

Approved as an American National Standard
ANSI Approval Date: April 27, 2021

#### ANSI/NEMA WC 70/ICEA S-95-658-2021

Power Cables Rated 2000 Volts or Less for the Distribution of Electrical Energy

Prepared by:

Insulated Cable Engineers Association, Inc.

www.icea.net

Published by:

National Electrical Manufacturers Association 1300 North 17<sup>th</sup> Street, Suite 900 Rosslyn, Virginia 22209

www.nema.org

©2021 National Electrical Manufacturers 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.

©2021 Insulated Cable Engineers Association, Inc. 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.

#### **NOTICE AND DISCLAIMER**

The information in this publication was considered technically sound by the consensus of persons engaged in the development and approval of the document at the time it was developed. Consensus does not necessarily mean that there is unanimous agreement among every person participating in the development of this document.

The National Electrical Manufacturers Association (NEMA) and the Insulated Cable Engineers Association Inc. (ICEA) Standards and guideline publications, of which the document contained herein is one, are developed through a voluntary consensus Standards development process. This process brings together persons who have an interest in the topic covered by this publication. While NEMA and ICEA administers the process and establishes rules to promote fairness in the development of consensus, they do not independently test, evaluate, or verify the accuracy or completeness of any information or the soundness of any judgments contained in its Standards and guideline publications.

NEMA and ICEA disclaims liability for personal injury, property, or other damages of any nature whatsoever, whether special, indirect, consequential, or compensatory, directly or indirectly resulting from the publication, use of, application, or reliance on this document. NEMA and ICEA disclaims and makes no guaranty or warranty, expressed or implied, as to the accuracy or completeness of any information published herein, and disclaims and makes no warranty that the information in this document will fulfill any of your purposes or needs. NEMA and ICEA do not undertake to guarantee the performance of any individual manufacturer's or seller's products or services by virtue of this Standard or guide.

In publishing and making this document available, NEMA and ICEA are not undertaking to render professional or other services for or on behalf of any person or entity, nor is NEMA and ICEA undertaking to perform any duty owed by any person or entity to someone else. Anyone using this document should rely on his or her own independent judgment or, as appropriate, seek the advice of a competent professional in determining the exercise of reasonable care in any given circumstances. Information and other Standards on the topic covered by this publication may be available from other sources, which the user may wish to consult for additional views or information not covered by this publication.

NEMA and ICEA have no power, nor do they undertake to police or enforce compliance with the contents of this document. NEMA and ICEA do not certify, test, or inspect products, designs, or installations for safety or health purposes. Any certification or other statement of compliance with any health or safety-related information in this document shall not be attributable to NEMA and ICEA and is solely the responsibility of the certifier or maker of the statement.

# Contents

Sect	tion 1 C	General	1
1.1	Sco	pe	1
1.2		neral Information	
1.3	Info	ormation to Be Supplied by Purchaser	
	1.3.1	Characteristics of System on Which Cable Is to Be Used	
	1.3.2	Quantities and Description of Cable	
1.4		initions	
1.5	Abb	previations and Symbols	4
Sect	tion 2 C	Conductor	5
2.0	Ger	neral	5
2.1	Phy	sical and Electrical Properties	5
	2.1.1	Copper Conductors	
		Aluminum Conductors	
	2.1.3		
2.2		nductor Size Units	
2.3		nductor DC Resistance per Unit Length	
	2.3.1	Direct Measurement of DC Resistance	
	2.3.2	- J	
2.4		nductor Diameter	
Sect		nsulation	
3.1		terial	
3.2		ulation Compound Levels	
3.3		ulation Thicknesses	
	3.3.1	Thickness Determination	
3.4		ditional Insulation Thickness for Non-Sheathed Submarine Cables	
3.5		pairs	
3.6		ulation Compound Classes and Requirements	19 10
	3.6.1 3.6.2	Insulation Compound Classes and Characteristics  Voltage Tests	
	3.6.2 3.6.3	Insulation Resistance	
	3.6.4	Flame Tests	
		Coverings	
		<del>-</del>	
4.1		kets	
	4.1.1 4.1.2		
	4.1.2 4.1.3	Optional Requirements Separator Under Jacket	
	4.1.4	Repairs	
	4.1. <del>4</del> 4.1.5	Jacket Thickness	
	4.1.6	Irregularity Inspection of Jackets over Cable	
4.2		tallic and Associated Coverings	
	4.2.1	General	
4.3		ision I	
	4.3.1	Smooth Metallic Sheaths	
4	4.3.2	Flat Steel Tape Armor	
4	4.3.3	Interlocked Metal Tape Armor	
4	4.3.4	Continuously Corrugated Metal Armor	43
	4.3.5	Galvanized Steel Wire Armor	
	4.3.6	Bedding over Cable Cores to Be Metallic Armored	
	4.3.7	Outer Servings	
	4.3.8	Crosslinked Jackets over Metallic Coverings (Sheaths and Armors)	
	4.3.9	Thermoplastic Jackets over Metallic Coverings (Sheaths or Armors)	
4.4	Divi	ision II	50

	4.4.1 4.4.2	Borehole Cable (Suspended at One End Only)	51
	4.4.3	Shaft Cable	
	4.4.4	Vertical Riser Cable	
4.5		ision III	
_	4.5.1	Buried Land Cables	
Sec		Assembly, Fillers, Conductor Identification, Grounding Conductors, and Shielding	
5.1		sembly of Multiple-Conductor Cables	
	5.1.1	Multiple-Conductor Round Cables with an Overall Covering	
	5.1.2	Multiple-Conductor Assemblies Without Overall Covering	
- 0	5.1.3	Flat Twin Cables	
5.2		ers	
5.3		nductor Identification	
5.4 5.5		ounding Conductorselding	
5.5	5.5.1		
	5.5.2	Metal Tapes	
80		Production Tests and Test Methods	
6.1		neral	
	6.1.1	Testing and Test Frequency	
	6.1.2 6.1.3	Test Methods	
6 2		Number of Test Specimens from Samplesckness Measurements	
0.2	6.2.1	Beddings and Servings	
	6.2.2	Other Components	
6.3		mples and Specimens for Physical and Aging Tests	
0.0	6.3.1	General	
	6.3.2	Sampling	
	6.3.3	Size of Test Specimens	
	6.3.4	Specimens with Jackets	
	6.3.5	Specimen Surface Irregularities	
	6.3.6	Specimens for the Aging Tests	
	6.3.7	Calculation of Area of Test Specimens	
6.4	Agi	ng Tests	62
	6.4.1	Air Oven Aging Test	62
	6.4.2	Oil Immersion Test	62
6.5		at Shock Test	
6.6		d-Bend Test	
6.7		htness of Polyethylene Jacket to Sheath Test	
6.8	Hot	t Creep Test	63
6.9		ap Test for Nylon-Covered Insulated Conductors	
6.1		ctrical Tests on Completed Cables	
		Voltage Tests	
		Insulation Resistance	
G 1		Shield Continuity	
6.1	6.11.1	Physical and Aging Proportion and Thickness	
		Physical and Aging Properties and Thickness Other Tests	
		Conductor Resistance Test	
0-			
		Qualification Tests	
7.1		neral	
7.2		celerated Water Absorption Test, Electrical Method at 60 Hz	
7.3		ulation Resistance Test	
7.4 7.5		nlight Resistance Test	67 67
1 7	Hal	oden Comeni di Nonneialic Fiemenis	n/

7.6	noke Generation Test	
7.7 7.8	id Gas Equivalent Test	
7.6 7.9	vironmental Stress Cracking Testsorption Coefficient	
7.9 7.10	et Insulation Resistance Stability Test	
7.10 7.11	ame Testing	
7.11 7.	Type A (Single Conductor)	
	Type B (Single Conductor)	
	Tray Cable Flame Test	
7.12	pact Test	
7.13	ush Test	
Section	Constructions of Specific Types	
8.1	eassembled Aerial Cables	
8.´	Scope	
8.1	Conductors	
8.1	Insulation	
8.1	Jacket	
8.1	Assembly	
8.1	Messenger	73
8.′	Design Criteria	
Sectio	Appendices	74
Apper	A NEMA, ICEA, ASTM, and DOD Standards	74
A.1	MA Publications*	
A.2	EA Publications*	
A.3	TM Standards**	
A.4	partment of Defense Standards	
	B Definitions of Maximum Temperatures of Insulated Cable Conductors	
д <b>ърс.</b> В.1	eximum Conductor Temperature—Continuous Operation	
B.2	eximum Conductor Temperature—Emergency Overload	
B.3	aximum Conductor Temperature—Short Circuit	
	C Emergency Overloads	
• •		
	D Representative Tensile Strength and Elongation of Nonmagnetic Metals	
	E Recommended Bending Radii for Cables	
E.1	ope	
E.2	nshielded Power Cables Without Metallic Sheath or Armor	
E.3	nshielded Cables with Metallic Sheath or Armor	
E.4	um Diameters of Reels	
E.5	stallation Temperatures	
• •	F Additional Conductor Information	
Apper	G Procedure for Determining Dimensional Requirements of Jackets and Associate	
	Coverings	
G.1	cket, Bedding, Sheath, and Armor Thicknesses; Armor Wire Size; and Armor Metal Tape	
	dth	
G.	The Calculated Diameter over the Single-Conductor Core	
G.	The Calculated Diameter over the Individual Conductor Jacket	
G.	The Calculated Diameter over the Assembly of Multiple Conductors	
G.	The Calculated Diameter over a Bedding Layer	
G.	The Calculated Diameter over Flat Metal Armoring Tapes	
G.	The Calculated Diameter over an Interlocking or Corrugated Armor	92
G.	The Calculated Diameter over a Smooth Sheath	
G. G.2	The Calculated Diameter over a Steel Armor Wireample Calculation	
	·	
Apper	H Acceptance Testing After Installation	9t

### LIST OF TABLES

Table 2-1 Resistance and Weight Increment Factors*	7
Table 2-2 Schedule for Establishing Maximum Direct Current Resistance per Unit Length of	
Completed Cable Conductors Listed in Tables 2-4 Through 2-6	8
Table 2-3 Nominal Diameters for Copper and Aluminum Conductors	
Table 2-3M (Metric) Nominal Diameters for Copper and Aluminum Conductors	11
Table 2-4 Nominal Direct Current Resistance in Ohms per 1000 Feet at 25°C of Solid and	
Stranded Conductor	13
Table 2-4M (Metric) Nominal Direct Current Resistance in Ohms per Kilometer at 25°C of Solid	
and Stranded Conductor	14
Table 2-5 Nominal Direct Current Resistance in Ohms per 1000 Feet at 25°C for Flexible	
	15
Table 2-5M (Metric) Nominal Direct Current Resistance in Ohms per Kilometer at 25°C for	
Flexible Annealed Copper Conductors	16
Table 2-6* Factors for Determining Nominal Resistance of Stranded Conductors per 1000 Feet at	
25°C <sup>†</sup>	
Table 3-1 Insulation Compound Ratings	21
Table 3-2 Voltage Test Reference Paragraphs	
Table 3-3 Conductor Sizes, Insulation Thicknesses, and Test Voltages for Class R Insulations	23
Table 3-4 Conductor Sizes, Insulation Thicknesses, and Test Voltages for Class T-4, T-5, T-6,	
and All Class X and E Insulation	24
Table 3-5 Conductor Sizes, Insulation Thickness, and Test Voltages for Class T-3 Polyvinyl	
Chloride/Nylon-Insulated Power Cables	25
Table 3-6 Conductor Sizes, Insulation Thickness, and Test Voltages for Class T-1 and T-2	
Polyvinyl-Chloride-Insulated Power Cables	
Table 3-7 Insulation Requirements	
Table 3-8 Insulation Compound Requirements	
Table 4-1 Jacket Requirements	
Table 4-2 Low Smoke Halogen-Free (LS HF) Jacket Requirements	
Table 4-3 Jacket Thickness for Single-Conductor Cables	35
Table 4-4 Thickness of Optional Jacket on Individual Conductors of Multiple-Conductor Cables	
Under a Common Jacket	
Table 4-5 Thickness of Common Overall Jacket of Multiple-Conductor Cable	
Table 4-6 Irregularity Inspection Test Method	
Table 4-7 Thickness of Lead Sheath on Unjacketed Cables	38
Table 4-8 Thickness of Lead Sheath for Cables Having a Crosslinked or Thermoplastic Jacket	0.0
over Lead Sheath	
Table 4-9 Thickness of Smooth Aluminum Sheath	
Table 4-10 Width of Steel Tape for Flat Armor (Plain or Zinc Coated)	
Table 4-11 Thickness of Steel Tape for Flat Armor (Plain or Zinc Coated)	
Table 4-12 Width of Metal Tape for Interlocked Armor	
Table 4-13 Thickness of Metal Tape for Interlocked Armor	
Table 4-14 Minimum Thickness of Metal for Corrugated Armor	
Table 4-15 Number of Twists (Torsion Test)	
Table 4-17 Mandrel Diameter for Adherence of Coating Tests Table 4-18 Size of Galvanized Steel Armor for Submarine Cable	
Table 4-18 Size of Galvanized Steel Armor for Submarine Cable Table 4-19 Tolerances in Diameter	
Table 4-19 Tolerances in Diameter	40
Jacketed Cores	<b>1</b> -
Table 4-21 Thickness of Servings over Metallic Sheath (Without Metallic Armor)	
Table 4-22 Thickness of Extruded Crosslinked and Extruded Thermoplastic Jacket over Metallic	+€
Sheath & ArmorsSheath & Armors	10
CHOCKET & / KITHOLO	

Table 4-23 Jacket Irregularity AC Spark Test Voltage for Nonconducting Jackets*	50
Table 4-24 Size of Galvanized Steel Armor Wire for Borehole Cable	51
Table 4-25 Spacing and Length of Band Servings	51
Table 4-26 Pitch Ratio of Galvanized Wire Armor for Dredge Cable	52
Table 4-27 Size of Galvanized Steel Armor Wire for Dredge Cable	52
Table 4-28 Size of Galvanized Steel Armor Wire for Shaft Cable and Vertical Riser Cable	52
Table 4-29 Thickness of Jute Bedding and Size of Armor Wire (Division III)	53
Table 5-1 Lay Factors	
Table 5-2 Grounding Conductor Size for Cables Rated 0-2000 Volts	55
Table 6-1 Summary of Production Tests and Suggested Sampling Frequency Requirements	58
Table 6-2 Mandrel Diameter for Cold-Bend Test	62
Table 7-1 Test Samples and Constructions that They Represent	70
Table E-1 Nonshielded Power Cables Without Metallic Sheath or Armor	81
Table E-2 Sheathed or Armored Cable Bending Radius	82
Table F-1 Solid Aluminum and Copper Conductors	83
Table F-2 Stranded Class B Aluminum and Copper Conductors	84
Table F-3 Stranded Class C and D Aluminum and Copper Conductors	85
Table F-4 Rope-Lay Aluminum and Copper Conductors, Class G	87
Table F-5 Rope-Lay Aluminum and Copper Conductors, Class H	88
Table F-6 Aluminum and Copper Conductors, Class I Each Individual Strand 24 AWG, 0.0201	
Inch (0.511 mm)	89
Table F-7 Copper Conductors, Class K Each Individual Strand 30 AWG, 0.0100 Inch (0.254 mm)	90
Table F-8 Copper Conductors, Class M Each Individual Strand 34 AWG, 0.0063 Inch (0.160 mm)	91
Table G-1 Diameter Multipliers for Round Core Cables	93
Table G-2 Armor Tape Thickness Adder	94

#### **Foreword**

This Standards publication for *Power Cables Rated 2000 Volts or Less for the Distribution of Electrical Energy* was developed by the Insulated Cable Engineers Association (ICEA) and approved by the National Electrical Manufacturers Association (NEMA).

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, Inc. via www.icea.net.

An official written interpretation will be provided once approved by ICEA and NEMA. Suggestions for improvements gained in the use of this Standard are welcome and should be referred to the ICEA or NEMA.

The Members of the ICEA working group contributing to the writing of this Standard consisted of the following:

E. J. Bartolucci. Chairman

J. Armstrong	M. Bodziony	W. Crawford
A. Davila	B. Fleming	F. Kuchta
P. Leblanc	C. Lindler	J. Maximo
B. Miller	J. Mumm	R. Murphy
R. Neumann	K. Nuckles	K. Porter
C. Spradlin	R. Szilagyi	J. Weitzel
T. West	<b>0.</b>	

This Standard was processed and approved for submittal to ANSI by the NEMA C8 Committee on Insulated Wire and Cables, Excluding Magnet Wire. Committee approval of the Standard does not necessarily imply that all committee Members voted for its approval. At the time it approved this Standard, the C8 committee had the following Members:

Kenneth	Bow	Kable Consult LLC
Lauri	Hiivala	Power Cable Consultant
Trung	Hiu	USDA Rural Development Utilities Programs
Michael	Kinard	Consultant
Anthony	Tassone	UL LLC
Todd	Taylor	Enfinity Engineering
Gerald	Dorna	Belden
Christel	Hunter	Cerrowire
Kevin	Porter	Encore Wire Corporation
Michael	Stover	Optical Cable Corporation
Henson	Toland	OFS Fitel
David	Watson	Southwire Company
Jared	Weitzel	Prysmian Group
Lee	Perry	Service Wire Company
Nigel	Hampton	NEETRAC
Ewell	Robeson	Carolina Power & Light

## Section 1 General

### 1.1 Scope

This Standard applies to materials, constructions, and testing of 2000 volts and less thermoplastic and thermoset insulated wires and cables that are used for the transmission and distribution of electrical energy for normal conditions of installation and service, either indoors, outdoors, aerial, underground, or submarine.