

UL 1072

Medium-Voltage Power Cables



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UL Standard for Safety for Medium-Voltage Power Cables, UL 1072

Fourth Edition, Dated June 30, 2006

Revisions: This Standard contains revisions through and including September 19, 2007.

SUMMARY OF TOPICS

This revision is being issued to incorporate the following changes in requirements:

- 1. Reduction of the Assembly Jacket Thickness Under Armor for Multiconductor Cable**
- 2. Correction of the Inadvertent Deletion of "Nonshielded" from the Scope**
- 3. Correction to the Performance Criteria for the FT4/IEEE 1202 Vertical-Tray Flame Test**

Text that has been changed in any manner is marked with a vertical line in the margin. Changes in requirements are marked with a vertical line in the margin and are followed by an effective date note indicating the date of publication or the date on which the changed requirement becomes effective.

The new and/or revised requirements are substantially in accordance with UL's Proposal(s) on this subject dated June 29, 2007.

The revisions dated September 19, 2007 include a reprinted title page (page1) for this Standard.

As indicated on the title page (page 1), this UL Standard for Safety is an American National Standard. Attention is directed to the note on the title page of this Standard outlining the procedures to be followed to retain the approved text of this ANSI/UL Standard.

The UL Foreword is no longer located within the UL Standard. For information concerning the use and application of the requirements contained in this Standard, the current version of the UL Foreword is located on ULStandardsInfoNet at: <http://ulstandardsinfo.net/ulforeword.html>.

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New product submittals made prior to a specified future effective date will be judged under all of the requirements in this Standard including those requirements with a specified future effective date, unless the applicant specifically requests that the product be judged under the current requirements. However, if

the applicant elects this option, it should be noted that compliance with all the requirements in this Standard will be required as a condition of continued Listing and Follow-Up Services after the effective date, and understanding of this should be signified in writing.

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The most recent designation of ANSI/UL 1072 as an American National Standard (ANSI) occurred on September 13, 2007.

This ANSI/UL Standard for Safety, which consists of the Fourth edition with revisions through September 19, 2007 is under continuous maintenance, whereby each revision is ANSI approved upon publication.

An effective date included as a note immediately following certain requirements is one established by Underwriters Laboratories Inc.

Revisions of this Standard will be made by issuing revised or additional pages bearing their date of issue. A UL Standard is current only if it incorporates the most recently adopted revisions, all of which are itemized on the transmittal notice that accompanies the latest set of revised requirements. Comments or proposals for revisions on any part of the Standard may be submitted to UL at any time. Proposals should be submitted via a Proposal Request in UL's On-Line Collaborative Standards Development System (CSDS) at <http://csds.ul.com>.

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INTRODUCTION

1 Scope

1.1 These requirements cover the shielded and nonshielded medium-voltage power cables that are described in Tables 1.1 (single-conductor) and 1.2 (multiple-conductor). Multiple-conductor cables may include one or more individually jacketed non-conductive optical-fiber members. These electrical and hybrid electrical and optical-fiber cables are for use (optical and electrical functions associated in the case of a hybrid cable) in accordance with Article 328 and other applicable parts of the National Electrical Code (NEC), ANSI/NFPA 70.

1.1 revised September 19, 2007

1.2 These cables have one or more stranded copper or aluminum conductors that are insulated with a solid, extruded dielectric. Cables that have a metal sheath or interlocked armor incorporate an effective grounding path. A grounding conductor is optional in other cables. Cables for direct burial are so marked and have an overall covering (see 1.4 for direct-burial cables that are not covered). Cables that are for use in cable trays generally are so marked (see 62.1 and 62.2). Cables that are sunlight-resistant generally are so marked (see 64.1 – 64.3). Cables that are marked “MV-90” or “MV-90 dry” have a maximum operating temperature of 90°C (194°F). Cables that are marked “MV-105” have a maximum operating temperature of 105°C (221°F) for use where design conditions require a maximum conductor temperature above 90°C (194°F). Cables that are marked “dry” have insulation for use only in dry locations. All other cables have insulation that is for use in both wet and dry locations. Multiple-conductor cables that include one or more optical-fiber members are surface marked to so indicate. Cables that are marked “oil resistant II” are for exposure to mineral oil at temperatures not in excess of 75°C (167°F). Cables that are marked “oil resistant I” are for exposure to mineral oil at temperatures not in excess of 60°C (140°F).

1.3 A multiple-conductor Type MV cable that has a smooth (other than lead) or corrugated metal sheath or that has interlocked metal armor may be marked for use also as Type MC cable.

1.4 This standard does not include requirements for cables with concentric neutral conductors. However, it is possible to have a single-conductor cable with a concentric neutral conductor manufactured in accordance with the requirements of other standards, that meets the requirements for jacketed single-conductor shielded cable in this standard.

Table 1.1
Single-conductor Type MV cables

Table 1.1 effective June 30, 2007

Voltage rating	Size	Use	Insulation material	Percent insulation level	Insulation thicknesses	Shield	Overall covering
2400	8 AWG – 1000 kcmil	90°C (194°F) dry	XLPE or EPCV	–	Column A Table 15.3	nonshielded	None
		90°C (194°F) dry	XLPE, EPCV, DREP, or EP	–	Column B Table 15.3	nonshielded	Nonconductive jacket Column B Table 27.20
		90°C (194°F) wet or dry	XLPE, DREP, or EP	–	Column C Table 15.3	nonshielded	Nonconductive jacket Column C Table 27.20
5000	8 AWG – 2000 kcmil	90°C (194°F) or 105°C (221°F) wet or dry	XLPE, DREP, or EP	100 or 133	Table 15.1 or Table 15.2	Shielded	a
8000	6 AWG – 2000 kcmil	90°C (194°F) or 105°C (221°F) wet or dry	XLPE, DREP, or EP	100, 133, or 173	Table 15.1 or Table 15.2	Shielded	a
15000	2 AWG – 2000 kcmil	90°C (194°F) or 105°C (221°F) wet or dry	XLPE, DREP, or EP	100, 133, or 173	Table 15.1 or Table 15.2	Shielded	a
25000	1 AWG – 2000 kcmil	90°C (194°F) or 105°C (221°F) wet or dry	XLPE, DREP, or EP	100, 133, or 173	Table 15.1 or Table 15.2	Shielded	a
28000	1 AWG – 2000 kcmil	90°C (194°F) or 105°C (221°F) wet or dry	XLPE, DREP, or EP	100, 133, or 173	Table 15.1 or Table 15.2	Shielded	a
35000	1/0 AWG – 2000 kcmil	90°C (194°F) or 105°C (221°F) wet or dry	XLPE, DREP, or EP	100, 133, or 173	Table 15.1 or Table 15.2	Shielded	a

^a The overall covering consists of one of the following (see Table 26.1 for complete descriptions):

- 1) Conductive nonmetallic insulation covering (Table 17.3) as part of shielding, with or without nonmagnetic metal sheath or armor over conductive nonmetallic insulation covering as part of shielding, with or without supplementary non-conductive jacket (Table 29.1) over metal sheath or armor.
- 2) Non-conductive jacket (Table 27.18) over shielding, with or without nonmagnetic metal sheath or armor over non-conductive jacket, with or without supplementary non-conductive jacket (Table 29.1) over metal sheath or armor.
- 3) Nonmagnetic metal sheath or armor as part of shielding, with or without supplementary non-conductive jacket (Table 29.1) over metal sheath or armor.

Table 1.2
Multiple-conductor Type MV cables

Table 1.2 effective June 30, 2007

Voltage rating	Circuit conductors							Grounding conductor	Overall covering
	Size	Use	Insulation material	Percent insulation level	Insulation thicknesses	Shield	Individual covering		
2400	8 AWG – 1000 kcmil	90°C (194°F) dry	XLPE or EPCV	–	Column A Table 15.3	nonshielded	None	Optional Covered 23.1	None – assembly of single-conductor cables
		90°C (194°F) dry	XLPE, EPCV, DREP, or EP	–	Column B Table 15.3	nonshielded	Non-conductive jacket Column B Table 27.20	Optional Covered 23.1	None – assembly of single-conductor cables
		90°C (194°F) wet or dry	XLPE, DREP, or EP	–	Column C Table 15.3	nonshielded	Non-conductive jacket Column C Table 27.20	Optional Covered 23.1	None – assembly of single-conductor cables
		90°C (194°F) or 105°C (221°F) wet or dry	XLPE, DREP, or EP	–	Column C Table 15.3	nonshielded	None or Non-conductive jacket (Table 19.1)	Optional Bare 23.5	Non-conductive jacket (Table 27.18)
								Required Bare 23.1	Interlocked armor with or without Supplementary jacket
								May be required Bare 23.3 and 23.4	Metal sheath with or without Supplementary jacket

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Table 1.2 Continued

Voltage rating	Circuit conductors							Grounding conductor	Overall covering
	Size	Use	Insulation material	Percent insulation level	Insulation thicknesses	Shield	Individual covering		
5000	8 AWG – 2000 kcmil	90°C (194°F) or 105°C (221°F)	XLPE, DREP, or EP	100	Table 15.1, Table 15.2	Shielded	Non-conductive jacket (Table 27.18) over shield	Optional Covered 23.1	None
							Conductive nonmetallic insulation covering (Table 17.3) as part of shield	Optional Covered 23.1	None
							Metal sheath as part of shield with or without Supplementary jacket	Optional Covered 23.1	None
8000	6 AWG – 2000 kcmil	90°C (194°F) or 105°C (221°F) wet or dry	XLPE, DREP, or EP	100, 133, or 173	Table 15.1, Table 15.2	Shielded	None or Non-conductive jacket (Table 19.1)	Optional Bare 23.5	Non-conductive jacket (Table 27.18)
								Required Bare 23.1	Interlocked armor with or without Supplementary jacket
15000	2 AWG – 2000 kcmil	90°C (194°F) or 105°C (221°F) wet or dry	XLPE, DREP, or EP	100, 133, or 173				May be required to Bare 23.3 and 23.4	Metal sheath with or without Supplementary jacket
								Non-conductive jacket (Table 27.18) over shield	Optional Covered 23.1

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Table 1.2 Continued

Voltage rating	Circuit conductors							Grounding conductor	Overall covering
	Size	Use	Insulation material	Percent insulation level	Insulation thicknesses	Shield	Individual covering		
25000	1 AWG – 2000 kcmil	90°C (194°F) or 105°C (221°F) wet or dry	XLPE, DREP, or EP	100, 133, or 173			Conductive nonmetallic insulation covering (Table 17.3) as part of shield	Optional Covered 23.1	None
							Metal sheath as part of shield with or without supplementary jacket	Optional Covered 23.1	None
28000	1 AWG – 2000 kcmil	90°C (194°F) or 105°C (221°F) wet or dry	XLPE, DREP, or EP	100, 133, or 173	Table 15.1, Table 15.2		None or Non-conductive jacket (Table 19.1)	Optional Bare 23.5	Non-conductive jacket (Table 27.18)
								Required Bare 23.2	Interlocked armor with or without Supplementary jacket
								May be required Bare 23.3 and 23.4	Metal sheath with or without Supplementary jacket
35000	1/0 AWG – 2000 kcmil	90°C (194°F) or 105°C (221°F) wet or dry	XLPE, DREP, or EP	100, 133, or 173	Table 15.1, Table 15.2	Shielded	Non-conductive jacket (Table 27.18) over shield	Optional Covered 23.1	None
							Conductive nonmetallic insulation covering (Table 17.3) as part of shield	Optional Covered 23.1	None
							Metal sheath as part of shield with or without Supplementary jacket	Optional Covered 23.1	None

2 Units of Measurement

2.1 In addition to being stated in the inch/pound units that are customary in the USA, each numerical requirement in this standard is also stated in units that make the requirement conveniently usable in countries employing the various metric systems (practical SI and customary). Equivalent – although not necessarily exactly identical – results are to be expected from applying a requirement in USA or metric terms. Equipment calibrated in metric units is to be used when a requirement is applied in metric terms.

3 References

3.1 Wherever the designation “UL 1581” is used in this cable standard, reference is to be made to the designated part(s) of the Reference Standard for Electrical Wires, Cables, and Flexible Cords (UL 1581).

3.2 Any undated reference to a code or standard appearing in the requirements of this standard shall be interpreted as referring to the latest edition of that code or standard.

CONSTRUCTION

4 Materials

4.1 Only materials that are acceptable for the particular use shall be used in a cable.

4.2 Each material used in a cable shall be compatible with all of the other materials used in the cable.

5 General

5.1 Medium-voltage cable shall be designated as Type MV and shall comply in all respects with the applicable requirements for construction details, test performance, and markings.

CONDUCTOR(S)

6 Materials

6.1 The conductor(s) in a cable shall be of soft-annealed copper or of semi-annealed (1/2 – 3/4 hard) or hard-drawn aluminum. Soft-annealed copper wires (strands) shall comply with ASTM B 3. A metal coating that is provided on soft-annealed copper in accordance with 9.1 or 9.2 shall be of tin complying with ASTM B 33. An aluminum conductor shall comply with the Requirements for Aluminum Conductors of an 8000 Series Alloy, Section 10 of UL 1581, or shall be of a 1/2 – 3/4 hard 1350 Series aluminum alloy having either the tensile strength required for a 1350-H19 (extra-hard) aluminum alloy in the American Society for Testing and Materials Standard Specification for Aluminum 1350-H19 Wire for Electrical Purposes, ASTM B 230, or the tensile strength required for a semi-annealed 8000 Series alloy.

6.2 An individual conductor shall not be smaller than 8 AWG (8.367 mm²) and shall not be larger than 2000 kcmil or 113 mm². The nominal cross-sectional area of a conductor is indicated in Table 20.1 of UL 1581.

7 Resistance

7.1 The direct-current resistance of any length of conductor in ohms per thousand conductor feet or in ohms per conductor kilometer shall not be higher than the maximum (nominal x 1.02) resistance indicated in the applicable table in D-C Conductor Resistance, Section 30 of UL 1581, at 20°C (68°F) or at 25°C (77°F) when measured as described in D-C Conductor Resistance, Section 220 of UL 1581, except that the equipment selected shall be accurate to within 0.5 percent of the value read. If, as provided for in 11.2, metal-coated wires are used in only the outer layer of an uncoated copper conductor, the direct-current resistance of the resulting conductor shall not exceed the value tabulated for an uncoated conductor of the same size and construction. See 7.2 for cabling factors applicable to multiple-conductor cables.

7.2 In a finished multiple-conductor cable, the increased resistance of a conductor because of cabling shall not be higher than the applicable value multiplied by the following factor, with the result rounded off to the same number of decimal places as the tabulated value.

- a) One layer of conductors: 1.02
- b) More than one layer of conductors: 1.03

8 Conductor Diameter

8.1 The nominal, maximum (1.01 x nominal), and minimum (0.98 x nominal) diameters of solid and stranded conductors are shown in Tables 20.1, 20.2, 20.3, 20.3.1, 20.4, and 20.6 of UL 1581. Conductor diameter is to be measured using the method shown in Conductor Diameter, Section 200 of UL 1581.

8.2 Compressed unilay copper conductors that are smaller in diameter than the requirement (0.98 x nominal as indicated in Table 20.3 of UL 1581) for compressed concentric-lay conductors shall be marked the same as compact conductors in accordance with 70.1(n).

9 Stranding

9.1 Each conductor shall be solid: concentric-lay-stranded (in this standard, this term includes compressed-stranded and compact-stranded), with at least the number of strands indicated in Table 9.1, or shall be rope-lay-stranded. The outer layer shall be left-hand in all cases. Copper wires (strands) smaller than 36 AWG (0.005 inch or 0.127 mm in diameter) and aluminum wires (strands) smaller than 22 AWG (0.0253 inch or 0.642 mm in diameter) shall not be used.

Table 9.1
Conductor stranding

Conductor size	Number of strands in combination unilay	Minimum number of strands	
		Compact stranded	All others
8 AWG	19 ^a	7	7
7	—	7	7
6 – 2	19	7	7
1 – 4/0	19	18	19
213 – 500 kcmil	—	35	37
501 – 1000	—	58	61
1001 – 1500	—	—	91
1501 – 2000	—	—	127

^a Copper only
^b Conductors with a lesser number of strands shall be permitted based on the results of an investigation which shall include testing for connectability and bending.

9.2 A compact-stranded conductor shall be a round conductor consisting of a central core wire (one or more strands) surrounded by one or more layers of helically laid (strands). A compact-stranded copper conductor shall consist of uncoated strands. A compact-stranded aluminum conductor shall have all layers with the same direction of lay (unidirectional). A compact-stranded copper conductor shall be unidirectional or shall have the direction of lay reversed in adjacent layers (concentric-lay-stranded) and with each layer rolled, drawn, or otherwise compressively formed to change the originally round strands to various close-fitting shapes that achieve almost complete filling of the spaces originally present between the strands. Each compacted layer – including the outermost layer – shall have a smooth, round outer surface. The length of lay of the strands in the outer layer of a 1 AWG – 1000 kcmil conductor shall be 8 – 16 times the overall diameter of that layer. The length of lay of the strands in the outer layer of an 8 – 2 AWG conductor shall be 8.0 – 17.5 times the overall diameter of that layer. A compact-stranded conductor shall not be segmented.

9.3 A compressed-stranded conductor shall be a round conductor consisting of a central core wire (one or more strands) surrounded by one or more layers of helically laid (strands) having the unilay construction, the unidirectional lay construction, or with the direction of lay reversed in successive layers. The strands of one or more layers shall be slightly compressed by rolling, drawing, or other means to change the originally round strands to various shapes that achieve filling of some of the spaces originally present between the strands.

9.4 A 19-wire combination round-wire unilay-stranded soft-annealed copper or an acceptable aluminum alloy conductor shall be round and shall consist of a straight central wire, an inner layer of six wires of the same diameter as the central wire with the six wires having identical lengths of lay, and an outer layer consisting of six wires of the same diameter as the central wire alternated with six smaller wires having a diameter of 0.732 times the diameter of the central wire and with all twelve wires of the outer layer having the same length of lay and direction of lay as the six wires of the inner layer.

9.5 Concentric-lay-stranded coated or uncoated annealed copper conductors (including compressed conductors) shall comply with the applicable parts of ASTM B 8. Compact round concentric-lay-stranded uncoated copper conductors shall comply with the applicable parts of ASTM B 496.

9.6 Concentric-lay-stranded aluminum conductors (including compressed conductors) shall comply with the applicable parts of ASTM B 231. Compact stranded aluminum shall comply with the applicable parts of ASTM B 400.

9.7 The length of lay in only the outer layer of a 1 AWG – 1000 kcmil round compact-stranded conductor shall neither be less than 8 nor more than 16 times the overall diameter of that layer. The length of lay of the strands in the outer layer of a 8 – 2 AWG compact-stranded conductor shall be 8.0 – 17.5 times the overall diameter of that layer. The direction of lay of the outer layer shall be left-hand.

9.8 Every stranded conductor other than a compact-stranded conductor shall comply with the following:

- a) The direction of lay of the strands, members, or ropes in a 6 AWG – 2000 kcmil conductor other than a combination unilay, compressed unilay, or compressed unidirectional lay conductor shall be reversed in successive layers. Rope-bunched lay and rope-concentric lay conductors shall be either unidirectional or reversed.
- b) For a bunch-stranded member of a rope-lay-stranded conductor in which the members are formed into rope-stranded components that are then cabled into the final conductor, the length of lay of the individual strands within each component shall not be more than 30 times the outside diameter of one of those members.
- c) For a concentric-stranded member of a rope-lay-stranded conductor, the length of lay of the individual strands in a member shall be 8 – 16 times the outside diameter of the member. The direction of lay of the strands in each member shall be reversed in successive layers of the member.
- d) The length of lay of the strands in both layers of a 19-wire combination round-wire unilay-stranded copper or aluminum conductor shall be 8 – 16 times the outside diameter of the completed conductor. Otherwise, the length of lay of the strands in every layer of a concentric-lay-stranded conductor consisting of fewer than 37 strands shall be 8 – 16 times the outside diameter of that layer.
- e) The length of lay of the strands in the outer two layers of a concentric-lay-stranded conductor consisting of 37 or more strands shall be 8 – 16 times the outside diameter of the conductor.
- f) The length of lay of the members or ropes in the outer layer of a rope-lay-stranded conductor shall be 8 – 16 times the outside diameter of that layer.

10 Strand Filler

10.1 A moisture-excluding filler material is acceptable in the interstices of the inner layers of the conductor strands for the purpose of keeping moisture from entering the cable. Such a material shall be investigated and found acceptable. The investigation shall consist of testing to determine that the material does not have a detrimental effect on either of the following:

- a) The conductor stress relief layer – The test is described in the Insulated Cable Engineers Association Publication T-32-645, 1993 "Guide for Establishing Compatibility of Sealed Conductor Filler Compounds with Conducting Stress Control Materials".
- b) The ability to properly terminate the cable as intended – The tests are described in the Standard for Wire Connectors, UL 486A-486B. These tests could include one or all of the following: secureness, heating, pullout, and cyclic heating.

11 Metal Coating

11.1 If the insulation or other material adjacent to a copper conductor corrodes unprotected copper in the test in 32.1, each of the individual strands of that conductor shall be separately covered with a metal coating that complies with 6.1.

11.2 In the case of a copper conductor on whose wires a coating is not needed for corrosion protection but is used, it is acceptable to coat only the wires of the outer layer (see 7.1) or to coat all of the wires. The metal coating used shall comply with 6.1.

12 Joints

12.1 A joint in one of the individual wires (strands) shall be made in a workmanlike manner, shall not change the diameter of the wire (strand) or of the overall conductor, and shall not lessen the mechanical strength or impair the flexibility of the overall conductor. A joint shall not be made in the stranded conductor as a whole but, for other than a rope-lay-stranded conductor (see 12.2) shall be made by separately joining each individual wire (strand) in a manner that does not increase the overall diameter of the entire stranded conductor. A joint in a compact-stranded or compressed-stranded conductor shall be made before compacting or compressing. A joint in any conductor shall be made before the conductor-stress-relief material, the insulation, and other coverings are applied.

12.2 In a rope-lay-stranded conductor consisting of a central core surrounded by one or more layers of stranded members (primary groups), each member may be considered to be equivalent to a solid wire and, as such, may be spliced as a unit. These joints are to be dispersed throughout the length of the conductor so that the diameter and configuration of the completed conductor are not substantially affected, and so that the flexibility of the completed conductor is not adversely affected thereby. In no case shall these joints be closer together than two lay lengths.

CONDUCTOR STRESS RELIEF (CONDUCTOR SHIELDING)

13 Details

13.1 Conductor stress relief shall be provided on each circuit conductor. It shall be readily removable from the conductor and shall be bonded to the insulation (the tension necessary to remove the stress relief from the insulation is not specified). The conductor stress relief used with XLPE or EPCV insulation shall be of conductive nonmetallic material. The conductor stress relief used with EP or DREP insulation shall be of either conductive or non-conductive nonmetallic material. The conductor stress relief shall comply with Tables 13.1 (form), 13.2 (thicknesses), and 13.3 (material).

13.2 The thickness(es) of a conductive tape used alone, of a conductive or non-conductive extrusion used alone, or of a conductive or non-conductive extrusion plus a conductive tape are to be determined on a full cross section of the conductor shielding produced by cutting a specimen of the finished conductor through perpendicular to its longitudinal axis. All measurements are to be made over the tops of strands or at the impressions left by strands. In the case of a conductive tape used alone, the minimum thickness is to be measured directly by means of one of the following:

- a) A dead-weight dial micrometer having a presser foot 0.250 ± 0.010 inch or 6.4 ± 0.2 mm in diameter and exerting a total of 3.0 ± 0.1 ozf or 85 ± 3 gf or 0.84 ± 0.02 N on the specimen – the load being applied by means of a weight, or
- b) An optical device that is accurate to at least 0.001 inch or 0.01 mm.

In all other cases, the minimum thicknesses are each to be measured directly by means of an optical device that is accurate to at least 0.001 inch or 0.01 mm.

13.3 The volume resistivity of the finished conductive conductor shielding taken as a unit shall comply with 44.1. The relative permittivity and the dielectric withstand stress of specimens of the non-conductive conductor stress control shall comply with 45.1.

Table 13.1
Conductor shielding

Table 13.1 effective June 30, 2007

Voltage ratings	Construction of conductor stress relief
2400, 5000, 8000, and 15000	A conductive or non-conductive extrusion of any insulation or jacketing material mentioned in Section 14 or 27 directly on the conductor or Overlapping ^a conductive tape covered by a conductive or non-conductive extrusion of any insulation or jacketing material mentioned in Section 14 or 27 or Overlapping ^a conductive tape alone
25000, 28000, and 35000	A conductive or non-conductive extrusion of any insulation or jacketing material mentioned in Section 14 or 27 directly on the conductor or Overlapping ^a conductive tape covered by a conductive or non-conductive extrusion of any insulation or jacketing material mentioned in Section 14 or 27
^a The amount of overlap is not specified.	

Table 13.2
Thicknesses of conductor stress relief

Material	Minimum thickness at any point ^a
Conductive tape of any convenient width applied with an unspecified overlap directly to the conductor	2.5 mils or 0.06 mm
A conductive extrusion of any insulation or jacketing material mentioned in Section 14 or 27 over the above-mentioned tape or directly on the conductor.	6 mils or 0.15 mm
The properties of the material used shall comply with Table 13.3 when specimens are prepared and tested as indicated in the method to which reference is made in Table 13.3.	
^a Where both tape and extruded material are used, no reduction is acceptable in any of the specified thicknesses of the tape or extruded material.	

Table 13.3
Properties of extruded conductor stress relief

Property	Value
I. Ultimate elongation (see Section 30 for method) using 1-inch or 25-mm bench marks on specimens that first are die-cut from a specially molded slab that is not more than 0.1 inch or 2.5 mm thick and then are aged as follows in a full-draft circulating-air oven for 168 h at 121.0 ±1.0°C (249.8 ±1.8°F) for 90°C (194°F) cable or at 136.0 ±1.0°C (276.8 ±1.8°F) for 105°C (221°F) cable.	100 percent (minimum)
II. Brittleness temperature by the Acceptance Impact Procedure B described in ASTM D 746 using five die-punched specimens that are 0.25 ±0.02 inch or 6.35 ±0.51 mm wide	-10°C (+14°F) (maximum)
III. Cold – see Section 38 for method	No damage shall result

INSULATION

14 Material, Application, and Centering

14.1 Each circuit conductor shall be insulated for its entire length with a thermoset insulation that complies with Table 14.1 (XLPE), Table 14.4 (EP), Table 14.7 (EPCV), or Table 14.10 [DREP (Discharge Resistant EP)] – see 14.4 for the long-term evaluation of a thermoset insulation material not named in Table 14.1 or 14.4 or not complying with the specified short-term tests. The insulation shall be applied directly to the outer surface of the conductor stress relief and shall be bonded thereto (see 13.1). The insulation shall not have any repairs or joints and shall not have defects (bubbles, open spots, rips, tears, cuts, or foreign material) that are visible with normal or corrected vision without magnification.

14.2 The insulation in 2400 V nonshielded single-conductor cables constructed as indicated in columns A and B of Table 15.3 is not required to be for use in wet locations. Insulation that is for use in wet locations shall be used in all other single-conductor cables and in all multiple-conductor cables other than those consisting of an assembly of the 2400 V nonshielded single-conductor cables constructed without any overall covering as indicated in column A or B of Table 15.3.

14.2 effective June 30, 2007

14.3 The insulation shall have a circular cross section and shall be applied concentrically about the conductor and the conductor stress relief.

14.4 Either of the following materials that the manufacturer wishes to use as insulation or a jacket shall be evaluated for the requested temperature rating as described in Long-Term Aging, Section 481 of UL 1581:

- a) Material generically different from any insulation material that is named in 14.1 or any – jacket material that is referenced in 19.2, 27.1, or 29.1 (new material).
- b) Material that is named in 14.1 or referenced in 19.2, 27.1, or 29.1 yet does not comply with the short-term tests specified for the material.

The temperature rating of materials (a) and (b) shall be as required for the particular construction of medium-voltage cable. The thicknesses of insulation and/or jacket using materials (a) and/or (b) shall be as required for the particular construction. Investigation of the electrical, mechanical, and physical characteristics of the cable using material (a) and/or (b) shall show the material(s) to be comparable in performance to the insulation or non-conductive jacket materials named or referenced in 14.1, 19.2, 27.1, or 29.1 for the required temperature rating. The investigation shall include tests such as crushing, impact, abrasion, deformation, heat shock, insulation resistance, and dielectric voltage-withstand.

Table 14.1
Properties of XLPE^a insulation from 90°C (194°F) and 105°C (221°F) cables

Table 14.1 effective June 30, 2007

Property	Value
I. Physical properties – see Section 31 for method	See Table 14.2
II. Hot creep at 150.0 ±2.0°C (302.0 ±3.6°F) – see Section 62 for method	
Maximum elongation	Filled – 100 percent ^b Unfilled – 175 percent ^b
Maximum set	Filled – 5 percent ^b Unfilled – 10 percent ^b
III. Cold bend– see Section 38 for method	No damage shall result
IV. Heat distortion – Maximum reduction in thickness at 121.0 ±1.0°C (249.8 ±1.8°F) – see Section 34 for method	
8 – 4/0 AWG conductors (round specimens)	25 percent
250 – 1000 kcmil conductors (flat, rectangular specimens)	15 percent
V. Insulation resistance at 60.0°F (15.6°C)	See Table 14.3
VI. Accelerated water absorption, electrical method – see Section 40 for method ^c	
Maximum relative permittivity after 24 h	3.5
Maximum increase in capacitance	1 – 14 d: 3.0 percent 7 – 14 d: 1.5 percent
Maximum stability factor after 14 d ^d	1.0 percent
Maximum stability factor difference ^d	1 – 14 d: 0.5 percent
VII. Relative permittivity – see Section 41 for method ^e	Maximum – 3.5
VIII. Power factor – see Section 41 method ^e	Maximum – 2.0 percent
XI. Dry electrical test ^f	See Section 42
^a XLPE designates a cross-linked compound whose characteristic constituent is cross-linked polyethylene. For 2400 V cables only, the compound may be pigmented by the addition of carbon black. ^b Greater elongation or set is acceptable if the loss of weight does not exceed 30 percent in a solvent extraction test made as described in ASTM D 2765. ^c Not required for dry-locations cable (nonshielded 2400 V single-conductor cable insulated as indicated in column A or B of Table 15.3). ^d Only one of these tests is required [see 40.1(d)].	

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Table 14.1 Continued on Next Page



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Table 14.1 Continued

Property	Value
^e Not required for 2400 V or 5-kV cable.	
^f Required only for 105°C (221°F) cable.	

Table 14.2
Physical properties of XLPE^a insulation from 90°C (194°F) and 105°C (221°F) cables

Table 14.2 effective June 30, 2007

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength
Unaged	250 percent (2-1/2 inches or 62.5 mm)	1800 lbf/in ² or 12.4 MPa
Aged in a full-draft circulating-air oven for 168 h at 121.0 ±1.0°C (249.8 ±1.8°F) for 90°C cable or at 136.0 ±1.0°C (276.8 ±1.8°F) for 105°C cable.	75 percent of the result with unaged specimens	75 percent of the result with unaged specimens
Specimens of 75°C (167°F) oil-resistant insulation from nonshielded dry-locations 2400 V single-conductor cable insulated as indicated in column A of Table 15.3 and marked "oil resistant II" – see 70.1(h): Aged in oil (see 480.5 of UL 1581) for 60 d at 75.0 ±1.0°C (167.0 ±1.8°F)	65 percent of the result with unaged specimens	65 percent of the result with unaged specimens
Specimens of 60°C (140°F) oil-resistant insulation from nonshielded dry-locations 2400 V single-conductor cable insulated as indicated in column A of Table 15.3 and marked "oil resistant I" – see 70.1(h): Aged in oil (see 480.5 of UL 1581) for 96 h at 100.0 ±1.0°C (212.0 ±1.8°F)	50 percent of the result with unaged specimens	50 percent of the result with unaged specimens
^a XLPE designates a cross-linked compound whose characteristic constituent is cross-linked polyethylene. For 2400 V cables only, the compound may be pigmented by the addition of carbon black.		

Table 14.3
Insulation resistance of XLPE^a insulation from 90°C (194°F) and 105°C (221°F) cables

Table 14.3 effective June 30, 2007

Property	Minimum value
V. Insulation resistance at 60.0°F (15.6°C) 1) Insulation and individual non-conductive circuit-conductor jacket tested together – see Section 60 for method On jacketed nonshielded dry-locations 2400 V single-conductor cable insulated as indicated in column B of Table 15.3 On jacketed nonshielded wet-or-dry- locations 2400 V single-conductor cable insulated as indicated in column C of Table 15.3 2) Insulation alone In nonshielded dry-locations 2400 V single-conductor cable insulated as indicated in column A of Table 15.3 – see Section 60 for method In shielded single-conductor cable insulated as indicated in Table 15.1 or Table 15.2 – see Section 59 for method In shielded multiple-conductor cable insulated as indicated in Table 15.1 or Table 15.2 – see Section 59 for method In nonshielded multiple-conductor cable insulated as indicated in Table 15.1 or Table 15.2 without a non-conductive jacket on each circuit conductor – see Section 60 for method	Minimum K: 12,000 megohms based on 1000 conductor feet Minimum K: 20,000 megohms based on 1000 conductor feet or Minimum K: 6100 megohms based on a conductor kilometer
^a XLPE designates a cross-linked compound whose characteristic constituent is cross-linked polyethylene. For 2400 V cables only, the compound may be pigmented by the addition of carbon black.	

Table 14.4
Properties of EP^a insulation from 90°C (194°F) and 105°C (221°F) cables

Table 14.4 effective June 30, 2007

Property	Value
I. Physical properties – see Section 31 for method	See Table 14.5
II. Cold bend – see Section 38 for method	No damage shall result
III. Hot creep at 150.0 ±2.0°C (302.0 ±3.6°F) – see Section 65 for method Maximum elongation Maximum set	50 percent 5 percent
IV. Insulation Resistance at 60.0°F (15.6°C)	See Table 14.6
V. Accelerated water absorption ^b Electrical method – see Section 40 for method Maximum relative permittivity after 24 h Maximum increase in capacitance Maximum stability factor after 14 d ^c Maximum stability factor difference ^c	4.0 1 – 14 d: 3.5 percent 7 – 14 d: 1.5 percent 1.0 percent 1 – 14 d: 0.5 percent
VI. Relative permittivity – see Section 41 for method ^d	Maximum: 4.0
VII. Power factor – see Section 41 for method ^d	Maximum: 2.0 percent

Table 14.4 Continued

Property	Value
VIII. Dry Electrical Test ^e	See Section 42
^a EP designates a cross-linked compound whose characteristic constituent is one of the following: A copolymer (EPM) of ethylene and propylene. A terpolymer (EPDM) of ethylene, propylene, and a small amount of nonconjugated diene. A blend of EPM and EPDM.	
^b Not required for dry-locations cable (nonshielded 2400 V single-conductor cable insulated as indicated in column A or B of Table 15.3.	
^c Only one of these tests is required [see 40.1(d)].	
^d Not required for 2400 V or 5-kV cable.	
^e Required only for 105°C (221°F) cable.	

Table 14.5
Physical properties of EP^a insulation from 90°C (194°F) and 105°C (221°F) cables

Condition of specimens at time of measure	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength
Unaged	200 percent (2 inches or 50 mm)	700 lbf/in ² or 4.83 MPa
Aged in a full-draft circulating-air oven for 168 h at 121.0 ±1.0°C (249.8 ±1.8°F) for 90°C cable or at 136.0 ±1.0°C (276.8 ±1.8°F) for 105°C cable	75 percent of the result with unaged specimens	75 percent of the result with unaged specimens

^a EP designates a cross-linked compound whose characteristic constituent is one of the following:

- a) A copolymer (EPM) of ethylene and propylene.
- b) A terpolymer (EPDM) of ethylene, propylene, and a small amount of nonconjugated diene.
- c) A blend of EPM and EPDM.

Table 14.6
Insulation resistance of EP^a insulation from 90°C (194°F) and 105°C (221°F) cables

Table 14.6 effective June 30, 2007

Property	Value
IV. Insulation resistance at 60°F (15.6°C)	
Insulation and individual non-conductive circuit-conductor jacket tested together – see Section 60 for method	
On jacketed nonshielded dry-locations 2400 V single-conductor cable insulated as indicated in column B of Table 15.3	Minimum K: 12,000 megohms based on 1000 conductor feet
On jacketed nonshielded wet-or-dry-locations 2400 V single-conductor cable insulated as indicated in column C of Table 15.3	
In nonshielded multiple-conductor cable insulated as indicated in Table 15.1 or Table 15.2 with a non-conductive jacket on each circuit conductor	
Insulation alone	
In nonshielded dry-locations 2400 V single-conductor cable insulated as indicated in column A or Table 15.3 – see Section 60 for method	Minimum K: 20,000 megohms based on 1000 conductor feet

Table 14.6 Continued

Property	Value
In shielded single-conductor cable insulated as indicated in Table 15.1 or Table 15.2 – see Section 59 for method In shielded multiple-conductor cable insulated as indicated in Table 15.1 or Table 15.2 – see Section 59 for method In nonshielded multiple-conductor cable insulated as indicated in Table 15.1 or Table 15.2 without a non-conductive jacket on each circuit conductor – see Section 60 for method.	or Minimum K: 6100 megohms based on a conductor kilometer
^a EP designates a cross-linked compound whose characteristic constituent is one of the following: a) A copolymer (EPM) of ethylene and propylene. b) A terpolymer (EPDM) of ethylene, propylene, and a small amount of nonconjugated diene. c) A blend of EPM and EPDM.	

Table 14.7

Properties of EPCV^a insulation from 90°C (194°F) nonshielded 2400 V dry-locations cable

Table 14.7 effective June 30, 2007

Property	Value
I. Physical properties – see Section 31 for method	See Table 14.8
II. Cold bend – see Section 38 for method	No damage shall result
III. Hot creep at 150.0 ±2.0°C (302.0 ±3.6°F) – see Section 65 for method Maximum elongation Maximum set	50 percent 5 percent
IV. Heat distortion – Maximum reduction in thickness at 121.0 ±1.0°C (249.8 ±1.8°F) – see Section 34 for method 8 – 4/0 AWG conductors (round specimens) 250 – 1000 kcmil conductors (flat, rectangular specimens)	25 percent 15 percent
V. Insulation resistance at 60.0°F (15.6°C)	See Table 14.9
^a EPCV designates a cross-linked compound whose characteristic constituent is a covulcanizate of ethylene propylene (EP) and polyethylene (PE).	

Table 14.8
Physical properties of EPCV^a insulation from 90°C (194°F) nonshielded 2400 V dry-locations cable

Table 14.8 effective June 30, 2007

Condition of specimens at time of measurement	Minimum acceptable ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength
Unaged	200 percent (2 inches or 50 mm)	1500 lbf/in ² or 10.3 MPa
Aged in a full-draft circulating-air oven for 168 h at 121.0 ±1.0°C (249.8 ±1.8°F)	75 percent of the result with unaged specimens	75 percent of the result with unaged specimens
^a EPCV designates a cross-linked compound whose characteristic constituent is a covulcanizate of ethylene propylene (EP) and polyethylene (PE).		

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Table 14.9
Insulation resistance of EPCV^a insulation from 90°C (194°F) nonshielded 2400 V dry-locations cable

Table 14.9 effective June 30, 2007

Property	Minimum value
V. Insulation resistance at 60°F (15.6°C) Insulation and individual non-conductive circuit-conductor jacket tested together – on jacketed nonshielded, dry-locations, 2400 V single-conductor cable insulated as indicated in column B of Table 15.3 – see Section 60 for method Insulation in nonshielded dry-locations 2400 V single-conductor cable insulated as indicated in column A of Table 15.3 – see Section 60 for method	Minimum K: 12,000 megohms based on 1000 conductor feet or Minimum K: 3650 megohms based on a conductor kilometer Minimum K: 20,000 megohms based on 1000 conductor feet or Minimum K: 6100 megohms based on a conductor kilometer
^a EPCV designates a cross-linked compound whose characteristic constituent is a covulcanizate of ethylene propylene (EP) and polyethylene (PE).	

Table 14.10
Properties of DREP (discharge-resistant EP^a) insulation from 90°C (194°F) and 105°C (122°F) cables

Table 14.10 effective June 30, 2007

Property	Value	
	5 – 25kv 90°C (194°F)	5 – 35 kv 105°C (221°F)
I. Physical properties – see Section 31 for method	See Table 14.5	
II. Cold bend – See Section 38 for method	No damage shall result	
III. Hot creep at 150.0 ±2.0°C (302.0 ±3.6°F) – see Section 65 for method Maximum elongation Maximum set	30 percent 5 percent	
IV. Insulation resistance at 60.0°F (15.6°C)	See Table 14.6	
V. Accelerated water absorption ^b Electrical method – see Section 40 for method Maximum relative permittivity after 24 h Maximum increase in capacitance 1 – 14 d 7 – 14 d Maximum stability factor after 14 d ^c Maximum stability factor difference ^c	4.0 7.0 percent 4.0 percent 1.0 0.5	
VI. Relative permittivity – see Section 41 for method ^d	Maximum: 4.0	
VII. Power factor – see Section 41	Maximum: 2.0 percent	
VIII. Dry electrical test ^e	See Section 42	
^a EP designates a cross-linked compound whose characteristic constituent is one of the following: a) A copolymer (EPM) of ethylene and propylene. b) A terpolymer (EPDM) of ethylene, propylene, and a small amount of non-conjugated diene. c) A blend of EPM and EPDM.		
^b Not required for dry-locations cable (nonshielded 2400 V single conductor insulated as indicated in column B of Table 15.3.		
^c Only one of these tests is required [see 40.1(d)].		

Table 14.10 Continued

Property	Value
^d Not required for 2400 V or 5 kV cable.	
^e Required only for 105°C (221°F) cable	

Table 14.11
Physical properties of DREP (discharge-resistant EP^a) insulation from 90°C (194°F) and 105°C (122°F) cables

Condition of specimens at time of measure	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength
Unaged	250 percent (2.5 inches or 60 mm)	550 lbf/in ² or 3.79 MPa
Aged in full-draft circulating-air oven at: 121.0 ±1.0°C (249.8 ±1.8°F) for 90°C cable for 168 h or 136.0 ±1.0°C (276.8 ±1.8°F) for 105°C cable for 168 h	175 percent 75 percent of the result with unaged specimens	75 percent of the result with unaged specimens 75 percent of the result with unaged specimens
^a EP designates a cross-linked compound whose characteristic constituent is one of the following: a) A copolymer (EPM) of ethylene and propylene. b) A terpolymer (EPDM) of ethylene, propylene, and a small amount of non-conjugated diene. c) A blend of EPM and EPDM.		

15 Thicknesses

15.1 The maximum and minimum thicknesses at any point of the insulation shall comply with Table 15.1 or 15.2 (shielded single-conductor cable and shielded and nonshielded multiple-conductor cables) and the minimum average thickness and the minimum thickness at any point of the insulation shall comply with Table 15.3 (nonshielded single-conductor 2400 V cables) when determined as described in 15.2 (removal of bonded components damages the insulation) or 15.3 (insulation separable without being damaged).

15.1 effective June 30, 2007

15.2 In the case of a circuit conductor in which a bonded component (bonding to the insulation is required in 13.1 for conductor shielding and optional in 17.2 for extruded insulation shielding) cannot be removed without damage to the insulation, the thicknesses of the insulation are to be determined on a full cross section of the insulation produced by cutting a specimen of the finished conductor through perpendicular to its longitudinal axis. All measurements are to be made by means of an optical device that is accurate to at least 0.001 inch or 0.01 mm. The maximum and minimum thicknesses are to be measured directly and where an average thickness is needed (Table 15.3), the two are then to be averaged to determine the average thickness.

Table 15.1

Thicknesses, in mils, of XLPE, DREP, or EP insulation in 5 – 35 kV, shielded single- and multiple-conductor cable and of XLPE, EP, or DREP insulation in 2400 V, nonshielded multiple-conductor cable

Table 15.1 effective June 30, 2007

Voltage rating of cable (phase-to-phase circuit voltage)	Conductor size (AWG or kcmil)	Insulation thickness (mils)					
		100 percent level ^a		133 percent level ^a		173 percent level ^a	
		Minimum at any point	Maximum at any point	Minimum at any point	Maximum at any point	Minimum at any point	Maximum at any point
2400	8 – 1000	85	120	–	–	–	–
	1001 – 2000	135	170	–	–	–	–
5000	8 – 1000	85	120	85	120	135	170
	1001 – 2000	135	170	135	170	135	170
5001 – 8000	6 – 1000	110	145	135	170	165	205
	1001 – 2000	165	205	165	205	210	250
8001 – 15000	2 – 1000	165	205	210	250	245	290
	1001 – 2000	210	250	210	250	245	290
15001 – 25000	1 – 2000	245	290	305	350	400	450
25001 – 28000	1 – 2000	265	310	330	375	425	475
28001 – 35000	1/0 – 2000	330	375	400	450	555	610

^a The selection of the cable insulation level to be used is made on the basis of the fault current clearing times and other information as explained in the National Electrical Code (NEC) Table 310.64.

Table 15.2

Thicknesses, in mm, of XLPE, DREP, or EP insulation in 5 – 35 kV, shielded single- and multiple-conductor cable and of XLPE, EP, or DREP insulation in 2400 V, nonshielded multiple-conductor cable

Table 15.2 effective June 30, 2007

Voltage rating of cable (phase-to-phase circuit voltage)	Conductor size (AWG or kcmil)	Insulation thickness (mm)					
		100 percent level ^a		133 percent level ^a		173 percent level ^a	
		Minimum at any point	Maximum at any point	Minimum at any point	Maximum at any point	Minimum at any point	Maximum at any point
2400	8 – 1000	2.16	3.05	–	–	–	–
	1001 – 2000	3.43	4.32	–	–	–	–
5000	8 – 1000	2.16	3.05	2.16	3.05	3.43	4.32
	1001 – 2000	3.43	4.32	3.43	4.32	3.43	4.32
5001 – 8000	6 – 1000	2.79	3.68	3.43	4.32	4.19	5.21
	1001 – 2000	4.19	5.21	4.19	5.21	5.33	6.35
8001 – 15000	2 – 1000	4.19	5.21	5.33	6.35	6.22	7.37
	1001 – 2000	5.33	6.35	5.33	6.35	6.22	7.37
15001 – 25000	1 – 2000	6.22	7.37	7.75	8.89	10.2	11.4
25001 – 28000	1 – 2000	6.73	7.87	8.38	9.53	10.8	12.1
28001 – 35000	1/0 – 2000	8.38	9.53	10.2	11.4	14.1	15.5

^a The selection of the cable insulation level to be used is made on the basis of the fault current clearing times and other information as explained in the National Electrical Code (NEC) Table 310.64.

15.3 The thicknesses of insulation from which all bonded and other components can be removed without damage to the insulation are to be determined as described in 15.2 (basic optical method) or by one of the following methods:

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a) **DIFFERENCE METHOD** – Measurements are to be made by means of a machinist's micrometer caliper having a flat surface both on the anvil and on the end of the spindle and calibrated to read directly to at least 0.001 inch or 0.01 mm. All measurements are to be made on a length of the finished conductor from which all components over the insulation have been removed without damage to the insulation. The average thickness of the insulation is to be taken as 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 and the insulation shielding measured at the same point. The minimum thickness of the insulation is to be taken as the difference between a measurement (first measurement) made over the conductor and the conductor shielding plus the thinnest insulation wall, and the diameter over the conductor and the conductor shielding. The first measurement is to be made after slicing off the thicker side of the insulation. None of the thickness of the conductor shielding is to be included in the thickness of the insulation.

b) **DIRECT MEASUREMENT** – Measurements are to be made by means of the machinist's micrometer caliper described in (a) or by means of a dead-weight dial micrometer that exerts 10 ± 2 gf or 0.10 ± 0.02 N on a specimen through a flat, rectangular presser foot 0.078 inch by 0.375 inch or 1.98 mm by 9.52 mm. The anvil of the instrument is to be of the same dimensions as the presser foot. The instrument is to be calibrated as indicated in (a). The insulation is to be removed from a length of the finished conductor without damage to the insulation, and the maximum and minimum points are to be determined by direct measurement using the micrometer caliper or dial micrometer. The average of these determinations is to be taken as the average thickness of the insulation.

c) **REFEREE OPTICAL METHOD** – If the results obtained via the procedure described in 15.2 or in (a) or (b) above are in doubt, a micrometer microscope or other optical instrument calibrated (fine) to read directly to at least 0.0001 in or 0.001 mm is to be used. The insulation is to be removed from a length of the finished conductor without damage to the insulation and the maximum and minimum points are to be determined by direct measurement using the fine-calibration optical instrument. The average of these determinations is to be taken as the average thickness of the insulation. The results of this optical procedure are to be taken as conclusive.

Table 15.3
Thicknesses of insulation in nonshielded single-conductor cables rated 2400 V

Table 15.3 effective June 30, 2007

Size of conductor						
	Dry locations				Wet-or-dry-locations	
	XLPE or EPCV insulation without any covering over the insulation		XLPE, EPCV, DREP, or EP insulation with a non-conductive jacket over the insulation		XLPE, DREP, or EP insulation with a non-conductive jacket over the insulation	
	A		B		C	
	Minimum average thickness	Minimum thickness at any point	Minimum average thickness	Minimum thickness at any point	Minimum average thickness	Minimum thickness at any point
8 – 4/0 AWG 213 – 500 kcmil	mils					
	110	99	90	81	125	113
	120	108	90	81	140	126

Table 15.3 Continued

Size of conductor						
	Dry locations				Wet-or-dry-locations XLPE, DREP, or EP insulation with a non-conductive jacket over the insulation	
	XLPE or EPCV insulation without any covering over the insulation		XLPE, EPCV, DREP, or EP insulation with a non-conductive jacket over the insulation			
	A		B		C	
	Minimum average thickness	Minimum thickness at any point	Minimum average thickness	Minimum thickness at any point	Minimum average thickness	Minimum thickness at any point
501 – 750	130	117	90	81	155	140
751 – 1000	130	117	90	81	155	140
8 – 4/0 AWG 213 – 500 kcmil 501 – 750 751 – 1000	mm					
	2.79	2.51	2.29	2.06	3.18	2.87
	3.05	2.74	2.29	2.06	3.56	3.20
	3.30	2.97	2.29	2.06	3.94	3.56
	3.30	2.97	2.29	2.06	3.94	3.56

INSULATION SHIELDING

16 General

16.1 Insulation shielding, where required shall consist of both of the following elements:

- a) A conductive nonmetallic covering (see 17.1 – 17.8) directly over and in intimate contact with the insulation, and
- b) A nonmagnetic metal component (see 18.1) embedded in or directly over and in intimate contact with the conductive nonmetallic covering.

16.2 The insulation shielding on all of the individual conductors of a multiple-conductor cable shall be of the same physical makeup and construction.

17 Conductive Nonmetallic Covering

17.1 The conductive nonmetallic covering shall consist of a conductive extrusion of any insulation or jacketing material mentioned in Section 14 or 27 or, for 5-, 8-, or 15-kV cable, a conductive nonmetallic tape, or a conductive nonmetallic tape over a conductive nonmetallic coating. The covering shall be directly over and in intimate contact with the insulation. The covering shall enclose the insulation throughout the length of the circuit conductor. A supplementary conductive nonmetallic tape may be provided over a conductive extrusion. The covering shall be removable when the conductor is terminated or spliced (see marking requirement in 69.1).

17.2 An extruded covering that is not bonded to the insulation, a tape covering, and a coating-plus-tape covering shall be readily removable. An extruded covering may be bonded to the insulation (the means for removing a bonded covering from the insulation is not specified but typically is by means of a solvent, hot air, or a flame.) Extruded coverings with a stripping force of 3 – 24 lbf or 13.3 – 106.7 N or 1.36 – 10.9 kgf are not bonded. Bonded coverings have a stripping force greater than 24 lbf or 106.7 N or 10.9 kgf (see stripping-tension test in Section 33).

17.3 The volume resistivity of the finished extruded, tape, or coating-plus-tape covering taken as a unit shall comply with 46.1.

17.4 The properties of an extruded covering shall comply with Table 17.1 when specimens from the finished cable are prepared and tested as described in the paragraphs referenced in the table.

17.5 The thickness of an extruded covering shall not be less than indicated in Table 17.3 when measured as described in 17.6 (covering bonded to the insulation) or 17.7 (covering not bonded to the insulation).

17.6 The minimum thickness of an extruded covering that is bonded to the insulation is to be determined on a full cross section of the covering produced by cutting a specimen of the finished conductor through perpendicular to its longitudinal axis. All measurements are to be made by means of an optical device that is accurate to at least 0.001 inch or 0.01 mm. The minimum thickness is to be measured directly.

17.7 The minimum thickness of an extruded covering that is not bonded to the insulation is to be determined either optically as described in 17.6 or from measurements made on the covering removed from the finished conductor. In the latter case, direct measurements of the minimum thickness is to be made by means of a machinist's micrometer caliper having a flat surface both on the anvil and on the end of the spindle and calibrated to read directly to at least 0.001 inch or 0.01 mm.

17.8 Conductive tape may be of any convenient width, and shall be at least 2.5 mils or 0.06 mm in thickness at any point when removed from the finished conductor and measured using either of the following:

- a) A dead-weight dial micrometer that exerts 10 ± 2 gf or 0.10 ± 0.02 N on a specimen through a flat, rectangular presser foot 0.078 inch by 0.375 inch or 1.98 mm by 9.52 mm and having a flat anvil of the same dimensions as the presser foot, or
- b) A machinist's micrometer caliper having a flat surface both on the anvil and on the end of the spindle.

Each instrument is to be calibrated to read directly to at least 0.001 inch or 0.01 mm. The tape shall be applied helically with an overlap of at least 10 percent of the tape width. The tape shall be applied either directly over the insulation or over a conductive nonmetallic coating on the insulation.

Table 17.1
Properties of extruded conductive covering

Property	Value(s)
I. Physical properties – see note ^b to Table 27.11 and Section 31 for method	See Table 17.2
II. Brittleness temperature by the Acceptance Impact Procedure B described in ASTM D 746 using five die-punched specimens that are 0.25 ±0.02 inch or 6.35 ±0.51 mm wide	Maximum –10°C (+14°F)
III. Cold bend – see Section 38 for method	No damage shall result

Table 17.2
Properties of extruded conductive covering

Condition of specimens at time of measurement	From cable in which the metal component of the insulation shielding is embedded in the extruded covering		From cable in which the metal component of the insulation shielding is not embedded in the extruded covering	
	A		B	
	Minimum ultimate elongation (1 inch or 25 mm bench marks)	Minimum tensile strength	Minimum ultimate elongation (1 inch or 25 mm bench marks)	Minimum tensile strength
Unaged	100 percent (1 inch or 25 mm)	1200 lbf/in ² or 8.27 MPa	Not measured	Not measured
Aged in a full-draft circulating-air oven for 168 h at 121.0 ±1.0°C (249.8 ±1.8°F) for 90°C (194°F) cable, or at 136.0 ±1.0°C (276.8 ±1.8°F) for 105°C (221°F) cable	100 percent (1 inch or 25 mm)	85 percent of the result with unaged specimens	100 percent (1 inch or 25 mm)	Not measured
Specimens of 75°C (167°F) oil-resistant jacket from cable marked "oil resistant II" – see 70.1(h):	65 percent of the result with unaged specimens		Oil resistance is not applicable	
Aged in oil (see 480.5 of UL 1581) for 60 d at 75.0 ±1.0°C (167.0 ±1.8°F)				
Specimens of 60°C (140°F) oil-resistant jacket from cable marked "oil resistant I" – see 70.1(h)	65 percent of the result with unaged specimens		Oil resistance is not applicable	
Aged in oil (see 480.5 of UL 1581) for 96 h at 100.0 ±1.0°C (212.0 ±1.8°F)				

Table 17.3
Thicknesses of extruded conductive nonmetallic covering

Calculated minimum ^c diameter over insulation	On single-conductor cable in which the metal component of the insulation shielding is embedded in the extruded covering ^a	In jacketed multiple- conductor cable in which the metal component of the insulation shielding is embedded in the extruded covering ^b	In single- and multiple- conductor cable in which the metal component of the insulation shielding is not embedded in the extruded covering
	A	B	C
	Minimum thickness at any point	Minimum thickness at any point	Minimum thickness at any point
inches	mils		
0 – 0.700	60	24	24
Over 0.700 but not over 1.000	60	40	24
Over 1.000 but not over 1.500	64	40	24
Over 1.500 but not over 2.000	80	64	24
Over 2.000 but not over 2.500	90	64	24
mm	mm		
0 – 17.78	1.52	0.61	0.61
Over 17.78 but not over 25.40	1.52	1.02	0.61
Over 25.40 but not over 38.10	1.63	1.02	0.61
Over 38.10 but not over 50.80	2.03	1.63	0.61
Over 50.80 but not over 63.50	2.29	1.63	0.61
^a Acceptable as the overall cable jacket.			
^b Acceptable as an individual jacket (conductive insulation covering service as a jacket as well as part of the insulation shielding) on the insulated conductor (see 19.1 – 19.4).			
^c The minimum diameter over the insulation is to be the sum of the minimum conductor diameter; twice the minimum thickness at any point of the conductor stress relief; and twice the minimum thickness at any point of the insulation.			

18 Nonmagnetic Metal Component

18.1 The metal component shall be nonmagnetic, shall be electrically continuous throughout the length of the insulated conductor, and shall consist of one or a combination of the constructions detailed in Table 18.1.

Table 18.1
Construction of metal component of insulation shielding

Form	Material and dimensions ^a	Application	
		Manner	Placement throughout the length of the insulated conductor
Tape or tapes	Copper of any convenient width and at least 2.5 mils or 0.06 mm thick or Other nonmagnetic metal of any convenient width and of a thickness that results in a conductance at least that of copper that is 2.5 mils or 0.06 mm thick	Helically applied or Corrugated and longitudinally applied with an unspecified overlap	Directly over and in intimate contact with the conductive nonmetallic covering
Straps	Copper having an effective cross-sectional area of at least 5000 circular mils (0.004 square inch) per inch of diameter over the insulation or of at least 0.01 square millimeter per millimeter of diameter over the insulation	Helically or longitudinally applied	Directly over and in intimate contact with the conductive nonmetallic covering
Wires	or Other nonmagnetic metal having an effective cross-sectional area that results in a conductance at least that of the copper mentioned above	Helically or longitudinally applied	Directly over and in intimate contact with the conductive nonmetallic covering
		Helically applied	Directly over and in intimate contact with the conductive nonmetallic covering
		Corrugated and longitudinally applied	Embedded (0.005 inch or 0.13 mm minimum thickness at any point) in extruded insulation shielding (see 17.2, 17.4, and 17.5) with none of the metal exposed at either the inner or outer surface of the extruded insulation shielding before and after the cold-bend test in 38.1
Wire ^b braid		Applied around the underlying construction	Directly over and in intimate contact with the conductive nonmetallic covering