	2.57	21.0	31.2
10	7×37	259	0.126	3.20	32.5	48.2
9	7×48	336	0.146	3.71	42	62.5
8	7×60	420	0.162	4.11	53	78.1
7	19×28	532	0.196	4.98	67	100.0
6	19×35	665	0.215	5.46	84	125
5	19×44	836	0.240	6.10	105	157
4	19×56	1064	0.269	6.83	134	200
3	7×7×27	1323	0.305	7.75	169	251
2	7×7×34	1666	0.337	8.56	212	316
1	7×7×43	2107	0.376	9.55	268	399
1/0	7×7×54	2646	0.423	10.7	337	501
2/0	19×7×25	3325	0.508	12.9	427	636
3/0	19×7×32	4256	0.576	14.6	547	814
4/0	19×7×40	5320	0.645	16.4	684	1020
250	19×7×48	6384	0.713	18.1	821	1220
300	19×7×57	7581	0.768	19.5	975	1450
350	37×7×34	8806	0.825	21.0	1130	1685
400	37×7×39	10101	0.901	22.9	1300	1930
450	37×7×44	11396	0.940	23.9	1465	2180
500	37×7×49	12691	0.997	25.3	1630	2430
550	61×7×32	13664	1.035	26.3	1755	2615
600	61×7×35	14945	1.084	27.5	1920	2860
650	61×7×38	16226	1.133	28.8	2085	3105
700	61×7×41	17507	1.183	30.0	2250	3350
750	61×7×44	18788	1.207	30.7	2415	3595
800	61×7×47	20069	1.256	31.9	2580	3840
900	61×7×53	22631	1.331	33.8	2910	4330
1000	61×7×59	25193	1.404	35.7	3240	4820

Authorized Engineering Information 7-14-1982.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS

Not for Resale

WC 8-88 6470247 0008471 3

APPENDIX M
AMPACITIES FOR PREASSEMBLED AERIAL CABLES

For ampacities, see AIEE-ICEA Power Cable Ampacities, IEEE Publications No. S-135, 1962, Vol. 1 for Copper Conductors or Vol. 2 for Aluminum Conductors, pages 258 through 261.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS

Not for Resale

APPENDIX N
FLEXIBLE CORDS AND REMOTE CONTROL AND DRILL CORDS

N1.1 AMPACITIES OF FLEXIBLE CORDS

Ampacities of flexible cords are based on the number of current-carrying conductors. The ampacities shown below are based on an ambient temperature of 30°C.

Conductor Size, AWG	Number of Current-carrying Conductors in Cord		
	2	3	4
18	10	7	6
16	13	10	8
14	18	15	12
12	25	20	16
10	30	25	20

When cords are used with one or more layers wound on a reel, the ampacities shall be corrected as follows:

Number of Layers	Multiplying Correction Factors
1	0.85
2	0.65
3	0.45
4	0.35

N2.1 NATIONAL ELECTRICAL CODE TYPE DESIGNATIONS AND MAXIMUM VOLTAGE RATINGS OF MULTIPLE-CONDUCTOR FLEXIBLE CORDS

Conductor Size, AWG	Insulation Thickness		Jacket Thickness, 2,3, and 4 Conductors		NEC Type Designations*		Maximum Voltage Ratings, Volts
	mils	mm	mils	mm			
18	30	0.76	30	0.76	SJ, SJT	SJO, SJTO	300
18	30	0.76	60	1.53	S, ST	SO, STO	600
16	30	0.76	30	0.76	SJ, SJT	SJO, SJTO	300
16	30	0.76	60	1.53	S, ST	SO, STO	600
14	45	1.14	80	2.04	S, ST	SO, STO	600
14	30	0.76	30	0.76	SJ, SJT	SJO, SJTO	300
12	45	1.14	95	2.42	S, ST	SO, STO	600
10	45	1.14	95	2.42	S, ST	SO, STO	600

*S and SO designate extra hard service cords. SJ and SJO designate hard service cords. T designates a thermoplastic (polyvinyl chloride) jacket. O designates an oil-resistant jacket.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

N3.1 REMOTE CONTROL AND DRILL CORDS

Remote control and drill cords intended for use in underground mines in accordance with Schedule 2G of the U.S. Bureau of Mines comply with the constructions given in 7.4 in sizes 14 to 10 AWG, except for the jackets and number of conductors. The jackets shall be applied in two layers with a reinforcement between them and are approximately 50 mils (1.27 mm) thicker than those shown in Table 7.4-6. The cords shall comply with the flame resistance requirements of Schedule 2G. The outside diameters shall be in accordance with the following table:

Conductor Size, AWG	Number of Conductors	Outside Diameter		
		Nominal		Tolerances, Plus and Minus
		inches	mm	
14	2	0.64	16.3	0.02
	3	0.67	17.0	0.02
	4	0.71	18.0	0.02
	5	0.78	19.8	0.03
	6	0.83	21.1	0.03
	7	0.89	22.6	0.03
12	2	0.68	17.3	0.02
	3	0.72	18.3	0.03
	4	0.76	19.3	0.03
	5	0.83	21.1	0.03
	6	0.89	22.6	0.03
	7	0.98	24.9	0.03
10	2	0.73	18.5	0.03
	3	0.80	20.3	0.03
	4	0.84	21.3	0.03
	5	0.90	22.8	0.03
	6	1.00	25.4	0.03
	7	1.07	27.2	0.03

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS

Not for Resale

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 purchasers 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 two 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.

(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.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale