



STANDARD FOR
CONCENTRIC NEUTRAL CABLES
RATED 5 THROUGH 46 KV

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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).

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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.

- h. Description of installation.
 - 1. In underground ducts.
 - 2. Direct burial in ground.
 - 3. Descriptions other than the foregoing.
- i. Installation conditions.
 - 1. Ambient temperature.
 - 2. Number of loaded cables in duct bank or conduit. If in conduit, give size and 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 neutral.
 - 5. Wet or dry location.
 - 6. Thermal resistivity (ρ) of soil, concrete and/or thermal backfill.

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, three-conductor parallel, three-conductor triplexed, etc.
- c. Rated circuit voltage, phase-to-phase.
- d. Desired BIL level, if non standard.
- e. Type of conductor - copper or aluminum, filled or unfilled, stranded or solid.
- f. Size of conductors - AWG or circular mils. If conditions require other than standard stranding, a complete description should be given.
- g. Type of insulation.
- h. Thickness of insulation in mils.
- i. Size of neutral.
- j. Type of jacket.
- k. Maximum allowable overall diameter in inches. When duct space is not limited, it is desirable not to restrict the overall diameter.
- l. Method of cable identification.

1.4 DEFINITIONS AND SYMBOLS

Active Length:	Length of cable covered by insulation shield and metallic shield.
Agglomerate:	A discernible area of compound constituents in ethylene propylene based insulation which is generally opaque and can be broken apart.
Amber:	A localized area in crosslinked polyethylene (XLPE or TRXLPE) insulation which is dissimilar in color (ranging from bright yellow to dark red) from the surrounding insulation, which passes light and is not always readily removable from the insulation matrix. This does not include clouds, swirls or flow patterns which are normally associated with the extrusion process.
AWG:	American Wire Gauge
BIL:	Basic Impulse Insulation Level.
Bowtie Water Tree:	A water tree which originates within the insulation (usually at a contaminant or other imperfection) and develops radially toward the insulation shield and the conductor shield.

Cable Core:	The portion of a cable which includes the conductor, the conductor shield, the insulation and the insulation shield.
Cable Core Extruder Run:	A continuous run of cable core with one conductor size, one conductor shield compound, one insulation compound and thickness, and one insulation shield compound.
Certified Test Report:	A report containing the results of production tests or qualification tests which declares that the cable shipped to a customer meets the applicable requirements of this standard.
Completed Cable:	A length of cable which has finished all manufacturing processes but may not have been fully tested.
Contaminant:	Any solid or liquid material which is not an intended ingredient.
Dielectric Constant:	The ratio of the capacitance of a given configuration of electrodes with the material as a dielectric to the capacitance of the same electrode configuration with a vacuum (or air for most practical purposes) as the dielectric.
Discharge-Free Cable Design:	A cable meeting the maximum partial discharge magnitude requirement of this standard, when measured in the manner described herein, at the specified partial discharge test voltage.
Discharge-Resistant Cable Design:	A cable design capable of withstanding electrical discharge.
Dissipation Factor:	The cotangent of the dielectric phase angle of a dielectric material or the tangent of the dielectric loss angle. It is often called $\tan \delta$.
EPR Insulating Compound:	A mixture of ethylene propylene base resin and selected ingredients.
Filled Crosslinked Polyethylene Insulation:	XLPE and TRXLPE insulation containing 10 percent or more of mineral fillers by weight.
Gel:	A discernible region of compound constituents in ethylene propylene based insulation which is gelatinous, not readily removable from the insulation, and generally translucent.
High Dielectric Constant Compound:	An extruded compound used for the conductor shield which has a dielectric constant typically between 8 and 200.
Jacket Extruder Run:	A cable with a jacket which was applied in one continuous run with one jacket compound and one jacket thickness.
kcmil:	thousands of circular mils (formerly MCM)
Lay Length:	The lay of any helical element of a cable is the axial length of one turn of a helix of that element.
Lot (Cable):	The quantity of cable requiring one test.

Lot (Material):	A quantity of material used in cable construction which is produced at the same location under the same manufacturing conditions during the same time period.
Master Length:	A continuous length of cable collected on a reel at the end of an extrusion line.
Maximum Rated Conductor Temperatures:	
Normal Operating:	The highest conductor temperature permissible for any part of the cable line under normal operating current load.
Emergency Overload:	The highest conductor temperature permissible for any part of the cable line during emergency overload of specified time, magnitude, and frequency of application.
Short Circuit:	The highest conductor temperature permissible for any part of the cable line during a circuit fault of specified time and magnitude.
Nominal Value:	The value by which a quantity is designated and often used in tables (taking into account specified tolerances) but does not require testing or measurement for verification.
Partial Discharge Level:	The largest repeatedly occurring partial discharge magnitude, measured in picocoulombs, at the specified partial discharge test voltage.
pC:	picocoulombs
Power Frequency:	A voltage or current frequency between 49 and 61 Hz.
Production Tests:	Tests defined in Part 9 of this standard with specific test frequency.
Qualification Tests:	Tests defined in Part 10 of this standard with specific test frequency.
Room Temperature (RT):	25 ± 5°C air temperature.
Shipping Length:	A completed length of cable which has passed all test requirements. It may or may not be cut into shorter lengths before it is supplied to the end use customer.
Shipping Reel:	A completed reel of cable shipped to the end use customer.
Thermoplastic:	A polymeric material which can be repeatedly softened by heating and hardened by cooling through a temperature range characteristic of the material and that, in softened state, can be shaped through the application of force.
Thermoset:	A polymeric material which when crosslinked, will not flow on subsequent heating. Crosslinking is accomplished either chemically or by irradiation.
Translucent:	A localized area in crosslinked polyethylene (XLPE or TRXLPE) insulation dissimilar to the surrounding insulation which passes light and is not readily removable from the insulation matrix.

Tree Retardant XLPE Insulation:	A tree retardant crosslinked polyethylene (TRXLPE) insulation compound based on XLPE, containing an additive, a polymer modification or filler that retards the development and growth of water trees in the insulation compound.
Unfilled Crosslinked Polyethylene:	Crosslinked Polyethylene (XLPE and TRXLPE) insulation containing less than 10 percent mineral filler by weight.
V:	phase to phase voltage
V _g :	phase to ground voltage
Vented Water Tree:	A water tree which originates at the conductor shield or insulation shield.
Void:	Any cavity in a compound, either within or at the interface with another extruded layer.
Water Blocking Component:	A non-metallic material incorporated in a cable construction intended as an impediment to water penetration. A water blocking component can be a pumpable or extrudable conductor filler compound, a water swellable tape, yarn, or powder, or a combination thereof.
Water Tree:	Microchannels in the insulation which develop in the presence of moisture, voltage stress and some type of catalyst such as a contaminant, a protrusion, space charge or ion(s).
XLPE Insulation:	A crosslinked polyethylene insulation.

Part 2 CONDUCTOR

2.0 GENERAL

Conductors shall meet the requirements of the appropriate ASTM standards referenced in this Standard except that resistance will determine cross-sectional area as noted in 2.4 and diameters will be in accordance with 2.5. Compliance with cross-sectional area is not required.

Requirements of a referenced ASTM standard shall be determined in accordance with the procedure or method designated in the referenced ASTM standard unless otherwise specified in this standard.

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

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

2.1 PHYSICAL AND ELECTRICAL PROPERTIES

The conductors used in the cable shall be copper in accordance with 2.1.1 or aluminum in accordance with 2.1.2, as applicable, except as noted in 2.0. Conductors shall be solid or stranded. The outer layer of a stranded copper conductor may be coated to obtain free stripping of the adjacent polymeric layer. There shall be no water in stranded conductors in accordance with 9.15.

2.1.1 Copper Conductors

1. ASTM B 3 for soft or annealed uncoated copper.
2. ASTM B 5 for electrical grade copper.
3. ASTM B 8 for Class A, B, C, or D stranded copper conductors.
4. ASTM B 33 for soft or annealed tin-coated copper wire.
5. ASTM B 496 for compact-round stranded copper conductors.
6. ASTM B 784 for modified concentric lay stranded copper conductor.
7. ASTM B 787 for 19 wire combination unilay-stranded copper conductors.
8. ASTM B 835 for compact round stranded copper conductors using single input wire constructions.
9. ASTM B 902 for compressed round stranded copper conductors using single input wire constructions.

2.1.2 Aluminum Conductors

1. ASTM B 230 for electrical grade aluminum 1350-H19.
2. ASTM B 231 for Class A, B, C, or D stranded aluminum 1350 conductors.
3. ASTM B 233 for electrical grade aluminum 1350 drawing stock.
4. ASTM B 400 for compact-round stranded aluminum 1350 conductors.
5. ASTM B 609 for electrical grade aluminum 1350 annealed and intermediate tempers.
6. ASTM B 786 for 19 wire combination unilay-stranded aluminum 1350 conductors.
7. ASTM B 800 for 8000 series aluminum alloy annealed and intermediate tempers.
8. ASTM B 801 for 8000 series aluminum alloy wires, compact- round, compressed and concentric-lay Class A, B, C and D stranded conductors.
9. ASTM B 836 for compact round stranded aluminum conductors using single input wire constructions.
10. ASTM B 901 for compressed round stranded aluminum conductors using single input wire constructions.

2.2 OPTIONAL WATER BLOCKING COMPONENTS FOR STRANDED CONDUCTORS

With the approval of the purchaser, water blocking components designed as an impediment to longitudinal water penetration may be incorporated in the interstices of the stranded conductor. Compatibility with the conductor shield shall be determined in accordance with ICEA Publication T-32-645. Longitudinal water penetration resistance shall be determined in accordance with ICEA Publication T-31-610 and shall meet a minimum requirement of 5 psig.

2.3 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 2-4. The metric equivalents for all sizes are found in Table 2-4 (Metric).

2.4 CONDUCTOR DC RESISTANCE PER UNIT LENGTH

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

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

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

2.4.1 Direct Measurement of dc Resistance Per Unit Length

The dc resistance per unit length shall be determined by dc resistance measurements made in accordance with 9.3.1 to an accuracy of 2 percent or better. If measurements are made at a temperature other than 25°C, the measured value shall be converted to resistance at 25°C by using either of the following:

1. The appropriate multiplying factor obtained from ICEA T-27-581/NEMA WC-53.
2. A multiplying factor calculated using the applicable formula in ICEA T-27-581/NEMA WC-53.

If verification is required for the direct-current resistance measurement made on an entire length of completed cable, a sample at least 1 foot (0.3 m) long shall be cut from that reel length, and the direct-current resistance of each conductor shall be measured using a Kelvin-type bridge or a potentiometer. This verification test does not constitute a retest and can not be the basis to pass the entire length of cable.

2.4.2 Calculation of dc Resistance Per Unit Length

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

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

Where:

R = Conductor resistance in Ω /1000 ft.

K = Weight increment factor, as given in Table 2-1.

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 9.3.2.

When the volume resistivity is expressed in nanoohm meters ($n\Omega\cdot m$) and area is expressed in square millimeters (mm^2) the resistance is expressed in milliohms per meter ($m\Omega/m$).

2.5 CONDUCTOR DIAMETER

The conductor diameter shall be measured in accordance with 9.3.3. The diameter shall not differ from the nominal values shown in Table 2-4 by more than ± 2 percent.

Table 2-1
Weight Increment Factors*

Conductor Type/Size	Weight Factor (K)
Solid All Sizes	1
Concentric-lay Strand, Class A, B, C and D 8 AWG - 2000 kcmil ($8.37 - 1013 \text{ mm}^2$) >2000 - 3000 kcmil ($>1013 - 1520 \text{ mm}^2$)	1.02 1.03
Combination Unilay Strand All Sizes	1.02
Concentric-lay Strand 8000 Series Aluminum 8 AWG – 2000 kcmil ($8.37 - 1013 \text{ mm}^2$)	1.02

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

Table 2-2
Schedule for Establishing Maximum Direct Current Resistance
Per Unit Length of Completed Cable Conductors Listed in Table 2-3

Cable Type	Maximum dc Resistance
Single Conductor Cables and Flat Parallel Cables	Table 2-3 ^a Value Plus 2% ($R_{\text{max}} = R \times 1.02$)
Twisted Assemblies of Single Conductor Cables	Table 2-3 ^a Value Plus 2% Plus An Additional 2% For One Layer of Conductors ($R_{\text{max}} = R \times 1.02 \times 1.02$)

^a For conductor strandings or sizes not listed in Tables 2-3, the nominal direct current resistance per unit length of a completed single conductor cable shall be calculated from the factors given in Table 2-5 using the following formula:

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

Where:

R = Conductor resistance in $\Omega/1000 \text{ ft}$.

f = Factor from Table 2-5.

A = Cross-sectional area of conductor in kcmil.

See 9.3.2 for cross-sectional area determination

Table 2-3
Nominal Direct Current Resistance in Ohms Per 1000 Feet at 25°C
of Solid and Concentric Lay Stranded Conductor

Conductor Size AWG or kcmil	Solid			Concentric Lay Stranded*				
	Aluminum	Copper		Aluminum	Copper			
		Uncoated	Coated	Class B,C,D	Uncoated	Coated		
					Class B,C,D	Class B	Class C	Class D
8	1.05	0.640	0.659	1.07	0.652	0.678	0.678	0.680
7	0.833	0.508	0.522	0.851	0.519	0.538	0.538	0.538
6	0.661	0.403	0.414	0.675	0.411	0.427	0.427	0.427
5	0.524	0.319	0.329	0.534	0.325	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	...	...

* Concentric lay stranded includes compressed and compact conductors.

Table 2-3 (Metric)
Nominal Direct Current Resistance in Milliohms Per Meter at 25°C
of Solid and Concentric Lay Stranded Conductor

Conductor Size		Solid			Concentric Lay Stranded*				
		Aluminum	Copper		Aluminum	Copper			
AWG Or Kcmil	mm ²		Uncoated	Coated	Class B,C,D	Uncoated	Coated		
						Class B,C,D	Class B	Class C	Class D
8	8.37	3.44	2.10	2.16	3.51	2.14	2.22	2.22	2.23
7	10.6	2.73	1.67	1.71	2.79	1.70	1.76	1.76	1.76
6	13.3	2.17	1.32	1.36	2.21	1.35	1.40	1.40	1.40
5	16.8	1.72	1.05	1.08	1.75	1.07	1.11	1.11	1.11
4	21.1	1.36	0.830	0.856	1.39	0.846	0.882	0.882	0.882
3	26.7	1.08	0.659	0.679	1.10	0.672	0.699	0.699	0.699
2	33.6	0.856	0.522	0.538	0.872	0.531	0.554	0.554	0.554
1	42.4	0.679	0.413	0.426	0.692	0.423	0.440	0.440	0.440
1/0	53.5	0.538	0.328	0.335	0.551	0.335	0.348	0.348	0.348
2/0	67.4	0.426	0.260	0.267	0.436	0.266	0.276	0.276	0.276
3/0	85.0	0.338	0.207	0.212	0.344	0.211	0.219	0.219	0.219
4/0	107	0.269	0.164	0.168	0.274	0.167	0.172	0.174	0.174
250	127	0.228	...	...	0.232	0.141	0.147	0.147	0.147
300	152	0.190	...	...	0.194	0.118	0.123	0.123	0.123
350	177	0.162	...	...	0.166	0.101	0.105	0.105	0.105
400	203	0.142	...	...	0.145	0.0882	0.0909	0.0918	0.0918
450	228	0.126	...	...	0.129	0.0787	0.0807	0.0817	0.0817
500	253	0.114	...	...	0.116	0.0708	0.0728	0.0735	0.0735
550	279	...	...	...	0.105	0.0643	0.0669	0.0669	0.0669
600	304	...	...	...	0.0968	0.0590	0.0613	0.0613	0.0613
650	329	...	...	...	0.0892	0.0544	0.0561	0.0564	0.0567
700	355	...	...	...	0.0830	0.0505	0.0522	0.0525	0.0525
750	380	...	...	...	0.0774	0.0472	0.0485	0.0489	0.0492
800	405	...	...	...	0.0725	0.0443	0.0456	0.0459	0.0459
900	456	...	...	...	0.0643	0.0394	0.0403	0.0413	0.0413
1000	507	...	...	...	0.0581	0.0354	0.0364	0.0364	0.0367
1100	557	...	...	...	0.0528	0.0322	0.0331	0.0335	0.0335
1200	608	...	...	...	0.0482	0.0295	0.0303	0.0306	0.0306
1250	633	...	...	...	0.0462	0.0283	0.0291	0.0294	0.0294
1300	659	...	...	...	0.0446	0.0272	0.0280	0.0282	0.0283
1400	709	...	...	...	0.0413	0.0253	0.0260	0.0260	0.0263
1500	760	...	...	...	0.0387	0.0236	0.0243	0.0243	0.0245
1600	811	...	...	...	0.0364	0.0221	0.0228	0.0230	0.0230
1700	861	...	...	...	0.0341	0.0208	0.0214	0.0216	0.0216
1750	887	...	...	...	0.0331	0.0202	0.0208	0.0210	0.0210
1800	912	...	...	...	0.0322	0.0196	0.0202	0.0202	0.0204
1900	963	...	...	...	0.0305	0.0186	0.0192	0.0192	0.0193
2000	1013	...	...	...	0.0290	0.0177	0.0182	0.0182	0.0184
2500	1266	...	...	...	0.0235	0.0143	0.0147	...	...
3000	1520	...	...	...	0.0195	0.0119	0.0123	...	...

* Concentric lay stranded includes compressed and compact conductors.

Table 2-4
Nominal Diameters for Copper and Aluminum Conductors

Conductor Size		Nominal Diameters (Inches)							
AWG	kcmil	Solid	Concentric Lay Stranded					Combination Unilay	Unilay Compressed
			Compact*	Compressed	Class B**	Class C	Class D		
8	16.51	0.1285	0.134	0.141	0.146	0.148	0.148	0.143	...
7	20.82	0.1443	...	0.158	0.164	0.166	0.166	0.160	...
6	26.24	0.1620	0.169	0.178	0.184	0.186	0.186	0.179	...
5	33.09	0.1819	...	0.200	0.206	0.208	0.208	0.202	...
4	41.74	0.2043	0.213	0.225	0.232	0.234	0.235	0.226	...
3	52.62	0.2294	0.238	0.252	0.260	0.263	0.264	0.254	...
2	66.36	0.2576	0.268	0.283	0.292	0.296	0.297	0.286	...
1	83.69	0.2893	0.299	0.322	0.332	0.333	0.333	0.321	0.313
1/0	105.6	0.3249	0.336	0.362	0.373	0.374	0.374	0.360	0.352
2/0	133.1	0.3648	0.376	0.406	0.419	0.420	0.420	0.404	0.395
3/0	167.8	0.4096	0.423	0.456	0.470	0.471	0.472	0.454	0.443
4/0	211.6	0.4600	0.475	0.512	0.528	0.529	0.530	0.510	0.498
	250	0.5000	0.520	0.558	0.575	0.576	0.576	0.554	0.542
	300	0.5477	0.570	0.611	0.630	0.631	0.631	0.607	0.594
	350	0.5916	0.616	0.661	0.681	0.681	0.682	0.656	0.641
	400	0.6325	0.659	0.706	0.728	0.729	0.729	0.701	0.685
	450	0.6708	0.700	0.749	0.772	0.773	0.773	0.744	0.727
	500	0.7071	0.736	0.789	0.813	0.814	0.815	0.784	0.766
	550	...	0.775	0.829	0.855	0.855	0.855	...	0.804
	600	...	0.813	0.866	0.893	0.893	0.893	...	0.840
	650	...	0.845	0.901	0.929	0.930	0.930	...	0.874
	700	...	0.877	0.935	0.964	0.965	0.965	...	0.907
	750	...	0.908	0.968	0.998	0.999	0.998	...	0.939
	800	...	0.938	1.000	1.031	1.032	1.032	...	0.969
	900	...	0.999	1.061	1.094	1.093	1.095	...	1.028
	1000	...	1.060	1.117	1.152	1.153	1.153	...	1.084
	1100	...	...	1.173	1.209	1.210	1.211	...	1.137
	1200	...	...	1.225	1.263	1.264	1.264	...	1.187
	1250	...	...	1.251	1.289	1.290	1.290	...	1.212
	1300	...	...	1.276	1.315	1.316	1.316	...	1.236
	1400	...	...	1.323	1.364	1.365	1.365	...	1.282
	1500	...	...	1.370	1.412	1.413	1.413	...	1.327
	1600	...	...	1.415	1.459	1.460	1.460	...	1.371
	1700	...	...	1.459	1.504	1.504	1.504	...	1.413
	1750	...	...	1.480	1.526	1.527	1.527	...	1.434
	1800	...	...	1.502	1.548	1.548	1.549	...	1.454
	1900	...	...	1.542	1.590	1.590	1.591	...	1.494
	2000	...	...	1.583	1.632	1.632	1.632	...	1.533
	2500	...	...	1.769	1.824	1.824	1.824	...	...
	3000	...	...	1.938	1.998	1.999	1.999	...	...

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

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

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

Conductor Size		Nominal Diameters (mm)							
AWG Or Kcmil	mm ²	Solid	Concentric Lay Stranded					Combination Unilay	Unilay Compressed
			Compact*	Compressed	Class B**	Class C	Class D		
8	8.37	3.26	3.40	3.58	3.71	3.76	3.76	3.63	...
7	10.6	3.67	...	4.01	4.17	4.22	4.22	4.06	...
6	13.3	4.11	4.29	4.52	4.67	4.72	4.72	4.55	...
5	16.8	4.62	...	5.08	5.23	5.28	5.31	5.13	...
4	21.1	5.19	5.41	5.72	5.89	5.94	5.97	5.74	...
3	26.7	5.83	6.05	6.40	6.60	6.68	6.71	6.45	...
2	33.6	6.54	6.81	7.19	7.42	7.52	7.54	7.26	...
1	42.4	7.35	7.59	8.18	8.43	8.46	8.46	8.15	7.95
1/0	53.5	8.25	8.53	9.19	9.47	9.50	9.50	9.14	8.94
2/0	67.4	9.27	9.55	10.3	10.6	10.7	10.7	10.3	10.0
3/0	85.0	10.4	10.7	11.6	11.9	12.0	12.0	...	11.3
4/0	107	11.7	12.1	13.0	13.4	13.4	13.5	...	12.6
250	127	12.7	13.2	14.2	14.6	14.6	14.6	...	13.8
300	152	13.9	14.5	15.5	16.0	16.0	16.0	...	15.1
350	177	15.0	15.6	16.8	17.3	17.3	17.3	...	16.3
400	203	16.1	16.7	17.9	18.5	18.5	18.5	...	17.4
450	228	17.0	17.8	19.0	19.6	19.6	19.6	...	18.5
500	253	18.0	18.7	20.0	20.7	20.7	20.7	...	19.5
550	279	...	19.7	21.1	21.7	21.7	21.7	...	20.4
600	304	...	20.7	22.0	22.7	22.7	22.7	...	21.3
650	329	...	21.5	22.9	23.6	23.6	23.6	...	22.2
700	355	...	22.3	23.7	24.5	24.5	24.5	...	23.0
750	380	...	23.1	24.6	25.3	25.4	25.3	...	23.9
800	405	...	23.8	25.4	26.2	26.2	26.2	...	24.6
900	456	...	25.4	26.9	27.8	27.8	27.8	...	26.1
1000	507	...	26.9	28.4	29.3	29.3	29.3	...	27.5
1100	557	...	...	29.8	30.7	30.7	30.8	...	28.9
1200	608	...	...	31.1	32.1	32.1	32.1	...	30.1
1250	633	...	...	31.8	32.7	32.8	32.8	...	30.8
1300	659	...	...	32.4	33.4	33.4	33.4	...	31.4
1400	709	...	...	33.6	34.6	34.7	34.7	...	32.6
1500	760	...	...	34.8	35.9	35.9	35.9	...	33.7
1600	811	...	...	35.9	37.1	37.1	37.1	...	34.8
1700	861	...	...	37.1	38.2	38.2	38.2	...	35.9
1750	887	...	...	37.6	38.8	38.8	38.8	...	36.4
1800	912	...	...	38.2	39.3	39.3	39.3	...	36.9
1900	963	...	...	39.2	40.4	40.4	40.4	...	37.9
2000	1013	...	...	40.2	41.5	41.5	41.5	...	38.9
2500	1266	...	...	44.9	46.3	46.3	46.3	...	...
3000	1520	...	...	49.2	50.7	50.8	50.8	...	...

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

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

Table 2-5*
Factors† for Determining Nominal Resistance of Stranded Conductors Per 1000 Feet at 25°C

Conductor Size	All Sizes		Diameter of Individual Coated Copper Wires in Inches for Stranded Conductors				
	Aluminum	Uncoated copper	0.460 to 0.290, Inclusive	Under 0.290 to 0.103, Inclusive	Under 0.103 to 0.0201, Inclusive	Under 0.0201 to 0.0111, Inclusive	Under 0.0111 to 0.0010, Inclusive
Concentric Stranded 8 AWG - 2000 kcmil (8.37 - 1013 mm ²)	17692	10786	11045	11102	11217	11456	11580
> 2000 - 3000 kcmil (>1013 - 1520 mm ²)	17865	10892	11153	11211	11327	11568	11694
Conductivity utilized for above factors, Percent	61	100	97.66	97.16	96.16	94.16	93.15

* The factors given in Table 2-5 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 for tin coated copper.
3. A volume resistivity of 17.345 Ω -cmil/ft (61.0% conductivity) at 25 °C for aluminum.

B. Increase in Resistance Due to Stranding

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

† See Table 2-2 for Use of Factors.

Part 3

CONDUCTOR SHIELD (STRESS CONTROL LAYER)

3.1 MATERIAL

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

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

3.2 EXTRUDED SHIELD THICKNESS

(See 9.4.2). The extruded conductor shield thicknesses are given in Table 3-1. Minimum point thickness does not apply to points of protrusions or irregularities.

Table 3-1
Extruded Conductor Shield Thickness

Conductor Size, AWG or kcmil (mm ²)	Extruded Shield Thickness	
	Minimum Point	
	mils	mm
8 - 4/0 (8.37 - 107)	12	0.30
212 - 550 (107 - 279)	16	0.41
551 - 1000 (279 - 507)	20	0.51
1001 and larger (507 and larger)	24	0.61

3.2.1 Reduced Extruded Shield Thickness

For compact round and solid conductors which have a diameter eccentricity less than or equal to 2 mils (0.051 mm) measured before the extruded shield is applied, the extruded shield thickness may be 50 percent of Table 3-1 values with prior agreement between the manufacturer and the purchaser. Except where noted, all other requirements remain unchanged. Diameter eccentricity is defined as the maximum diameter minus the minimum diameter of a given cross section.

3.3 PROTRUSIONS AND CONVOLUTIONS

(See 9.4.13). The contact surface between the extruded conductor shield and the insulation shall be cylindrical and free from protrusions either discrete or continuous, that extend more than 3 mils (0.076 mm)

into the insulation and 7 mils (0.18 mm) into the extruded conductor shield for XLPE/TRXLPE insulations and 5 mils (0.127 mm) into the insulation and 7 mils (0.18 mm) into the extruded conductor shield for EPR insulations. Strand convolutions (the tendency of the conductor shield to follow the contour of a stranded conductor surface) shall be no greater than 7 mils (0.18 mm) when measured according to Figure 9-2. For conductor shields with reduced thickness, protrusions and convolutions into the conductor shield shall not exceed 50% of the required minimum point shield thickness.

3.4 VOIDS

(See 9.4.13). The interface between the extruded conductor shield and insulation shall be free of any voids larger than 3 mils (0.076 mm).

3.5 PHYSICAL REQUIREMENTS

The crosslinked material intended for extrusion as a conductor shield shall meet the following requirements:

Table 3-2
Extruded Conductor Shield Requirements

Physical Requirements	Extruded Conductor Shield
Elongation after air oven test for 168 hours at $121 \pm 1^\circ\text{C}$ (for insulations rated 90°C) or at $136 \pm 1^\circ\text{C}$ (for insulations rated 105°C), minimum percent	100
Brittleness temperature not warmer than, $^\circ\text{C}$	-25

3.6 ELECTRICAL REQUIREMENTS

3.6.1 Extruded Semiconducting Material

(See 9.8.1). The volume resistivity of the extruded semiconducting conductor shield shall not exceed 1000 ohm-meter at the maximum normal operating temperature and emergency operating temperature.

3.6.2 Extruded Nonconducting Material (For EPR Insulation Only)

The extruded nonconducting conductor shield shall withstand a 2.0 kV dc spark test. For test frequency see Table 9-4.

(See 10.5.8). The extruded nonconducting conductor shield shall meet the following requirements at room temperature, at the maximum normal operating temperature, and emergency operating temperature:

Dielectric Constant, range 8 - 200

Minimum ac voltage (49-61 Hz) withstand stress $kV / mm = \frac{60}{\text{dielectric constant}}$

3.6.3 Semiconducting Tape

If a semiconducting tape is used over the conductor, the maximum dc resistance of the tape at room temperature shall be 10,000 ohms per unit square when determined in accordance with ASTM D 4496.

3.7 CROSSLINKED (THERMOSET) REQUIREMENTS

(See 9.4.12). The extruded conductor shield shall be effectively crosslinked as determined by the wafer boil test.

Part 4 INSULATION

4.1 MATERIAL

The insulation shall be one of the following materials meeting the dimensional, electrical, and physical requirements specified in this section:

- Filled or unfilled crosslinked polyethylene (XLPE)
- Filled or unfilled tree retardant crosslinked polyethylene (TRXLPE)
- Ethylene propylene rubber (EPR)

XLPE and TRXLPE insulations are intended for use only in cables of the "DISCHARGE-FREE" design concept.

The compound supplier shall utilize sampling plans and optical detection systems to inspect the unfilled crosslinked polyethylene or unfilled tree retardant crosslinked polyethylene insulation compound for contamination. See Appendix J.

Ethylene propylene rubber insulation has four classifications:

- I & II are for use only in cables of the "DISCHARGE-FREE" design;
- III can be used in either the "DISCHARGE-FREE" design or the "DISCHARGE-RESISTANT" design;
- IV is for use only in cables of the "DISCHARGE-RESISTANT" design.

All of the insulations are suitable for use on cables in wet or dry locations at voltages 5 through 46 kV between phases at the 100 and 133 percent insulation level. The conductor temperature shall not exceed the following:

**Table 4-1
Conductor Maximum Rated Temperatures**

Insulation Material†	Normal Operation	Emergency Overload*	Short Circuit***
XLPE, TRXLPE, and EPR Classes I, II & IV	90°C	130°C	250°C
XLPE Class III, TRXLPE Class III & EPR Class III	105°C**	140°C	250°C

*See Appendix B

**Lower temperatures for normal operation may be required because of the type of material used in the cable joints, terminations and separable connectors or because of cable environmental conditions. Cable users should be aware that all of the jackets described in Part 7 are not necessarily suitable for cables having this maximum temperature rating. Consult cable manufacturer for further information.

***Conductor fault current shall be determined in accordance with ICEA P-32-382.

†Other insulation materials composed of Ethylene and Alkene units, which are designated as EAM, may be available and can meet the same physical and electrical requirements as the insulation materials described in this standard. See Appendix I and/or contact the manufacturer for further information.

4.2 INSULATION THICKNESS

The insulation thicknesses given in Table 4-7 are based on the rated phase-to-phase circuit voltage, conductor size and cable insulation level.

The minimum thickness and maximum thickness of the insulation shall be as specified in Table 4-7 (see 9.4.2 for method of measurement).

For identification, nominal thicknesses are shown in Table 8-1.

4.2.1 Selection of Proper Thickness

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

4.2.1.1 For Three-Phase Systems with 100 or 133 Percent Insulation Level

Use the thickness values given in the respective columns of Table 4-7.

4.2.1.2 For Delta Systems Where One Phase May Be Grounded For Periods Over One Hour

Use the 173 percent thickness values given in Table 4-7. Also, see 173 percent level in Note C following Table 4-7 (Metric).

4.2.1.3 For Single- and Two-Phase Systems with 100 Percent Insulation Level

Multiply the voltage to ground by 1.73 and use the resulting voltage value or next higher rating to select the corresponding insulation thickness in the 100 percent insulation level column of Table 4-7.

4.2.1.4 For Single- and Two-Phase Systems with 133 Percent Insulation Level

Multiply the voltage to ground by 1.73 and use the resulting voltage value or next higher rating to select the corresponding insulation thickness in the 133 percent insulation level column of Table 4-7.

4.3 INSULATION REQUIREMENTS

4.3.1 Physical and Aging Requirements

When tested in accordance with Part 9, the insulation shall meet the following physical requirements:

Table 4-2
Insulation Physical Requirements

Physical Requirements	Insulation Type					
	XLPE and TRXLPE	XLPE Class III and TRXLPE Class III	EPR Class			
			I	II	III	IV
Unaged Requirements						
Tensile Strength, Minimum psi (MPa)	1800 (12.5)		700 (4.8)	1200 (8.2)	700 (4.8)	550 (3.8)
Elongation at Rupture, Minimum Percent	250		250			
Aging Requirements After Air Oven Aging for 168 hours						
Aging Temperature, °C ± 1°C	121	136	121		136	121
Tensile Strength, Minimum Percentage of Unaged Value	75		75	80	75	
Elongation, Minimum Percentage of Unaged Value Minimum Percent at Rupture	75 --		75 --	80 --	75 --	-- 175
Hot Creep Test at 150 ± 2°C	Unfilled	Filled				
*Elongation, Maximum Percent			50			
*Set, Maximum Percent			5			

*For XLPE and TRXLPE insulations if this value is exceeded, the Solvent Extraction Test may be performed and will serve as a referee method to determine compliance (a maximum of 30 percent weight loss after 20 hour drying time).

4.3.2 Electrical Requirements

4.3.2.1 Partial-Discharge Extinction Level for Discharge-Free Designs Only

(See 9.13). Each shipping length of completed cable shall be subjected to a partial discharge test. The partial discharge shall not exceed 5 picocoulombs at the ac test voltage given in Table 4-7.

4.3.2.2 Discharge (Corona) Resistance for Discharge-Resistant Designs Only

(See 10.5.6) The insulation shall be verified as corona discharge resistant using a 21 kV 49-61 Hz voltage applied for 250 hours. No failure or surface erosion visible with 15 times magnification shall occur. Partial discharge measurements are not required for DISCHARGE-RESISTANT cables.

4.3.2.3 Voltage Tests

(See 9.12). Each shipping length of completed cable shall withstand, without failure, the ac test voltages given in Table 4-7. The test voltage shall be based on the rated voltage of the cable and the size of the conductor.

Factory dc testing is not required by this specification. However, a dc test may be performed with prior agreement between the manufacturer and the purchaser. Suggested dc test voltages are listed in Appendix F.

For purposes of this standard, the BIL shall be in accordance with Table 4-6. The minimum impulse withstand value for all cable designs shall be 800 V/mil (31.5 kV/mm) except for XLPE or TRXLPE insulated cable designs rated for 15 kV where the minimum impulse withstand value shall be 1200 V/mil (47.2 kV/mm).

4.3.2.4 Insulation Resistance Test

(See 10.5.1). Each insulated conductor in the completed cable shall have an insulation resistance not less than that corresponding to a constant (K) of 20,000 megohms – 1000 ft at 15.6°C.

4.3.2.5 Dielectric Constant and Dissipation Factor

(See 10.1.7). The insulation shall meet the following maximum requirements for dielectric constant and dissipation factor at room temperature when tested in accordance with ICEA T-27-581/NEMA WC-53.

Table 4-3
Dielectric Constant and Dissipation Factor

Properties	Insulation Type				
	XLPE and XLPE Class III	TRXLPE and TRXLPE Class III	EPR Class I, II & III	EPR Class IV	
				28 kV or less	Above 28 kV
Dielectric Constant	3.5		4.0		
Dissipation Factor, Percent	0.1	0.5	1.5	2.0	1.5

4.3.3 Voids, Ambers, Gels, Agglomerates and Contaminants as Applicable

4.3.3.1 Crosslinked Polyethylene Insulation (XLPE or TRXLPE)

(See 9.4.13 and Table 9-5). The insulation of the sample examined shall be free from:

- 1) Any void larger than 3 mils (0.076 mm). The number of voids larger than 2 mils (0.051 mm) shall not exceed 30 per cubic inch (1.8 per cm³) of insulation.
- 2) Any contaminant larger than 5 mils (0.127 mm) in its greatest dimension and no more than 15 per cubic inch (0.9 per cm³) between 2 and 5 mils (0.051 and 0.127 mm).
- 3) Any amber that is larger than 10 mils (0.254 mm) in its greatest dimension.

- 4) There are no requirements for transluents in this standard.

4.3.3.2 Ethylene Propylene Rubber (EPR)

(See 9.4.13 and Table 9-5). The insulation of the sample examined shall be free from:

- 1) Any void larger than 4 mils (0.102 mm).
- 2) Any contaminant, gel, or agglomerate larger than 10 mils (0.254 mm) in its greatest dimension. A distinction between contaminants, gels, and agglomerates is not required.

4.3.4 Shrinkback - Crosslinked Polyethylene Insulation (XLPE or TRXLPE) Only

(See 9.10). The conductor shall not protrude beyond the insulation (total of both ends) by more than the amounts shown in Table 4-4 or 4-5.

Table 4-4
Shrinkback Test Requirements
Cables Having Sealed Strand Conductors and/or a Tape
Over the Conductor

Oven Cycle	Total Shrinkback mils (mm)	Action
1	0 to 20 (0.51) > 20 (0.51)	Pass: Terminate Test Record and Continue Cycling
2	0 to 40 (1.02) > 40 (1.02)	Pass: Terminate Test Record and Continue Cycling
3	0 to 320 (8.13) > 320 (8.13)	Pass: Terminate Test Fail: Terminate Test

Table 4-5
Shrinkback Test Requirements
All Cables Not Covered by Table 4-4

Oven Cycle	Total Shrinkback mils (mm)	Action
1	0 to 20 (0.51) > 20 (0.51) but ≤ 60 (1.52) > 60 (1.52)	Pass: Terminate Test Record and Continue Cycling Fail: Terminate Test
2	0 to 40 (1.02) > 40 (1.02) but ≤ 100 (2.54) > 100 (2.54)	Pass: Terminate Test Record and Continue Cycling Fail: Terminate Test
3	0 to 100 (2.54) > 100 (2.54)	Pass: Terminate Test Fail: Terminate Test

**Table 4-6
Cable BIL Values**

Cable Rating kV	BIL kV
5	60
8	95
15*	110
25	150
28	150
35	200
46	250

*Cable used for qualification test

**Table 4-7
Conductor Sizes, Insulation Thicknesses and Test Voltages**

Rated Phase-to- Phase Circuit Voltage ^a	Conductor Size, (AWG or kcmil) ^b	Insulation Thickness (mils)						a-c Test Voltage, kV ^d		
		100 Percent Level ^c		133 Percent Level ^c		173 Percent Level ^c		Insulation Level		
		Min	Max	Min	Max	Min	Max	100%	133%	173%
2001-5000	8-1000 ^e	85	120	110	145	135	170	18	23	28
	1001-3000	135	170	135	170	135	170	28	28	28
5001-8000	6-1000	110	145	135	170	165	205	23	28	35
	1001-3000	165	205	165	205	210	250	35	35	44
8001-15000	2-1000	165	205	210	250	245	290	35	44	52
	1001-3000	210	250	210	250	245	290	44	44	52
15001-25000	1-3000	245	290	305	350	400	450	52	64	84
25001-28000	1-3000	265	310	330	375	425	495	56	69	89
28001-35000	1/0-3000	330	375	400	460	550	630	69	84	116
35001-46000	4/0-3000	425	495	550	630	*	*	89	116	150

Table 4-7 (Metric)
Conductor Sizes, Insulation Thicknesses and Test Voltages

Rated Phase-to-Phase Circuit Voltage ^a	Conductor Size, (sqmm) ^b	Insulation Thickness (mm)						a-c Test Voltage, kV ^d		
		100 Percent Level ^c		133 Percent Level ^c		173 Percent Level ^c		Insulation Level		
		Min	Max	Min	Max	Min	Max	100%	133%	173%
2001-5000	8.37-506.7 ^e	2.16	3.05	2.79	3.68	3.43	4.32	18	23	28
	506.8-1520	3.43	4.32	3.43	4.32	3.43	4.32	28	28	28
5001-8000	13.3-506.7	2.79	3.68	3.43	4.32	4.19	5.21	23	28	35
	506.8-1520	4.19	5.21	4.19	5.21	5.33	6.35	35	35	44
8001-15000	33.6-506.7	4.19	5.21	5.33	6.35	6.22	7.37	35	44	52
	506.8-1520	5.33	6.35	5.33	6.35	6.22	7.37	44	44	52
15001-25000	42.4-1520	6.22	7.37	7.75	8.89	10.2	11.4	52	64	84
25001-28000	42.4-1520	6.73	7.87	8.38	9.53	10.8	12.6	56	69	89
28001-35000	53.5-1520	8.38	9.53	10.2	11.7	14.0	16.0	69	84	116
35001-46000	107.2-1520	10.8	12.6	14.0	16.0	*	*	89	116	150

Notes on Table 4-7& 4-7 (Metric):

^a 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.

^b 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.

^c 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 that are on grounded systems, they may be used also on other systems for which the application of cable is acceptable provided the above clearing requirements are met in completely de-energizing the faulting section.

Where additional insulation thickness is desired, it shall be the same as for the 133 percent insulation level.

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