



STANDARD FOR  
CONCENTRIC NEUTRAL CABLES  
RATED 5 THROUGH 46 KV

Approved by  
AMERICAN NATIONAL STANDARDS INSTITUTE  
March 19,2013  
Publication # ANSI/ICEA S-94-649-2013

©2013 by  
INSULATED CABLE ENGINEERS ASSOCIATION, Inc.



**STANDARD FOR**  
**CONCENTRIC NEUTRAL CABLES**  
**RATED 5 THROUGH 46 KV**

**Standard**  
**ICEA S-94-649-2013**

Published By  
**INSULATED CABLE ENGINEERS ASSOCIATION, Inc.**  
Post Office Box 1568  
Carrollton, Georgia 30112, U.S.A.

Approved by Insulated Cable Engineers Association, Inc.: June 2012  
Accepted by IEEE/ICC2-A 14: September 2010  
Accepted by AEIC: Cable Engineering Committee: March 2011  
Approved by ANSI: March 19, 2013

© Copyright 2013 by the 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 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 ICEA administers the process and establishes rules to promote fairness in the development of consensus, it does not independently test, evaluate, or verify the accuracy or completeness of any information or the soundness of any judgements contained in its standards and guideline publications.

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. 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 particular purposes or needs. ICEA does not undertake to guarantee the performance of any individual manufacturer or seller's products or services by virtue of this standard or guide.

In publishing and making this document available, ICEA is not undertaking to render professional or other services for or on behalf of any person or entity, nor is 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 judgement 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.

ICEA has no power, nor does it undertake to police or enforce compliance with the contents of this document. ICEA does 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 ICEA and is solely the responsibility of the certifier or maker of the statement.

## FOREWORD

This Standards Publication for Concentric Neutral Cables Rated 5 to 46 kV (ICEA S-94-649) was developed by the Insulated Cable Engineers Association Inc. (ICEA).

ICEA standards are adopted in the public interest and are designed to eliminate misunderstandings 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 standard does not in any respect preclude the manufacture or use of products not conforming to the standard. The user of this Standards Publication 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 the Insulated Cable Engineers Association, Inc., P. O. Box 1568, Carrollton, Georgia 30112. An official written interpretation will be provided. Suggestions for improvements gained in the use of this Standard will be welcomed by the Association.

The ICEA expresses thanks to the Association of Edison Illuminating Companies, Cable Engineering Committee for providing the basis for some of the material included herein through their participation in the Utility Power Cable Standards Technical Advisory Committee (UPCSTAC), and to the Institute of Electrical and Electronics Engineers, Insulated Conductors Committee, Subcommittee A, Discussion Group A-14 for providing user input to this Standard.

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

F. Kuchta, Chairman

E. Bartolucci  
B. Fleming  
B. Temple  
E. Walcott

R. Bristol  
K. Nuckles  
R. Thrash  
R. Williamson

J. Cancelosi  
A. Pack  
B. Vaughn

## TABLE OF CONTENTS

<b>Part 1 GENERAL</b> .....	1
<b>1.1 SCOPE</b> .....	1
<b>1.2 GENERAL INFORMATION</b> .....	1
<b>1.3 INFORMATION TO BE SUPPLIED BY PURCHASER</b> .....	1
1.3.1 Characteristics of Systems on which Cable is to be Used .....	1
1.3.2 Quantities and Description of Cable .....	2
<b>1.4 DEFINITIONS AND SYMBOLS</b> .....	2
<b>Part 2 CONDUCTOR</b> .....	6
<b>2.0 GENERAL</b> .....	6
<b>2.1 PHYSICAL AND ELECTRICAL PROPERTIES</b> .....	6
2.1.1 Copper Conductors .....	6
2.1.2 Aluminum Conductors .....	6
<b>2.2 OPTIONAL WATER BLOCKING COMPONENTS FOR STRANDED CONDUCTORS</b> .....	7
<b>2.3 CONDUCTOR SIZE UNITS</b> .....	7
<b>2.4 CONDUCTOR DC RESISTANCE PER UNIT LENGTH</b> .....	7
2.4.1 Direct Measurement of dc Resistance Per Unit Length .....	7
2.4.2 Calculation of dc Resistance Per Unit Length .....	7
<b>2.5 CONDUCTOR DIAMETER</b> .....	8
<b>Part 3 CONDUCTOR SHIELD (STRESS CONTROL LAYER)</b> .....	14
<b>3.1 MATERIAL</b> .....	14
<b>3.2 EXTRUDED SHIELD THICKNESS</b> .....	14
3.2.1 Reduced Extruded Shield Thickness .....	14
<b>3.3 PROTRUSIONS AND CONVOLUTIONS</b> .....	14
<b>3.4 VOIDS</b> .....	15
<b>3.5 PHYSICAL REQUIREMENTS</b> .....	15
<b>3.6 ELECTRICAL REQUIREMENTS</b> .....	15
3.6.1 Extruded Semiconducting Material .....	15
3.6.2 Extruded Nonconducting Material (For EPR Insulation Only) .....	15
3.6.3 Semiconducting Tape .....	16
<b>3.7 CROSSLINKED (THERMOSET) REQUIREMENTS</b> .....	16
<b>Part 4 INSULATION</b> .....	17
<b>4.1 MATERIAL</b> .....	17
<b>4.2 INSULATION THICKNESS</b> .....	18
4.2.1 Selection of Proper Thickness .....	18
4.2.1.1 For Three-Phase Systems with 100 or 133 Percent Insulation Level .....	18
4.2.1.2 For Delta Systems Where One Phase May Be Grounded For Periods Over One Hour .....	18
4.2.1.3 For Single- and Two-Phase Systems with 100 Percent Insulation Level .....	18
4.2.1.4 For Single- and Two-Phase Systems with 133 Percent Insulation Level .....	18
<b>4.3 INSULATION REQUIREMENTS</b> .....	18
4.3.1 Physical and Aging Requirements .....	18
4.3.2 Electrical Requirements .....	19
4.3.2.1 Partial-Discharge Extinction Level for Discharge-Free Designs Only .....	19
4.3.2.2 Discharge (Corona) Resistance for Discharge-Resistant Designs Only .....	19
4.3.2.3 Voltage Tests .....	20
4.3.2.4 Insulation Resistance Test .....	20
4.3.2.5 Dielectric Constant and Dissipation Factor .....	20

4.3.3	Voids, Ambers, Gels, Agglomerates and Contaminants as Applicable .....	20
4.3.3.1	Crosslinked Polyethylene Insulation (XLPE or TRXLPE) .....	20
4.3.3.2	Ethylene Propylene Rubber (EPR).....	21
4.3.4	Shrinkback - Crosslinked Polyethylene Insulation (XLPE or TRXLPE) Only.....	21
<b>Part 5</b>	<b>EXTRUDED INSULATION SHIELD.....</b>	<b>25</b>
5.1	<b>MATERIAL .....</b>	<b>25</b>
5.2	<b>THICKNESS AND INDENT REQUIREMENTS .....</b>	<b>25</b>
5.3	<b>PROTRUSIONS .....</b>	<b>26</b>
5.4	<b>INSULATION SHIELD REQUIREMENTS .....</b>	<b>26</b>
5.4.1	Insulation Shield for DISCHARGE-FREE Cable Designs Only.....	26
5.4.1.1	Removability .....	26
5.4.1.2	Voids .....	26
5.4.1.3	Physical Requirements .....	27
5.4.1.4	Electrical Requirements .....	27
5.4.1.5	Crosslinked (Thermoset) Requirements.....	27
5.4.2	Insulation Shield for DISCHARGE-RESISTANT Cable Designs Only.....	27
5.4.2.1	Removability .....	27
5.4.2.2	Physical Requirements .....	27
5.4.2.3	Electrical Requirements .....	28
5.4.2.4	Crosslinked (Thermoset) Requirements.....	28
<b>Part 6</b>	<b>CONCENTRIC NEUTRAL CONDUCTOR.....</b>	<b>29</b>
6.1	<b>MATERIAL .....</b>	<b>29</b>
6.2	<b>CROSS-SECTIONAL AREA .....</b>	<b>29</b>
6.3	<b>LAY LENGTH.....</b>	<b>29</b>
6.4	<b>CONCENTRIC WIRES.....</b>	<b>29</b>
6.4.1	Minimum Sizes and Number .....	29
6.4.2	Contra-helical Wire.....	29
6.4.3	Diameter and Area.....	29
6.5	<b>FLAT STRAPS.....</b>	<b>30</b>
6.6	<b>OPTIONAL WATER BLOCKING COMPONENTS FOR METALLIC SHIELD.....</b>	<b>30</b>
<b>Part 7</b>	<b>JACKETS.....</b>	<b>32</b>
7.1	<b>MATERIAL .....</b>	<b>32</b>
7.1.1	Low Density and Linear Low Density Polyethylene, Black (LDPE/LLDPE).....	32
7.1.2	Medium Density Polyethylene, Black (MDPE).....	33
7.1.3	High Density Polyethylene, Black (HDPE).....	34
7.1.4	Semiconducting Jacket Type I.....	35
7.1.5	Semiconducting Jacket Type II.....	36
7.1.6	Polyvinyl Chloride (PVC).....	37
7.1.7	Chlorinated Polyethylene (CPE).....	38
7.1.8	Thermoplastic Elastomer (TPE) .....	39
7.1.9	Polypropylene, Black (PP).....	40
7.2	<b>JACKET APPLICATION AND THICKNESS.....</b>	<b>41</b>
7.2.1	Extruded-To-Fill Jacket .....	41
7.2.2	Overlaying Jacket.....	41
7.3	<b>JACKET IRREGULARITY INSPECTION.....</b>	<b>41</b>
7.3.1	Non Conducting Jackets.....	41
7.3.2	Semiconducting Jackets .....	41
<b>Part 8</b>	<b>CABLE ASSEMBLY AND IDENTIFICATION.....</b>	<b>43</b>
8.1	<b>MULTIPLEX CABLE ASSEMBLIES .....</b>	<b>43</b>

<b>8.2 CABLE IDENTIFICATION</b> .....	43
8.2.1 Jacketed Cable .....	43
8.2.1.1 Optional Cable Identification .....	43
8.2.2 Unjacketed Cable .....	43
8.2.3 Optional Center Strand Identification .....	44
8.2.4 Optional Sequential Length Marking .....	44
<b>Part 9 PRODUCTION TESTS</b> .....	45
<b>9.1 TESTING</b> .....	45
<b>9.2 SAMPLING FREQUENCY</b> .....	45
<b>9.3 CONDUCTOR TEST METHODS</b> .....	45
9.3.1 Method for DC Resistance Determination .....	45
9.3.2 Cross-Sectional Area Determination .....	45
9.3.3 Diameter Determination .....	45
<b>9.4 TEST SAMPLES AND SPECIMENS FOR PHYSICAL AND AGING TESTS</b> .....	45
9.4.1 General .....	45
9.4.2 Measurement of Thickness .....	45
9.4.2.1 Micrometer Measurements .....	46
9.4.2.2 Optical Measuring Device Measurements .....	46
9.4.3 Number of Test Specimens .....	46
9.4.4 Size of Specimens .....	46
9.4.5 Preparation of Specimens of Insulation and Jacket .....	47
9.4.6 Specimen for Aging Test .....	47
9.4.7 Calculation of Area of Test Specimens .....	47
9.4.8 Unaged Test Procedures .....	47
9.4.8.1 Specimens and Test Temperature .....	47
9.4.8.2 Type of Testing Machine .....	48
9.4.8.3 Tensile Strength Test .....	48
9.4.8.4 Elongation Test .....	48
9.4.9 Aging Tests .....	48
9.4.9.1 Aging Test Specimens .....	48
9.4.9.2 Air Oven Test .....	49
9.4.9.3 Oil Immersion Test for Polyvinyl Chloride Jacket .....	49
9.4.10 Hot Creep Test .....	49
9.4.11 Solvent Extraction .....	49
9.4.12 Wafer Boil Test for Conductor and Insulation Shields .....	49
9.4.13 Amber, Agglomerate, Gel, Contaminant, Protrusion, Indent, Convolutions and Void Test .....	49
9.4.13.1 Sample Preparation .....	49
9.4.13.2 Examination .....	50
9.4.13.3 Resampling for Amber, Agglomerate, Gel, Contaminant, Protrusion, Convolutions and Void Test .....	50
9.4.13.4 Protrusion, Indentation and Convolutions Measurement Procedure .....	50
9.4.14 Internal Irregularity Test Procedure for Crosslinked Polyethylene Insulation (XLPE or TRXLPE) Only .....	51
9.4.14.1 Sample Preparation .....	51
9.4.14.2 Detection of Irregularity .....	51
9.4.14.3 Resampling for Internal Irregularity Test .....	51
9.4.15 Physical Tests for Semiconducting Material Intended for Extrusion .....	52
9.4.15.1 Test Sample .....	52
9.4.15.2 Test Specimens .....	52
9.4.15.3 Elongation .....	52
9.4.16 Retests for Physical and Aging Properties .....	52

9.4.17 Retests for Thickness.....	52
<b>9.5 DIMENSIONAL MEASUREMENTS OF THE METALLIC SHIELD.....</b>	<b>52</b>
<b>9.6 DIAMETER MEASUREMENT OF INSULATION AND INSULATION SHIELD.....</b>	<b>53</b>
<b>9.7 TESTS FOR JACKETS.....</b>	<b>53</b>
9.7.1 Heat Shock (PVC only).....	53
9.7.2 Heat Distortion.....	54
9.7.3 Cold Bend (PVC and CPE only).....	54
<b>9.8 VOLUME RESISTIVITY.....</b>	<b>54</b>
9.8.1 Conductor Shield (Stress Control).....	54
9.8.2 Insulation Shield.....	55
9.8.3 Test Equipment.....	55
9.8.4 Test Procedure.....	55
9.8.4.1 Two-electrode Method.....	55
9.8.4.2 Four-electrode Method.....	55
9.8.4.3 Measurement.....	55
9.8.5 Semiconducting Jacket Radial Resistivity Test.....	56
9.8.5.1 Sample Preparation.....	56
9.8.5.2 Test Equipment Setup.....	56
9.8.5.3 Calculation.....	57
<b>9.9 ADHESION TEST.....</b>	<b>58</b>
<b>9.10 SHRINKBACK TEST PROCEDURE.....</b>	<b>58</b>
9.10.1 Sample Preparation.....	58
9.10.2 Test Procedure.....	58
9.10.3 Pass/Fail Criteria and Procedure.....	58
<b>9.11 RETESTS ON SAMPLES.....</b>	<b>58</b>
<b>9.12 AC VOLTAGE TEST.....</b>	<b>59</b>
9.12.1 General.....	59
9.12.2 AC Voltage Test.....	59
<b>9.13 PARTIAL-DISCHARGE TEST PROCEDURE.....</b>	<b>59</b>
<b>9.14 METHOD FOR DETERMINING DIELECTRIC CONSTANT AND DIELECTRIC STRENGTH OF EXTRUDED NONCONDUCTING POLYMERIC STRESS CONTROL LAYERS.....</b>	<b>59</b>
<b>9.15 WATER CONTENT.....</b>	<b>59</b>
9.15.1 Water Under the Jacket.....	60
9.15.2 Water in the Conductor.....	60
9.15.3 Water Expulsion Procedure.....	60
9.15.4 Presence of Water Test.....	60
<b>9.16 PRODUCTION TEST SAMPLING PLANS.....</b>	<b>61</b>
<b>Part 10 QUALIFICATION TESTS.....</b>	<b>64</b>
<b>10.0 GENERAL.....</b>	<b>64</b>
<b>10.1 CORE QUALIFICATION TESTS.....</b>	<b>64</b>
10.1.1 Core Material Qualification Requirements.....	64
10.1.1.1 Conductor Shield/Insulation Qualification.....	65
10.1.1.2 Insulation/Insulation Shield Qualification.....	65
10.1.2 Manufacturing Qualification Requirements.....	65
10.1.2.1 Conductor Shield/Insulation Test.....	65
10.1.2.2 Insulation/Insulation Shield Test.....	65
10.1.3 High Voltage Time Test (HVTT) Procedure.....	67
10.1.4 Hot Impulse Test Procedure.....	68
10.1.5 Cyclic Aging.....	68
10.1.5.1 Cable Length.....	68
10.1.5.2 Sample Preparation.....	68

10.1.5.3	Conduit.....	69
10.1.5.4	Load Cycle.....	69
10.1.6	Accelerated Water Treeing Test (AWTT) Procedure.....	69
10.1.6.1	General.....	69
10.1.6.2	Quantity of Cable To Be Aged.....	69
10.1.6.3	Aging Time.....	69
10.1.6.4	Conduit Fixture.....	69
10.1.6.4.1	Structures Above Conduit Fixtures.....	70
10.1.6.4.2	Conduit Fixtures Dimensions.....	70
10.1.6.5	Water.....	70
10.1.6.6	Ambient Temperature.....	70
10.1.6.7	Test Procedure.....	70
10.1.6.8	Water pH.....	72
10.1.6.9	High Voltage Time Test Requirements.....	72
10.1.6.10	Retesting.....	73
10.1.7	Qualification Test Electrical Measurements.....	74
10.1.8	Qualification Test Physical Measurements.....	74
<b>10.2</b>	<b>THERMOMECHANICAL QUALIFICATION TEST - Optional.....</b>	<b>74</b>
10.2.1	Scope.....	74
10.2.2	Procedure.....	74
10.2.2.1	Fixture.....	74
10.2.2.2	Load Cycling.....	74
10.2.2.3	Electrical Measurements.....	75
10.2.2.4	Physical Measurements Before and After the Thermomechanical Design Test.....	75
<b>10.3</b>	<b>JACKET MATERIAL QUALIFICATION TESTS.....</b>	<b>76</b>
10.3.1	Polyethylene And Polypropylene Jackets.....	77
10.3.1.1	Environmental Stress Cracking Test.....	77
10.3.1.1.1	Test Specimen.....	77
10.3.1.1.2	Test Procedure.....	77
10.3.1.2	Absorption Coefficient Test.....	77
10.3.2	Semiconducting Jackets.....	77
10.3.2.1	Brittleness Test.....	77
10.3.3	Polyvinyl Chloride and Chlorinated Polyethylene Jackets.....	77
10.3.3.1	Sunlight Resistance.....	77
10.3.3.1.1	Test Samples.....	77
10.3.3.1.2	Test Procedure.....	77
10.3.4	Extruded Red Stripe For Jackets.....	78
10.3.4.1	Sunlight Resistance.....	78
10.3.4.1.1	Test Samples.....	78
10.3.4.1.2	Test Procedure.....	78
<b>10.4</b>	<b>CV EXTRUSION QUALIFICATION TEST.....</b>	<b>78</b>
10.4.1	Thermal Conditioning.....	78
10.4.2	Dissipation Factor Verification.....	78
10.4.3	AC Withstand Verification.....	79
<b>10.5</b>	<b>OTHER QUALIFICATION TESTS.....</b>	<b>79</b>
10.5.1	Insulation Resistance.....	79
10.5.2	Accelerated Water Absorption Tests.....	79
10.5.3	Resistance Stability Test.....	80
10.5.4	Brittleness Temperature for Semiconducting Shields.....	80
10.5.5	Dry Electrical Test for Class III Insulation Only.....	80
10.5.5.1	Test Samples.....	80
10.5.5.2	Test Procedure.....	80

10.5.5.3	Electrical Measurements.....	81
10.5.6	Discharge Resistance Test for EPR Class IV Insulation Only.....	81
10.5.6.1	Test Specimens.....	81
10.5.6.2	Test Environment.....	81
10.5.6.3	Test Electrodes.....	81
10.5.7	Dissipation Factor Characterization Test.....	82
10.5.7.1	Test Samples.....	82
10.5.7.2	Thermal Conditioning.....	82
10.5.7.3	Dissipation Factor Testing.....	82
10.5.8	Dielectric Constant and Voltage Withstand for Nonconducting Stress Control Layers.....	82
<b>Part 11</b>	<b>APPENDICES.....</b>	<b>83</b>
<b>APPENDIX A</b>	<b>NEMA, ICEA, IEEE, ASTM AND ANSI STANDARDS (Normative).....</b>	<b>83</b>
A1	NEMA PUBLICATIONS.....	83
A2	ICEA PUBLICATIONS.....	83
A3	IEEE AND ANSI STANDARDS.....	83
A4	ASTM STANDARDS.....	83
<b>APPENDIX B</b>	<b>EMERGENCY OVERLOADS (Normative).....</b>	<b>86</b>
<b>APPENDIX C</b>	<b>PROCEDURE FOR DETERMINING DIAMETERS OF CABLE (Normative).....</b>	<b>87</b>
<b>APPENDIX D</b>	<b>SHIELDING (Informative).....</b>	<b>93</b>
D1	DEFINITION OF SHIELDING.....	93
D2	FUNCTIONS OF SHIELDING.....	93
D3	USE OF INSULATION SHIELDING.....	93
D4	GROUNDING OF THE INSULATION SHIELD.....	94
D5	SHIELD MATERIALS.....	94
D6	SPLICES AND TERMINATIONS.....	94
<b>APPENDIX E</b>	<b>HANDLING AND INSTALLATION PARAMETERS (Informative).....</b>	<b>95</b>
E1	INSTALLATION TEMPERATURES.....	95
E2	RECOMMENDED MINIMUM BENDING RADIUS.....	95
E3	DRUM DIAMETERS OF REELS.....	95
E4	MAXIMUM TENSION AND SIDEWALL BEARING PRESSURES.....	95
E5	TESTS DURING AND AFTER INSTALLATION.....	95
E5.1	During Installation.....	95
E5.2	After Installation.....	95
E5.3	In Service.....	95
<b>APPENDIX F</b>	<b>OPTIONAL FACTORY DC TEST (Informative).....</b>	<b>97</b>
<b>APPENDIX G</b>	<b>REDUCED NEUTRAL DESIGNS (Informative).....</b>	<b>98</b>
<b>APPENDIX H</b>	<b>ADDITIONAL CONDUCTOR INFORMATION (Informative).....</b>	<b>102</b>
<b>APPENDIX I</b>	<b>ETHYLENE ALKENE COPOLYMER (EAM) (Informative).....</b>	<b>105</b>
<b>APPENDIX J</b>	<b>INSULATION COMPOUND INSPECTION (Normative).....</b>	<b>106</b>
K1	SCOPE.....	106
K2	PROCEDURE.....	106
K2.1	Compound Tape Inspection Sampling Plan.....	106
K2.2	Compound Pellet Inspection Sampling Plan.....	106

**LIST OF TABLES**

<b>Table 2-1</b>	<b>Weight Increment Factors.....</b>	<b>8</b>
<b>Table 2-2</b>	<b>Schedule for Establishing Maximum Direct Current Resistance Per Unit Length of Completed Cable Conductors listed in Table 2-4.....</b>	<b>8</b>
<b>Table 2-3</b>	<b>Nominal Direct Current Resistance in Ohms Per 1000 Feet at 25°C of Solid and Concentric Lay Stranded Conductor.....</b>	<b>9</b>

Table 2-3 (Metric)	Nominal Direct Current Resistance in Milliohms Per Meter at 25°C of Solid and Concentric Lay Stranded Conductor .....	10
Table 2-4	Nominal Diameters for Copper and Aluminum Conductors.....	11
Table 2-4 (Metric)	Nominal Diameters for Copper and Aluminum Conductors.....	12
Table 2-5	Factors for Determining Nominal Resistance of Stranded Conductors Per 1000 Feet at 25°C .....	13
Table 3-1	Extruded Conductor Shield Thickness.....	14
Table 3-2	Extruded Conductor Shield Requirements .....	15
Table 4-1	Conductor Maximum Rated Temperatures .....	17
Table 4-2	Insulation Physical Requirements.....	19
Table 4-3	Dielectric Constant and Dissipation Factor .....	20
Table 4-4	Shrinkback Test Requirements Cables Having Sealed Strand Conductors and/or a Tape Over the Conductor .....	21
Table 4-5	Shrinkback Test Requirements All Cables Not Covered by Table 4-4 .....	21
Table 4-6	Cable BIL Values.....	22
Table 4-7	Conductor Sizes, Insulation Thicknesses and Test Voltages .....	22
Table 4-7 (Metric)	Conductor Sizes, Insulation Thicknesses and Test Voltages .....	23
Table 5-1	Insulation Shield Thickness Cables With Wire Neutral .....	25
Table 5-2	Insulation Shield Thickness Cables With Flat Strap Neutral .....	26
Table 5-3	Extruded Insulation Shield Requirements Discharge-Free Designs .....	27
Table 5-4	Extruded Insulation Shield Requirements Discharge-Resistant Designs .....	28
Table 6-1	Concentric Neutral Wire Size .....	30
Table 6-2	Full Neutral Concentric Copper Conductor .....	30
Table 6-3	One-third Neutral Concentric Copper Conductor .....	31
Table 7-1	Low Density and Linear Low Density Polyethylene, Black (LDPE/LLDPE) .....	32
Table 7-2	Medium Density Polyethylene, Black (MDPE) .....	33
Table 7-3	High Density Polyethylene, Black (HDPE).....	34
Table 7-4	Semiconducting Jacket Type I.....	35
Table 7-5	Semiconducting Jacket Type II.....	36
Table 7-6	Polyvinyl Chloride (PVC).....	37
Table 7-7	Chlorinated Polyethylene (CPE) .....	38
Table 7-8	Thermoplastic Elastomer (TPE).....	39
Table 7-9	Polypropylene, Black (PP) .....	40
Table 7-10	Extruded-To-Fill Jacket Thickness and Test Voltage .....	41
Table 7-11	Overlaying Jacket Thickness and Test Voltage .....	42
Table 8-1	Nominal Insulation Thickness .....	44
Table 9-1	Test Specimens for Physical and Aging Tests.....	46
Table 9-2	Bending Requirements for Heat Shock Test .....	54
Table 9-3	Bending Requirements for Cold Bend Test.....	54
Table 9-4	Summary of Production Tests and Sampling Frequency Requirements .....	61
Table 9-5	Plan E .....	63
Table 9-6	Plan F.....	63
Table 10-1	Minimum ac Withstand Values .....	73
Table 10-2	Maximum Temperature Gradient for Thermal Aging .....	75
Table 10-3	Generic Grouping of Cable Components .....	76
Table 10-4	AC Withstand Voltage Requirements 15-35 kV Rated Cables.....	79
Table 10-5	Accelerated Water Absorption Properties .....	80
Table C-1	Insulation Diameter Calculation .....	87
Table C-2	Insulation Shield Adders For Wire Neutral.....	88
Table C-3	Insulation Shield Adders For Flat Strip Neutral.....	88
Table C-4	Calculated Dimensions For Round Wire Neutral – Concentric Stranding.....	90
Table C-5	Calculated Dimensions For Round Wire Neutral – Compressed Stranding .....	91

Table C-6	Calculated Dimensions For Round Wire Neutral – Compact Stranding .....	92
Table E-1	DC Field Test Voltages.....	96
Table F-1	DC Test Voltages .....	97
Table G-1	One-sixth Neutral Concentric Conductor for Copper Center Conductor .....	98
Table G-2	One-eighth Neutral Concentric Conductor for Copper Center Conductor.....	98
Table G-3	One-twelfth Neutral Concentric Conductor for Copper Center Conductor .....	99
Table G-4	One-sixth Neutral Concentric Conductor for Aluminum Center Conductor .....	99
Table G-5	One-eighth Neutral Concentric Conductor for Aluminum Center Conductor..	100
Table G-6	One-twelfth Neutral Concentric Conductor for Aluminum Center Conductor.	100
Table H-1	Solid Aluminum and Copper Conductors .....	102
Table H-2	Concentric Stranded Class B Aluminum and Copper Conductors .....	103
Table H-3	Concentric Stranded Class C and D Aluminum and Copper Conductors.....	104

## Part 1 GENERAL

### 1.1 SCOPE

These standards apply to materials, constructions, and testing of crosslinked polyethylene, tree retardant crosslinked polyethylene and ethylene propylene rubber insulated single conductor or multiplexed concentric neutral cables rated 5 to 46 kV which are used for the transmission and distribution of electrical energy.

### 1.2 GENERAL INFORMATION

This publication is so arranged to allow selection from two design concepts, one known as "DISCHARGE-FREE" and the other as "DISCHARGE-RESISTANT", as well as allowing for selection of those individual components (such as conductors, insulation type and thickness, concentric neutral sizes, optional jackets, etc.) as required for specific installation and service conditions.

Parts 2 to 7 cover the major components of cables:

Part 2 - Conductor

Part 3 - Conductor Shield

Part 4 - Insulation

Part 5 - Extruded Insulation Shield

Part 6 - Concentric Neutral Conductor (See ANSI/ICEA S-97-682 for Utility Shielded Power Cable)

Part 7 - Jacket

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

Part 8 covers the assembly and identification of cables.

Part 9 covers production test procedures applicable to cable component materials and to completed cables.

Part 10 covers qualification test procedures.

Part 11 contains appendices of pertinent information.

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

### 1.3 INFORMATION TO BE SUPPLIED BY PURCHASER

When requesting proposals from cable manufacturers, the prospective purchaser should describe the cable desired by reference to pertinent provisions of these standards. To help avoid misunderstandings and possible misapplication of the cables, the purchaser should also furnish the following information:

#### 1.3.1 Characteristics of Systems on which Cable is to be Used

- a. Load current.
- b. Frequency - hertz.
- c. Normal operating voltage between phases or phase to ground on single phase circuits.
- d. Number of phases and conductors.
- e. Fault current and duration.
- f. Cable insulation level.
- g. Minimum temperature at which cable will be installed.