



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

STANDARDS

IEEE Industry Applications Society

Developed by the
Petroleum and Chemical Industry Committee

IEEE Std 1580™-2021
(Revision of IEEE Std 1580-2010)



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of the
IEEE Industry Applications Society

Approved 9 November 2021

IEEE SA Standards Board

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Abstract: This recommended practice is for single or multiconductor cables, with or without metal armor and/or jacket, and rated 300 V to 35 kV AC (RMS phase-to-phase) or up to 2000 V dc, 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.

Keywords: IEEE 1580™, marine cable, offshore facilities, platforms, shipboard

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⁴ Available at: <https://standards.ieee.org/standard/index.html>.

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Participants

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Rudy Bright, *Chair*
Damian Billeudeau, *Secretary*

John Abel
Ettore Bartolucci
Evangeline Cometa
Altin Dabulla

Tony Davenport
Michael Hammons
Paul Knapp

Art Maldonado
Gary Savage
Mark Thiele
Wayne Walters

The following members of the individual Standards Association balloting group voted on this recommended practice. Balloters may have voted for approval, disapproval, or abstention.

John Amy
James Babcock
Ettore Bartolucci
Damian Billeudeau
Rudy Bright
Gustavo Brunello
William Byrd
Paul Cardinal
William Chen
James Conrad
Tony Davenport
Donald Dunn
Robert Durham
Michael Edds
Mark Fillip

Victor Garcia
J. Travis Griffith
Randall Groves
Michael Hammons
Chris Heron
Lee Herron
Werner Hoelzl
Christel Hunter
Ben C. Johnson
Yuri Khersonsky
Paul Knapp
Robert Konnik
Wei-Jen Lee
William McBride
Lorraine Padden
Kevin Peterson

Joseph Piff
Ryandi Ryandi
Gary Savage
Bartien Sayogo
Robert Seitz
Nikunj Shah
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Jerry Smith
Gary Smullin
Gregory Steinman
John Vergis
Wayne Walters
Kenneth White
Jian Yu
Charles Yung

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Chenhui Niu
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Annette Reilly
Dorothy Stanley

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Lei Wang
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Howard Wolfman
Daidi Zhong

*Member Emeritus

Introduction

This introduction is not part of IEEE Std 1580-2021, IEEE Recommended Practice for Marine Cable for Use on Shipboard and Fixed or Floating Facilities.

Prior to 2001, IEEE Std 45™, Recommended Practice for Electrical Installations on Shipboard, was the standard that addressed the construction, testing, and installation of marine wire and cable for shipboard use on commercial vessels or military coastal vessels. With the advancement and expansion of new insulation and jacketing materials, as well as new uses and applications for the cables (for example, offshore oil and gas drilling and production facilities, variable frequency drives, critical circuits requiring fire resistance, etc.), it was decided to move the content related to the construction details and testing requirements for these cables to a standalone document. IEEE Std 1580™, Recommended Practice for Marine Cable for use on Shipboard and Fixed or Floating Facilities, was first published in 2001. It was subsequently revised in 2010. The second revision incorporated changes in technology and addressed revisions to referenced standards.

For topics related to the selection and installation of these cables, the user should refer to IEEE Std 45.8™.

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1. Overview

1.1 Scope

This recommended practice ~~is contains the requirements~~ for single or multiconductor cables, with or without metal armor and/or jacket, and rated 300 V to 35 kV ~~ac~~ (RMS phase-to-phase); ~~or up to 2000 V dc~~, 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

[IEEE Std 1580™ provides a consensus of recommended practices for the construction and testing of electrical power, signal, control, data, and specialty marine cable systems on shipboard.](#)

~~6. Cable application and installation~~

For cable application and installation guidelines refer to [IEEE Std 45.8™ for shipboard applications and API RP14F or API RP14FZ, as applicable, for fixed and floating offshore facilities](#) ~~and IEEE Std 45 for shipboard~~. Other cables not listed in this document are provided in [IEEE Std 45.8, API RP14F, and API RP14FZ,](#) ~~and IEEE Std 45.~~

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

1.3 Word usage

[The word *shall* indicates mandatory requirements strictly to be followed in order to conform to the standard and from which no deviation is permitted \(*shall* equals *is required to*\).^{1, 2}](#)

[The word *should* indicates that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others; or that a certain course of action is preferred but not necessarily required \(*should* equals *is recommended that*\).](#)

[The word *may* is used to indicate a course of action permissible within the limits of the standard \(*may* equals *is permitted to*\).](#)

[The word *can* is used for statements of possibility and capability, whether material, physical, or causal \(*can* equals *is able to*\).](#)

¹ [The use of the word *must* is deprecated and cannot be used when stating mandatory requirements, *must* is used only to describe unavoidable situations.](#)

² [The use of *will* is deprecated and cannot be used when stating mandatory requirements, *will* is only used in statements of fact.](#)

1.4 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 [group](#) ~~groups~~ 1 and [group](#) 2. Recreational vessels are governed by other standards.

1.5 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.^{[3](#)} ~~†~~

^{[3](#)} ~~†~~API publications are available from the ~~Publications Section~~, American Petroleum Institute, ~~1200 L Street NW, Washington, DC 20005, USA~~ (<https://www.api.org/>).

ASTM B3, Standard Specification for Soft or Annealed Copper Wire.⁴ ~~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.

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 B784, Standard Specification for Modified Concentric-Lay-Stranded Copper Conductors for Use in Insulated Electrical Cables](#)

[ASTM B787, Standard Specification for 19 Wire Combination Unilay-Stranded Copper Conductors for Subsequent Insulation](#)

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).

~~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.~~

⁴ ~~2~~ASTM publications are available from the American Society for Testing and Materials, ~~100 Barr Harbor Drive, West Conshohocken, PA 19428-2959, USA~~ ([https](https://www.astm.org/) ~~http~~://www.astm.org/).

~~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.~~

~~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.^{5 4}

[ICEA T-24-380, Standard for Partial Discharge Test Procedure.](#)

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

IEC 60068-2-6, Environmental testing.^{6 4}

IEC 60228, Conductors of insulated cables.

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

IEC 60331-^{1 21}, Tests for electric cables under fire conditions—Circuitry integrity—[Part 1: Test Method for Fire with Shock at a Temperature of at Least 830C for Cables of Rated Voltage up to and including 0.6/1.0 kV and with an Overall Diameter Exceeding 20mm.](#)

[IEC 60331-2, Tests for electric cables under fire conditions—Circuitry integrity—Part 2: Test Method for Fire with Shock at a Temperature of at Least 830C for Cables of Rated Voltage up to and including 0.6/1.0 kV and with an Overall Diameter Not Exceeding 20mm.](#)

⁵ ~~ICEA 3CSA~~ publications are available from the [Insulated Cable Engineers Canadian Standards Association \(Standards Sales\)](#), 178 Rexdale Blvd., Etobicoke, Ontario, Canada M9W 1R3 ([https http://www.icea.org/esa-ca](https://www.icea.org/esa-ca)).

^{6 4} IEC 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~~ ([https http://www.iec.ch/](https://www.iec.ch/)), ~~and 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. (https://www.ansi.org/).~~

IEC 60331-~~3~~ ²³, Tests for electric cables under fire conditions—Circuitry integrity-[Part 3: Test Method for Fire with Shock at a Temperature of at Least 830C for Cables of Rated Voltage up to and including 0,6/1,0 kV tested in a metal enclosure](#) ~~Electric data cable~~.

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

IEEE Std 45.⁸TM, IEEE Recommended Practice for [Electrical](#) ~~Electric~~ Installations on Shipboard:—[Cable Systems](#). ^{7, 8} ~~5, 6~~

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

MIL-STD-167-1 (ships), Mechanical Vibrations of Shipboard Equipment.⁹ ~~7~~

[NEMA WC 53/ICEA T-27-581, Standard Test Methods for Extruded Dielectric Power, Control, Instrumentation, and Portable Cables for Test](#).⁸

NEMA WC 54/ICEA T-26-465, Guide for Frequency of Sampling Extruded Dielectric Power, Control, Instrumentation, and Portable Cables for Test.¹⁰ ~~8~~

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

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¹⁰ ~~8~~NEMA publications are available from [the National Electrical Manufacturers Association \(<https://www.nema.org/>\)](#) ~~Global Engineering Documents, 15 Inverness Way East, Englewood, CO 80112, USA (<http://global.ihs.com/>).~~

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 2001-5000 V 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.

[NMX-J-451-ANCE/CSA C22.2 No. 38/UL 44, Thermoset-Insulated Wires and Cables.](#)¹¹ 9

[NMX-J-556-ANCE/CSA C22.2 No. 2556/UL 2556, Wire and Cable Test Methods.](#) UL 1072, Medium-Voltage Power Cables.

UL 1569, Metal-Clad Cables.

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

UL ²¹⁹⁶ ~~1685~~, Standard [for Vertical-Tray](#) Fire ~~Propagation and Smoke Release~~ Test for [Circuit Integrity of Fire-resistive Power, Instrumentation, Control, and Data](#) ~~Electrical and Optical Fiber~~ Cables.

[UL 2556, Wire and Cable Test Methods.](#)

~~UL 2196, Tests for Fire-Resistive Cables.~~

¹¹ 9UL ~~publications standards~~ are available from Underwriters Laboratories (<https://www.ul.com/>). ~~Global Engineering Documents, 15 Inverness Way East, Englewood, CO 80112, USA (<http://global.ihs.com/>).~~

3. Definitions, acronyms, and abbreviations

3.1 Definitions

For the purposes of this document, the following terms and definitions apply. The *IEEE Standards Dictionary* [Online should be consulted](#); ~~Glossary of Terms & Definitions should be referenced~~ for terms not defined in this clause. ¹² ~~10~~

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.)

ampacity: The current that a device [or cable](#) can carry within specified temperature limitations in a specified environment.

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

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

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.

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

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

¹² ~~10~~ The *IEEE Standards Dictionary: Online Glossary of Terms & Definitions* is available at: <http://dictionary.shop.ieee.org/>. [An IEEE Account is required for access to the dictionary, and one can be created at no charge on the dictionary sign-in page.](#)

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

current: The rate of transfer of electricity.

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.)

derating: Lowering of the cable ampacity.

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.)

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.

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.

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.¹³ ~~11~~

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

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

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

¹³ ~~11~~Notes in text, tables, and figures are given for information only and do not contain requirements needed to implement the standard.

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.

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.

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

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

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

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

oil-resistant: Ability to withstand exposure to oil.

NOTE—As defined in 5.17.8.

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).

sunlight-resistant: Ability to withstand exposure to direct sunlight as defined by [the requirements in this document and the method in NMX-J-556-ANCE/CSA C22.2 No. 2556/UL 2556, Weather \(sunlight\) resistance](#) ~~1581 Section 1200 using a 720 h exposure.~~

twisting: [Cause to rotate around something that remains stationary.](#)

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

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

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

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)

3.2 Acronyms and abbreviations

AHJ authority having jurisdiction

AWG american wire gauge

~~ABS American Bureau of Shipping~~

~~API American Petroleum Institute~~

CFR code of federal regulations

CWCMC continuously welded and corrugated metal clad

~~CSA Canadian Standards Association~~

~~CDA Copper Development Association~~

~~ETL Intertek Testing Services~~

~~ICEA Insulated Cable Engineers Association~~

~~IEC International Electrotechnical Commission~~

NRTL nationally recognized testing laboratory (as recognized by OSHA)

~~NEMA National Electrical Manufacturer Association~~

~~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 [construction and](#) 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–[V to](#) 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 [such as Classes H, I, K and M](#), or conductors as described in Table 11 may be substituted for Class B concentric stranded conductors.

5.1.4 Separator

Where required to [improve](#) ~~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). [Protrusions should be measured in accordance with NEMA WC 53, 3.4, Protrusion and Convolution Measurement.](#) 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 ~~1000~~ ~~100-000~~ $\Omega\cdot\text{m}$ (39 370 $\Omega\cdot\text{in}$) at room temperature and at the maximum normal operating temperature of the cable. [when tested in accordance with NEMA WC53 or UL 1072.](#)

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			Maximum conductor temperature °C (°F)
T	PVC	Polyvinylchloride	75 (167)
T/N	PVC/polyamide	Polyvinylchloride/nylon	90 (194)
E ^b	EPR	Ethylene propylene rubber	90 (194)
X ^b	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	110 (230)

^a Where specifically listed by an NRTL, Composite Insulation consisting of silicone rubber with a crosslinked polyolefin outer ~~layer covering~~ in accordance with Table 15 or Table 17, as applicable, of UL-44 is acceptable.

^b For 5000 V and above, Type E (EP) or Type X (XLPE) meeting UL 1072, may be rated 90 °C or 105 °C.

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 V to ~~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 2400 V to ~~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 kV to ~~–~~35 kV shielded cable)

Shielded cable rated 5 kV to ~~–~~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 [as determined by NMX-J-451-ANCE/CSA C22.2 No. 38/UL 44, Appendix F](#). The glass braid, if used, shall be treated with a suitable antifraying coating. The glass braid is [not required](#) ~~optional~~ for silicone insulated cables that meet the IEC 60331 [\(-1, -2, or -3, as applicable\)](#) 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 [23](#) ~~22~~ or Table [24](#) ~~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~~ 2400 V and higher

Grounding conductors for cables rated ~~2001~~ 2400 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	110 °C (230 °F) rated conductors
20	20	20	20	20
18	18	18	18	18
16	16	16	16	16
14	14	14	14	14
12	12	12	12	12
10	10	10	10	10
8	10	10	8	8
6	8	8	8	8
5	8	8	6	6

(New)

4	8	6	6	6
3	6	6	6	6
2	6	6	6	6
1	6	6	6	6
1/0	6	6	6	4
2/0	6	4	4	4
3/0	4	4	4	4
4/0	4	4	3	3
250	4	3	3	3
263	4	3	3	3
313	3	3	3	2
350	3	3	2	2
373	3	2	2	2
444	3	2	1	1
500	2	2	1	1
535	2	2	1	1
646	2	1	1/0	1/0
750	1	1/0	1/0	1/0
777	1	1/0	1/0	1/0

(New)

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

(Deleted)

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-hygroscopic 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

Specialty ~~Special~~ cables for specific applications should ~~shall~~ be in accordance with 4.4 ~~24.6~~ of IEEE Std 45.8TM-2016 ~~2002~~. Cables covered in Clause 5 may include optical fiber members or other specialty cables to form a composite cable. Composite cables shall ~~must~~ pass the IEEE Std 1202TM 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, [as recommended by an NRTL, to ensure](#) ~~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 [20](#) ~~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 CWCMC, 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 [according to the formulas that follow](#).

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 [is the](#) = angle of braid with axis of cable:

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

[where](#)

d [is the](#) = diameter of individual braid wire (mm)

C [is the](#) = number of carriers

D [is the](#) = diameter of cable under armor (mm)

N [is the](#) = number of wires per carrier

P [is the](#) = 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/mm^2 (50000 lbf/in^2) 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; [Unified Numbering System \(UNS\)](#) ~~Copper Development Association (CDA)~~ alloy number [C22000](#) ~~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 [improve](#) ~~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 ^h	—
Jacket (Table 16, Table 17, and Table 18)	X	X ^{dh}	—
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	—	—
Vibration (5.17.13)	X ^f	—	—
Incidental motion (repeated flexing) (5.17.14)	X ^g	—	—
Insulation discharge resistance test (5.17.15)	X	—	—

^a Type 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.

^b Production 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 [or as stated in this document](#).

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

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

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

~~F~~^g This test applies to Type MC (CWCMC) for use in areas of high vibration.

~~G~~^h This test applies to Type MC (CWCMC) for use in areas of repeated flexing.

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

~~f~~ This 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.

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 [or Table 20](#), 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 [the dielectric voltage-withstand test in NMX-J-556-ANCE/CSA C22.2 No. 2556/UL 2556](#) ~~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 [V to](#) –2000 V manufactured without shield or armor, the [ac](#) spark test ~~requirement of UL 1581, section 900, with the values of Table 20~~ may be used in lieu of wet tank testing [using the values in Table 21 and in accordance with NMX-J-556-ANCE/CSA C22.2 No. 2556/UL 2556](#).

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 [20](#) ~~19~~. This test is not applicable to discharge resistant cables. [The test shall be carried out in accordance with ICEA T-24-380, Standard for Partial Discharge Test Procedure.](#)

5.17.3 Conductor resistance test

Conductor resistance should be measured on finished cable in accordance with the procedures outlined in [NMX-J-556-ANCE/CSA C22.2 No. 2556/UL 2556, dc resistance](#) ~~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 [SI](#) ~~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 [V to](#) ~~–~~2000 V manufactured without shield or armor, the [ac](#) ~~insulation resistance test is not required when~~ spark [test may be used in lieu](#) ~~tested according to the spark test requirement~~ of [wet tank testing using](#) ~~UL 1581, section 900, with~~ the values [in](#) ~~of~~ Table [21](#) ~~and in accordance with NMX-J-556-ANCE/CSA C22.2 No. 2556/UL 2556~~ ~~20 in this recommended practice.~~