

IEEE Recommended Practice for Marine Cable for Use on Shipboard and Fixed or Floating Facilities

IEEE Industry Applications Society

Sponsored by the
Marine Industry Standards Committee

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IEEE Recommended Practice for Marine Cable for Use on Shipboard and Fixed or Floating Facilities

Sponsor

Marine Industry Standards Committee
of the
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Abstract: Requirements are given for single or multiconductor cables, with or without metal armor and/or jacket, and rated 300 V to 35 kV, intended to be installed aboard marine vessels, fixed and floating offshore facilities, and in accordance with industry installation standards and the regulations of the authorities having jurisdiction (AHJ).

Keywords: marine cable, offshore facilities, platforms, shipboard

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1. Overview

1.1 Scope

This recommended practice contains the requirements for single or multiconductor cables, with or without metal armor and/or jacket, and rated 300 V to 35 kV (RMS phase-to-phase), intended to be installed aboard marine vessels, fixed and floating offshore facilities, and in accordance with industry installation standards and the regulations of the authorities having jurisdiction (AHJ).

The recommendations define what is considered good engineering practice with reference to the reliability and durability of the cable.

1.2 Purpose

This revision will incorporate the latest developments in marine cable materials and performance enhancements.

1.3 Vessel classification

Marine vessels and offshore facilities are grouped as follows:

- *Group 1:* Ocean-going vessels that navigate on any ocean, gulf, bay, sound, lake, or river.
- *Group 2:* Fixed and floating offshore facilities on any ocean, gulf, bay, sound, lake, or river.

These recommendations have been prepared for application to all vessels in groups 1 and 2. Recreational vessels are governed by other standards.

1.4 Cable construction, testing, and certification

Electrical cable should be constructed and tested in accordance with this recommended practice and referenced industry standards. The cable should be listed or classified by a nationally recognized testing laboratory (NRTL) in accordance with this recommended practice.

2. Normative references

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used, so each referenced document is cited in text and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

API RP 2A-WSD, Recommended Practice for Planning, Designing and Constructing Fixed Offshore Platforms—Working Stress Design.¹

API RP 14F, Recommended Practice for Design and Installation of Electrical Systems for Fixed and Floating Offshore Petroleum Facilities for Unclassified and Class 1, Division 1 and Division 2 Locations.

API RP 14FZ, Recommended Practice for Design and Installation of Electrical Systems for Fixed and Floating Offshore Petroleum Facilities for Unclassified and Class 1, Zone 0, Zone 1 and Zone 2 Locations.

ASTM B3, Standard Specification for Soft or Annealed Copper Wire.²

ASTM B8, Standard Specification for Concentric-Lay-Stranded Copper Conductors, Hard, Medium-Hard, or Soft.

ASTM B33, Standard Specification for Tinned Soft or Annealed Copper Wire for Electrical Purposes.

ASTM B172, Standard Specification for Rope-Lay-Stranded Copper Conductors Having Bunch-Stranded Members, for Electrical Conductors.

¹API publications are available from the Publications Section, American Petroleum Institute, 1200 L Street NW, Washington, DC 20005, USA (<http://www.api.org/>).

²ASTM publications are available from the American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959, USA (<http://www.astm.org/>).

ASTM B173, Standard Specification for Rope-Lay-Stranded Copper Conductors Having Concentric-Stranded Members, for Electrical Conductors.

ASTM B174, Standard Specification for Bunch-Stranded Copper Conductors for Electrical Conductors.

ASTM B496, Standard Specification for Compact Round Concentric Lay Stranded Copper Conductor.

ASTM D470, Standard Methods of Testing Crosslinked Insulations and Jackets for Wire and Cable.

ASTM D4066 Type VIII, Standard Classification System for Nylon Injection and Extrusion Materials (PA).

CSA C22.2 No. 0.3, Test Methods for Electrical Wires and Cables.³

ICEA P-45-482, Short Circuit Performance of Metallic Shields and Sheaths on Insulated Cables.⁴

ICEA T-28-562, Test Method for Measurement of Hot Creep of Polymeric Insulations.

IEC 60068-2-6, Environmental testing.⁴

IEC 60228, Conductors of insulated cables.

IEC 60331-11, Tests for electric cables under fire conditions—Circuit Integrity.

IEC 60331-21, Tests for electric cables under fire conditions—Circuit Integrity-Cables of rated voltage up to and including 0.6/1.0 kV.

IEC 60331-23, Tests for electric cables under fire conditions—Circuit Integrity-Electric data cable.

IEC 60331-25, Tests for electric cables under fire conditions—Circuit Integrity-Optical fibre cable.

IEEE Std 45™, IEEE Recommended Practice for Electric Installations on Shipboard.^{5, 6}

IEEE Std 1202™, IEEE Standard for Flame Propagation Testing of Wire and Cable.

MIL-STD-167-1 (ships), Mechanical Vibrations of Shipboard Equipment.⁷

NEMA WC 54/ICEA T-26-465, Guide for Frequency of Sampling Extruded Dielectric Power, Control, Instrumentation, and Portable Cables for Test.⁸

³CSA publications are available from the Canadian Standards Association (Standards Sales), 178 Rexdale Blvd., Etobicoke, Ontario, Canada M9W 1R3 (<http://www.csa.ca/>).

⁴IEC publications are available from the Sales Department of the International Electrotechnical Commission, Case Postale 131, 3, rue de Varembe, CH-1211, Genève 20, Switzerland/Suisse (<http://www.iec.ch/>). IEC publications are also available in the United States from the Sales Department, American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036, USA.

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⁷ MIL publications are available from Customer Service, Defense Printing Service, 700 Robbins Ave., Bldg. 4D, Philadelphia, PA 19111-5094.

⁸NEMA publications are available from Global Engineering Documents, 15 Inverness Way East, Englewood, CO 80112, USA (<http://global.ihs.com/>).

NEMA WC 57/ICEA S-73-532, Standard for Control, Thermocouple Extension, and Instrumentation Cables.

NEMA WC 70/ICEA S-95-658, Standard for Nonshielded Power Cables Rated 2000 V or Less for the Distribution of Electrical Energy.

NEMA WC 71/ICEA S-96-659 Standards for Nonshielded Cable Rated 2001-5000V for use in the Distribution of Electrical Energy.

NEMA WC 74/ICEA S-93-639, 5-46 kV Shielded Power Cable For Use in the Transmission and Distribution of Electrical Energy.

UL 44, Thermoset-Insulated Wires and Cables.⁹

UL 1072, Medium-Voltage Power Cables.

UL 1569, Metal-Clad Cables.

UL 1581, Reference Standard for Electrical Wires, Cables, and Flexible Cords.

UL 1685, Standard Vertical-Tray Fire-Propagation and Smoke-Release Test for Electrical and Optical-Fiber Cables.

UL 2196, Tests for Fire Resistive Cables.

3. Definitions, acronyms, and abbreviations

3.1 Definitions

For the purposes of this document, the following terms and definitions apply. *The IEEE Standards Dictionary: Glossary of Terms & Definitions* should be referenced for terms not defined in this clause.¹⁰

3.1.1 alternating current (ac): A periodic current with an average value over a period of time of zero. (The term refers to a current that reverses at regularly recurring intervals of time and that has alternately positive and negative values.)

3.1.2 ampacity: The current that a device can carry within specified temperature limitations in a specified environment.

3.1.3 approved: Acceptable to the authority having jurisdiction (AHJ). Electrical devices, which carry NRTL approval, are normally acceptable.

⁹ UL standards are available from Global Engineering Documents, 15 Inverness Way East, Englewood, CO 80112, USA (<http://global.ihs.com/>).

¹⁰ *The IEEE Standards Dictionary: Glossary of Terms & Definitions* is available at <http://shop.ieee.org/>.

3.1.4 bending radius: The minimum inside radius at which a cable can be bent without causing damage to the cable.

3.1.5 capacitance (capacity): That property of a system of conductors and dielectrics that permits the storage of electricity when potential differences exist between the conductors. Its value is expressed as the ratio of a quantity of electricity to a potential difference. A capacitance value is always positive.

3.1.6 continuous duty: A requirement of service that demands operation at a constant load for an indefinite period of time.

3.1.7 continuously welded and corrugated metal-clad cable (CWCMC): *See:* MC cable.

3.1.8 copper-free or low copper content aluminum: Aluminum alloys containing 0.4% or less copper.

3.1.9 current: The rate of transfer of electricity.

3.1.10 cycle: The complete series of values of a periodic quantity that occurs during a period. (It is one complete set of positive and negative values of an alternating current.)

3.1.11 derating: Lowering of the cable ampacity.

3.1.12 direct current (dc): A unidirectional current in which the changes in polarity are zero or so small that they may be neglected. (As ordinarily used, the term designates a nonpulsating current.)

3.1.13 discharge resistant cable: Cable that has been deemed to be highly resistant to corona discharge in accordance with the requirements of NEMA WC 74, subclauses 3.3.2 and 9.16, for discharge resistant cables.

3.1.14 festooned cable: Flexible cable that is installed in hanging loops to facilitate movement as on a trolley system used to move cargo or equipment as part of a crane or hoisting device.

3.1.15 frequency: The number of periods occurring in unit time of a periodic quantity, in which time is the independent variable.

3.1.16 halogen-free: A material with a halogen content of less than 0.2% by weight.

3.1.17 hertz (Hz): The unit of frequency, one cycle per second.

3.1.18 incidental motion: Repeated flexing as listed in Title 46 CFR Subchapter J, clause 111.60-23, and defined in MC cable with the test in 5.17.14 of IEEE Std 977-2010.

3.1.19 jacket/sheath: a nonmetallic protective covering over the cable core is considered a jacket. When it is applied over the armor, it is considered a sheath.

3.1.20 marine cable: *See:* shipboard cable, marine.

3.1.21 metal-clad (MC) cable: Continuously welded and corrugated metal-clad cable as defined by UL 1569.

The following definitions apply to the use of continuously welded and corrugated metal (CWCMC) armored cables:

3.1.21.1 flexing, repeated: Items that exceed the average wave motion of one wave every 13 s (4.6 waves per minute) as defined in API RP 2A-WSD for platforms, or for ships the average revolutions of a ship propeller times the number of blades on the propeller.

NOTE—The repeated flexing test in 5.17.14 reflects the actual type of incidental motion that the cable would be subjected to when installed aboard ship with the cable securely fastened at intervals not exceeding 2 m or installed in a raceway.¹¹

3.1.21.2 movement, excessive: Any motion at less than the bending radius of the cable.

3.1.21.3 twisting: Flexing and bending at less than the bending radius of the cable.

3.1.21.4 vibration, high: Items that exceed the vibration limitations shown in Table 1.

Table 1—Vibration limitations

Frequency range (Hz)	Amplitude, mm (in)
4–15	0.763 ± 0.152 (0.030±0.006)
16–25	0.508 ± 0.102 (0.020±0.004)
26–33	0.254 ± 0.051 (0.010±0.002)
34–40	0.128 ± 0.025 (0.005±0.001)
40–50	$0.076 + 0.000 - 0.025$ (0.003+0.000-0.001)

3.1.22 medium voltage (MV) cable: Medium voltage cable rated 2.4 kV to 35 kV as defined by UL 1072.

3.1.23 oil-resistant: Ability to withstand exposure to oil.

NOTE—As defined in 5.17.8.

3.1.24 shipboard cable, marine: Armored or unarmored cable constructed in accordance with this recommended practice, and listed or classified by a nationally recognized testing laboratory (NRTL).

3.1.25 sunlight-resistant: Ability to withstand exposure to direct sunlight as defined by UL 1581 Section 1200 using a 720 h exposure.

3.2 Acronyms and abbreviations

ABS	American Bureau of Shipping
AHJ	authority having jurisdiction
API	American Petroleum Institute
AWG	American Wire Gauge
CDA	Copper Development Association

¹¹ Notes in text, tables, and figures are given for information only and do not contain requirements needed to implement the standard.

CFR	Code of Federal Regulations
CSA	Canadian Standards Association
CWCMC	continuously welded and corrugated metal clad
ETL	Intertek Testing Services
ICEA	Insulated Cable Engineers Association
IEC	International Electrotechnical Commission
NEMA	National Electrical Manufacturer Association
NRTL	nationally recognized testing laboratory (as recognized by OSHA)
OSHA	Occupational Safety and Health Administration
UL	Underwriters Laboratories Inc.
USCG	United States Coast Guard
VFD	variable frequency drive

4. Government codes, rules, and regulations

Federal regulatory agencies have established certain requirements for the design, installation, and operation of facilities in marine applications. These requirements may influence the design, installation, and operation of the electrical systems. The following codes may pertain to offshore oil and gas producing operations and should be used when applicable:

- a) CFR Title 30, Part 250, Oil and Gas and Sulfur Operation in the Outer Continental Shelf (U.S. Department of the Interior, Minerals Management Service).
- b) CFR Title 33, Subchapter N, Outer Continental Shelf Activities, Parts 140–147 (USCG).
- c) CFR Title 46, Shipping Subchapter I-A, Parts 107-108, Mobile Offshore Drilling Units (USCG).
- d) CFR Title 46, Shipping Subchapter J. Electrical Engineering, Parts 110–113 (USCG).

5. Cable construction

5.1 Conductors

5.1.1 General

The conductors should be of soft annealed copper wire. All conductors should be tin-coated where necessary for the application. Solid conductors shall not be used.

5.1.2 Composition

Conductors should be manufactured in accordance with the most current edition of following: ASTM B3, B8, B33, B172, B173, B174, B496, B784, B787, or in accordance with IEC 60228 Class 2 or Class 5.

CAUTION

Care should be taken when mixing IEC and ASTM conductors due to the inherent differences in conductor resistance values.

Verification of conductor size shall be determined by the maximum DC resistance value given in Table 10 or Table 11. The nominal cross sectional area of a conductor is also shown in these tables for reference purposes only and is not a requirement.

5.1.3 Stranding

The construction requirements and nominal resistance of standard Class B concentric conductors shall be in accordance with Table 10. Compact stranded conductors may not be used in cables rated 0–2000 V in areas that are subject to vibration or flexing.

Combination stranded, compressed stranded to a reduction in diameter of 3% maximum of concentric stranded conductors, flexible stranded conductors, or conductors as described in Table 11 may be substituted for Class B concentric stranded conductors.

5.1.4 Separator

Where required to ensure free stripping, a suitable separator tape may be applied to the conductor.

The separator shall be colored or shall be opaque to make the separator clearly distinguishable from the conductor once the insulation is removed. The color shall be other than copper, silver, green, or green and yellow and shall be solid, striped, or in some other pattern.

5.2 Conductor shield

A conductor shield should be used on conductors of cables rated 2001 V or higher.

The conductor shield should be an extruded semiconducting compound to a minimum thickness of 0.305 mm (0.012 in). The semiconducting compound should have an operating temperature equal to or greater than that of the overlying layer of insulation. It should be firmly bonded to the overlying layer of insulation with no protrusions into the insulation exceeding 0.254 mm (0.010 in). A semiconducting nonmetallic tape with a minimum thickness of 0.0635 mm (0.0025 in) may be used over the conductor and under the extruded semiconducting layer.

The extruded conductor shield should have a maximum volume resistivity of 100 000 $\Omega\cdot\text{cm}$ (39 370 $\Omega\cdot\text{in}$) at room temperature and at the maximum normal operating temperature of the cable. The extruded

conductor shield should meet the following requirements when tested according to procedure in UL 1072 or NEMA WC 74.

- a) Elongation after air oven at 121 ± 1 °C (249 ± 2 °F) for 168 h, minimum 100%
- b) Brittleness temperature, not warmer than -10 °C (14 °F)

For discharge resistant cables the conductor shield shall consist of a nonconducting high permittivity extruded compound as designated in NEMA WC 74, subclauses 3.3.2 and 9.16.

5.3 Insulation

5.3.1 General

The insulation should be one of the types shown in Table 2. For 5000 V and above, Type E(EP) or Type X(XL) rated at 105 °C (221°F) meeting UL 1072 may be used.

Table 2—Insulation types

Insulation-type designation			Max conductor temperature °C (°F)
T	PVC	Polyvinylchloride	75 (167)
T/N	PVC/polyamide	Polyvinylchloride/nylon	90 (194)
E	EPR	Ethylene propylene rubber	90 (194)
X	XLPE	Cross-linked polyethylene	90 (194)
LSE	LSEPR	Low-smoke, halogen-free ethylene propylene rubber	90 (194)
LSX	LSXLPO	Low-smoke, halogen-free cross-linked polyolefin	90 (194)
LSS ^a	LS-Silicone	Low-smoke, halogen-free silicone rubber	100 (212)
S ^a	Silicone	Silicone rubber	100 (212)
P	XLPO	Cross-linked polyolefin	100 (212)

^aWhere specifically listed by an NRTL, Composite Insulation consisting of silicone rubber with a crosslinked polyolefin outer covering in accordance with Table 15 of UL-44 is acceptable.

5.3.2 Properties

The physical and electrical properties of Type(s) T, T/N, E, X, LSE, LSX, LSS, S, and P insulation materials should meet the requirements of Table 12, Table 13, or Table 14. The material of the nylon jacket for Type T/N should additionally meet the requirements of ASTM-D4066 Type VIII. The manufacturer should perform type tests and periodic testing to ensure insulation materials meet these requirements.

5.3.3 Thickness of insulation

The insulation thicknesses of 300–2000 V rated cables shall be in accordance with Table 15 with the minimum thickness at any point being not less than 90% of the minimum average.

Insulation thicknesses of 2001–35000 V rated cables shall be in accordance with UL 1072 or NEMA WC74. For non-shielded 2.4 kV cables, the insulation and jacket thicknesses shall be in accordance with those for wet location use. When the fault clearing time exceeds one hour, a 173% insulation level thickness shall be used.

5.4 Insulation shield (5–35 kV shielded cable)

Shielded cable rated 5–35 kV shall contain an insulation shield in accordance with UL 1072.

The insulation shield compound should be free stripping from the underlying insulation. Minimum adhesion requirements, per UL 1072, shall be maintained.

Cables described in 5.18.4, 5.18.6, 5.18.8, and 5.18.9 shall have nonmagnetic metallic shielding.

5.4.1 Rating of metallic shield

When specified by the user, the metallic shield, or combination of metallic shield and grounding conductors (optional), shall have sufficient cross-sectional area to carry the ground fault current for the time duration specified. The ICEA P-45-482 method shall be used for calculating the cross-sectional area.

5.5 Tapes

Where binder or separator tapes are provided, a polyester film tape or compound-filled tape should be used. Where a compound-filled tape is used, the tape should be made from fabric treated on one or both sides with an insulating compound.

5.6 Glass braid

Silicone rubber insulated conductors should be covered with a glass braid with a minimum of 80% coverage. The glass braid, if used, shall be treated with a suitable antifraying coating. The glass braid is optional for silicone insulated cables that meet the IEC 60331 or UL-2196 circuit integrity flame test.

5.7 Conductor identification

Conductor identification of distribution and control cables should be printed with alphanumeric characters on solid colored insulation. Example: “1-ONE,” “2-TWO,” etc. or “1-BLACK,” “2-WHITE,” etc., per color code in Table 22 or Table 23. The legend shall be repeated at intervals not exceeding 8 cm (3 in). The characters shall be clear and legible. Colored insulation may be used as an alternate.

An insulated conductor functioning as a grounding conductor (normally not a current carrying conductor) in a distribution system shall be colored green or green with yellow stripe.

Conductor identification of signal cable is as follows:

- a) Pairs should contain one black insulated conductor and one white (or red) insulated conductor. The pair number should be identified on the pair. Pair numbering should be sequential.
- b) Triads should contain one black insulated conductor, one white insulated conductor, and one red insulated conductor. The triad number should be identified on the triad. Triad numbering should be sequential.
- c) Quads should contain one black insulated conductor, one white insulated conductor, one red insulated conductor, and one green (or blue) insulated conductor. The quad number should be identified on the quad. Quad numbering should be sequential.

5.8 Equipment grounding conductor (optional)

5.8.1 Equipment grounding conductors

Cables are manufactured with or without a bare or insulated equipment grounding (or bonding) conductor. When an insulated equipment grounding (or bonding) conductor is provided, the color of the insulation shall be green or green with yellow stripes. The insulation shall be of the same material and, for cables rated 2 kV or less, have the same voltage rating as the circuit conductors. The minimum size of the grounding conductor shall be in accordance with Table 3. The grounding conductor (bare or insulated) may be a single conductor or segmented (see 5.8.2 for size limitations).

5.8.2 Segmentation

A grounding conductor smaller than 14 AWG shall not be segmented. A segmented grounding conductor shall not have any part (segment) smaller than 18 AWG. A copper grounding conductor shall not be distributed helically (concentric).

5.8.3 Grounding conductors for cables rated 2001 V and higher

Grounding conductors for cables rated 2001 V and higher shall be in accordance with UL 1072.

5.8.4 Cables installed in parallel

When cables are installed in parallel, the grounding conductor sizes given in this subclause may not be adequate.

Table 3—Grounding conductor sizes (for cables rated 2 kV or less)

AWG or kcmil size of circuit conductors	Minimum grounding conductor size, AWG		
	75°C (167°F) rated conductors	90°C (194°F) rated conductors	100°C (212°F) rated conductors
20	20	20	20
18	18	18	18
16	16	16	16
14	14	14	14
12	12	12	12
10	10	10	10
8	10	10	8
6	8	8	8
5	8	8	6
4	8	6	6
3	6	6	6
2	6	6	6
1	6	6	6
1/0	6	6	6
2/0	6	4	4
3/0	4	4	4
4/0	4	4	3
250	4	3	3
263	4	3	3
313	3	3	3
350	3	3	2
373	3	2	2
444	3	2	1
500	2	2	1
535	2	2	1
646	2	1	1/0
750	1	1/0	1/0
777	1	1/0	1/0

5.9 Cabling

Conductors, pairs, triads, quads, or groups of conductors should be cabled in concentric layers. Lay lengths should be in accordance with Table 4.

Table 4—Cable or unit lay

No. of conductors or units	Maximum lay length
2 conductors or units	$30 \times$ individual conductor or unit diameter
3 conductors or units	$35 \times$ individual conductor or unit diameter
4 conductors or units	$40 \times$ individual conductor or unit diameter
5 or more conductors or units	$15 \times$ calculated overall diameter of the outer layer

5.10 Fillers

Fillers should be non-hygrosopic and compatible with other cable components. Fillers may be used, as necessary, to give the completed cable a substantially circular cross section.

Fillers used in low-smoke, halogen-free cables shall comply with the halogen content requirements for Type LSE, LSX, and LSS insulations per Table 13.

5.11 Specialty cables

Special cables for specific applications shall be in accordance with 24.6 of IEEE Std 45-2002. Cables covered in Clause 5 may include optical fiber members or other specialty cables to form a composite cable. Composite cables must pass the IEEE 1202 flame test.

5.12 Shielding

When required, instrumentation and signal cables shall contain shielded components, which may consist of shielding over single conductors, pairs, triads, groups, and/or the completed cable core.

5.12.1 Individually shielded components and overall shielding

5.12.1.1 Shield types and drains

The shielding should consist of either aluminum/polyester or copper/polyester tape applied helically with a minimum overlap of 25% with a drain wire or a bare or tin coated copper braid. Where an aluminum/polyester tape shield is used, a tin coated copper, stranded drain wire should be applied in contact with the aluminum side.

The size of the drain wire should be no less than two sizes smaller than the circuit conductor size. The smallest acceptable drain wire size shall be a 22 AWG or 0.32 mm².

Where a braided tin coated or bare copper shield is used, it should be constructed using a minimum of 36 AWG wire. The minimum coverage should be 85%.

Individually shielded components shall be isolated from each other. The measured shield-to-shield insulation resistance shall not be less than 0.305 megohm-km (1.0 megohm-1000 ft) after a one minute application of 500 VDC.

5.12.1.2 Shield identification

Cables with individual and overall shielding should be identified as such in accordance with 5.19.

5.13 Cable jackets

5.13.1 General

The jacket should be thermoplastic Type T (PVC) or TPO (TPPO), Thermoset Type CP (CSPE), CPE, N (PCP), P (XLPO) or L (XLPO) complying with the requirements of Table 14, Table 16, or Table 17. The manufacturer should perform type tests and periodic testing to insure jacket materials meet these requirements. The temperature rating of a jacket may be less than that of the insulation with the difference in temperature ratings not exceeding 15 °C (27 °F).

5.13.2 Thickness of overall jacket

The minimum average thickness of the cable jacket is shown in Table 18. The minimum thickness at any point should not be less than 80% of the minimum average values shown. For cables armored with CWCMT, the outer sheath thicknesses should be in accordance with UL 1569.

5.14 Armor

5.14.1 General

Armor should be basket-weave type braid or continuously welded and corrugated metal. The armor is not to be used as a shield or grounding conductor but must be grounded.

5.14.2 Basket-weave armor

The armor should consist of wire laid closely together, flat and parallel, and forming a basket weave that should firmly grip the cable. The wire should be 0.32 mm diameter ± 0.01 mm (0.0126 in diameter ± 0.0004 in), and should be free from cracks, splits, or other flaws. The wire should be commercial bronze, aluminum, stainless steel, or tinned copper. The weave should be either the one-over-one under or the two-over-two under type. The selection of the number of ends per carrier and the number of carriers per braider should be such as to produce a basket weave with a braid angle and coverage within the limits shown in Table 5.

Table 5—Braid angle and coverage

Diameter over jacket (mm)	Diameter over jacket (in)	Percent coverage		Braid angle	
		Min	Max	Min	Max
0–15.24	0–0.600	88	94	30	60
15.25–25.4	0.601–1.000	88	94	35	60
25.41–38.1	1.001–1.500	88	94	40	70
38.11–50.8	1.501–2.000	88	94	45	70
50.81 and larger	2.001 and larger	88	94	50	80

The percent coverage = $(2F - F^2) 100$ and

$$F = \frac{NPd}{\sin a}$$

where

a = angle of braid with axis of cable:

$$\tan a = \frac{2 \pi DP}{C}$$

d = diameter of individual braid wire (mm)
 C = number of carriers
 D = diameter of cable under armor (mm)
 N = number of wires per carrier
 P = picks per mm of cable length

5.14.2.1 Aluminum armor

Aluminum armor braid should be aluminum alloy 5154 or an equivalent alloy having a minimum tensile strength of 350 N/mm² (50000 lbf/in²) and a minimum elongation of 2% in 254 mm (10 in). An overall sheath is required on cables with an aluminum braid armor when installed in wet environments.

5.14.2.2 Commercial bronze armor

Commercial bronze armor braid should be annealed 90-10 bronze; Copper Development Association (CDA) alloy number 220.

5.14.2.3 Tin-coated copper armor

Tin-coated copper armor braid should meet the requirements of ASTM B33. An overall sheath is required on cables with a tin-coated armor.

5.14.2.4 Stainless steel armor

Stainless steel armor braid should be made out of annealed austenitic steel, American Iron and Steel Institute, AISI steel no. 304, 304L or 316, 316L. The suffix "L" denotes a stainless steel grade with a carbon content below 0.03%.

5.14.3 Continuously welded and corrugated metal armor

This armor should be a continuously welded and corrugated metal tube in accordance with the requirements of UL 1569 (Type MC cable). The armor material should be copper free aluminum alloy (containing no more than 0.4% of copper), commercial bronze, copper, or stainless steel. An overall sheath is required on cables with a continuously welded and corrugated metal armor of aluminum or copper.

5.15 Overall sheath

Where an overall sheath is applied, the sheath material should be in accordance with the requirements for cable jackets in 5.13. An optional separator may be used over the armor to ensure strippability.

5.16 Dimension and weight tolerances

The dimensional and weight values given in Table B.1 through Table B.16 are for informational purposes only. As these values vary from manufacturer to manufacturer, a consultation is recommended with individual manufacturers for specific dimensional and weight values.

5.17 Performance tests on finished cable

Finished cable should be tested in accordance with the requirements shown in Table 6.

Table 6—Performance test requirements

Test to be performed	Test categories		
	Type test (TT) ^a	Production sample (PST) ^b	Routine test (RT) ^c
Insulation (Table 12, Table 13, Table 14, and Table 15)	X	X ⁱ	—
Jacket (Table 16, Table 17, and Table 18)	X	X ^{d,i}	—
High voltage (5.17.1)	—	X	X
Partial discharge (5.17.2)	—	—	X
Conductor resistance (5.17.3)	—	—	X
Insulation resistance (5.17.4)	—	—	X
Flammability (5.17.5)	X	X ^e	—
Ease of stripping (5.17.6)	—	X	—
Salt water immersion (5.17.7)	X	—	—
Cable immersion in oil (5.17.8)	X	—	—
Pull-through metal plates (5.17.9)	X	—	—
Bending endurance (5.17.10)	X	—	—
Cold bend test (5.17.11)	X	—	—
Cold impact test (5.17.12) (optional)	X ^f	—	—
Vibration (5.17.13)	X ^g	—	—
Incidental motion (repeated flexing) (5.17.14)	X ^h	—	—

Table 6—Performance test requirements

Test to be performed	Test categories		
	Type test (TT) ^a	Production sample (PST) ^b	Routine test (RT) ^c
Insulation discharge resistance test (5.17.15)	X	—	—

^aType tests (TT)—Type tests are the minimum initial testing for a manufacturer to determine compliance with this recommended practice. TT should be qualified by a third party NRTL as meeting this recommended practice. Unless otherwise specified, TT should be performed on a 3 conductor 6 AWG cable for power and distribution, 7 conductor 12 or 14 AWG cable for control, and a 7 or 8 pair 18 AWG for signal cables. Any other cables in their respective cable designation for distribution, control, or signal that are 23 mm (0.9 in) in diameter or larger may also be considered representative. This does not relieve the manufacturer from ensuring compliance with the test requirements for all cable types and sizes.

^bProduction sample tests (PST)—Production sample tests should be performed at the frequency established in NEMA WC 54 (ICEA T-26-465). Where no frequency is identified for a particular test in NEMA WC 54 (ICEA T-26-465), the testing frequency should be determined by the NRTL.

^cRoutine tests (RT)—Routine tests should be performed on each length of finished cable.

^dPST for Sunlight Resistance and mechanical water absorption as related to the jacket/sheath shall be done at a frequency of every three years.

^ePST for flammability, as related to the insulation/jacket/sheath shall be done at a frequency of every three years.

^fThis test applies to Transport Canada requirements test at -35°C (-31°F) cold impact test per subclause 4.13 of CSA 22.2 No. 03.

^gThis test applies to Type MC (CWCMC) for use in areas of high vibration.

^hThis test applies to Type MC (CWCMC) for use in areas of repeated flexing.

ⁱPST for smoke, acid gas, and toxicity tests as related to the insulation/jacket/sheath shall be done at a frequency of every three years.

5.17.1 High-voltage test

Each reel of finished cable should be tested and successfully withstand for a period of five minutes the high-voltage ac test potential given in Table 19, as applicable. The ac potential should be applied between conductor (or conductors) and the metallic sheath, metallic shield, metallic armor, or water, as applicable, as described in 5.17.1.1, 5.17.1.2, 5.17.1.3, or 5.17.1.4. The voltage shall be applied in accordance with UL 1581 Section 820.4.

5.17.1.1 Nonshielded or unarmored cable

Each reel of single conductor nonshielded or unarmored cable should be immersed in water for at least 6 h. The ac test potential should be applied between the insulated conductor and the metal water tank or other electrode immersed in the water if the tank is nonmetallic. For single conductor cables, rated 0–2000 V manufactured without shield or armor, the spark test requirement of UL 1581, section 900, with the values of Table 20 may be used in lieu of wet tank testing.

5.17.1.2 Shielded or armored cable

For shielded or armored single conductor cables, the voltage tests should be applied between the conductor and the shield or armor.

5.17.1.3 Cables having 2 to 5 conductors

For cables having from 2 to 5 conductors, with or without metallic armor, the voltage tests should be applied in turn between each conductor and all other conductors connected together and to the metal covering, if any.

5.17.1.4 Cables having more than five conductors

For cables having more than five conductors, the voltage test should be applied as follows:

- a) Between all conductors of uneven number in all layers and all conductors of even number in all layers
- b) Between all conductors of even layers and all conductors of uneven layers
- c) Between the first and last conductors of each layer where there are an uneven number of conductors

5.17.2 Partial discharge test

Shielded cables rated 5 kV and higher shall comply with the partial discharge test requirements as follows. In every length of finished cable, the partial discharge extinction level of each shielded circuit conductor shall not exceed 5 picocoulombs at the AC test voltage given in Table 19. This test is not applicable to discharge resistant cables.

5.17.3 Conductor resistance test

Conductor resistance should be measured on finished cable in accordance with the procedures outlined in UL 1581, section 220, and corrected to 20 °C (68 °F) or 25 °C (77 °F). Maximum resistance values should be in accordance with the appropriate standards referenced in 5.1.2.

5.17.4 Insulation resistance test (see Annex E for metric version)

Each reel of finished multiconductor cable should have the insulation resistance measured between each conductor and all other conductors, including other metallic components if present, tied together.

For shielded single conductor cables, the insulation resistance is measured between the conductor and shield.

For single conductor cables rated 0–2000 V manufactured without shield or armor, the insulation resistance test is not required when spark tested according to the spark test requirement of UL 1581, section 900, with the values of Table 20 in this recommended practice.

5.17.4.1 Method of test

Compliance with the insulation resistance test is determined in accordance with the method described in Clause 4.28.2 of CSA Standard C22.2 No. 03 or UL 1581. The insulation resistance constant K can be obtained from Table 12, Table 13, or Table 14 for the specific insulation under test.

The current should be measured after one minute with a continuous dc potential of not less than 100 V nor more than 500 V, the conductor being negative to ground. If the test for insulation resistance is carried out in water or air having a temperature differing from 60 °F, the measured value should be multiplied by the proper correction factor, M , obtained from Table 21. This factor appears in the formula for insulation resistivity as follows:

$$R = KM \log_{10}(D/d)$$

where

R = insulation resistivity [$M\Omega \cdot 1000$ ft]

K = insulation resistance constant (from Table 12, Table 13, or Table 14) ($M\Omega \cdot 1000$ ft)

M = temperature correction factor to 60 °F

D = diameter over the insulation

d = diameter under the insulation

The factor M should be determined in accordance with the method of 5.17.4.2.

The measured insulation resistivity is related to the measured insulation resistance of the sample under test by the following formula:

$$R = 0.001 R_{\text{meas}} L$$

where

R = insulation resistivity [$M\Omega \cdot 1000$ ft]

R_{meas} = measured insulation resistance ($M\Omega$)

L = length of the test sample (ft)

5.17.4.2 Test procedure for determining the multiplying-factor column for adjusting insulation resistance (see Annex E for metric version)

5.17.4.2.1 Samples

Two samples, conveniently of a No. 14, 12, or 10 AWG solid conductor with a 0.045 in or 45 mil wall of insulation, are to be selected as representative of the insulation under consideration. The samples are to be of a length (at least 200 ft) that yields insulation-resistance values that are stable within the calibrated range of the measuring instrument at the lowest water-bath temperature.

5.17.4.2.2 Water bath temperature

The two samples are to be immersed in a water bath equipped with heating, cooling, and circulating facilities. The ends of the samples are to extend at least 2 ft above the surface of the water to reduce electrical leakage. The samples are to be left in the water at room temperature for 16 h before adjusting the bath temperature to 50.0 °F or before transferring the samples to a 50.0 °F bath.

5.17.4.2.3 DC resistance

The dc resistance of the metal conductor is to be measured at applicable intervals of time until the temperature remains unchanged for at least five minutes. The insulation is then to be considered as being at the temperature of the bath indicated on the bath thermometer.

5.17.4.2.4 Test temperatures

Each of the two samples is to be exposed (5.17.4.2.3 applies) to successive water temperatures of 50.0 °F, 61.0 °F, 72.0 °F, 82.0 °F, and 95.0 °F, and returning 82.0 °F, 72.0 °F, 61.0 °F, and 50.0 °F. Insulation-resistance readings are to be taken at each temperature after equilibrium is established.

5.17.4.2.5 Plot

The two sets of readings (four readings in all) taken at the same temperature are to be averaged for the two samples. These four average values and the average of the single readings at 95.0 °F are to be plotted on semilog paper. A continuous curve (usually a straight line) is to be drawn through the five points. The value of insulation resistance at 60.0 °F is then to be read from the graph.

5.17.4.2.6 Results

The resistivity coefficient C for a 1 °F change in temperature is to be calculated to two decimal places by dividing the insulation resistance at 60.0 °F read from the graph by the insulation resistance at 61.0 °F. The temperature correction factor M required to correct to the standard test temperature of 60.0 °F is then calculated from the following formula:

$$M = C^{(t - 60)}$$

where

t is the actual test temperature in degrees Fahrenheit

5.17.5 Flammability test

All cable constructions covered in Clause 5 should be flame retardant and should meet IEEE Std 1202.

Cables meeting the flame and smoke requirements of UL 1685, Vertical Tray Fire-Propagation and Smoke-Release Test for Electrical and Optical-Fiber Cables (FT4/IEEE 1202 flame test with optical density check) may bear the “ST1” (limited smoke) marking. Cable damage height may not exceed 1.5 m (4.9 ft) as measured from the lower edge of the burner face and total smoke release may not exceed 150 m² (1615 ft²) with a peak rate of smoke release not to exceed 0.40 m²/s (4.3 ft²/s).

Cables designated fire resistant (-FS), in addition to meeting the flame test of IEEE Std 1202, should also meet the circuit integrity flame test with the equipment of IEC 60331-11 and the procedures of IEC 60331-21 for cables rated to and including 1000 V; IEC 60331-23 for electric data cable; or IEC 60331-25 for

optical fiber cable. Optionally, and in addition to the IEC 60331 testing stated previously, cables that pass the UL 2196 (tested without conduit) test may be so identified.

UL 1581 VW-1 is a requirement for insulated conductors installed as single conductors outside a metallic enclosure (switchboard, conduit, pipe, electrical box, etc.). Compliance should be determined by testing a 14 AWG or smaller insulated conductor.

5.17.6 Ease of stripping test

Cable should be tested in accordance with the following procedure:

- a) A specimen of multiple conductor cable approximately 38 cm (15 in) long should have its jacket and filler material cut using a razor blade or similar instrument.
- b) The cut should be longitudinally and vertically down to the insulation for approximately 15 cm (6 in).
- c) A second cut around the circumference of the cable is to be made at the end of the first cut.
- d) The resulting jacket piece is then to be removed by pulling at right angles away from the cable. When the jacket is removed, the cable core should show no evidence of damage. Remaining particles, which can be removed by light brushing, are acceptable.
- e) A 76 mm (3 in) length of the insulation should be stripped from a sample length of the finished stranded conductor and the outer layer of strands opened. When the insulation is removed, there should be no evidence of insulation compound beneath the outer layer of conductor strands.

5.17.7 Salt water immersion test

Cable should be tested in accordance with the following procedure:

Three 1.1 m (3.6 ft) lengths of cable should be immersed in a 20% (by weight) common salt (sodium chloride) solution at $60^{\circ}\text{C} \pm 1^{\circ}\text{C}$ ($140^{\circ}\text{F} \pm 2^{\circ}\text{F}$) for 240 h. The cable should be immersed in a U-bend such that each leg of the U-bend of the cable is 30 cm (12 in) above the water.

After immersion in salt water, the cable should comply with the following:

- a) The cable should pass the dielectric voltage withstand test described in 5.17.1.
- b) The mechanical properties of the jacket or insulation should not be degraded to the point where they will crack when wound around a mandrel having a diameter equal to nine times the sample overall diameter.
- c) The insulation and jacket should not degrade to the point where either will crack or separate from the cable during the conditioning or during the testing described in items a) or b) above.