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

IEEE Industry Applications Society

Sponsored by the
International Marine Industry Committee



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

Sponsor

Petroleum and Chemical Industry Committee
of the
IEEE Industrial Applications Society

Approved 14 June 2001

IEEE-SA Standards Board

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, platforms, shipboard

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Introduction

(This introduction is not part of IEEE Std 1580-2001, IEEE Recommended Practice for Marine Cable for Use on Shipboard and Fixed or Floating Platforms.)

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

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, 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 Vessel classification

Marine vessels and platforms 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 petroleum facilities on any ocean, gulf, bay, sound, lake, or river.

Applicability

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

1.3 Cable construction, testing, and certification

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

2. References

This recommended practice should be used in conjunction with the following publications. Various organizations have developed numerous codes, guides, and standards that have substantial acceptance by industry and governmental bodies. Codes, guides, and standards useful in the design and installation of electrical cable systems are listed below as references only. These documents are not considered a part of this recommended practice except for those specific clauses of documents referenced elsewhere in this recommended practice. Those publications listed with dates are specific to this publication and other versions should not be utilized.

API RP 2A-WSD, 1993, Recommended Practice for Planning, Designing and Constructing Fixed Offshore Platforms—Working Stress Design.¹

API RP 14F, 1999, 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 B117, Standard Practice for Operating Salt Spray (Fog) Apparatus.

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 B189, Standard Specification for Lead-Coated and Lead-Alloy-Coated Soft Copper Wire for Electrical Purposes.

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 D2671, Standard Test Methods for Heat-Shrinkable Tubing for Electrical Use.

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

ASTM F1166, Standard Practice for Human Engineering Design for Marine Systems, Equipment and Facilities.

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 G23, Standard Practice for Operating Light-Exposure Apparatus (Carbon-Arc Type) With and Without Water for Exposure of Nonmetallic Materials.

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

CSA C22.2 No. 38, Thermoset Insulated Wires and Cables.

ICEA T-28-562, Test Method for Measurement of Hot Creep of Polymeric Insulations.⁴

IEC 60068-2-6, 1995, Environmental testing.⁵

IEC 60228, Conductors of insulated cables.

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

IEC 60331-21, Cables of rated voltage up to and including 0.6/1.0 kV.

IEC 60331-23, Electric data cable.

IEC 60331-25, Optical fibre cable.

IEEE Std 4, IEEE Standard Techniques for High-Voltage Testing.⁶

IEEE Std 45, IEEE Recommended Practice for Electric Installations on Shipboard.

IEEE Std 1202, IEEE Standard for Flame Testing of Cables for Use in Cable Tray in Industrial and Commercial Occupancies.

MIL-DTL-24643B, General Specification for Cables and Cords, Electric, Low Smoke, for Shipboard Use.⁷

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

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

NEMA WC 57, Standard for Control Cables (ICEA S-73-532).

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

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

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

⁴ICEA publications are available from ICEA, P.O. Box 20048, Minneapolis, MN 55420, USA (<http://www.icea.org/>).

⁵IEC 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.

⁶IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA (<http://standards.ieee.org/>).

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

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

NFPA 70-1999, National Electrical Code.⁹

UL 62, Flexible Cord and Fixture Wire.¹⁰

UL 44, Thermoset Insulated Wires and Cables.

UL 83, Thermoplastic-Insulated Wires and Cables.

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.

3. Definitions, abbreviations, and acronyms

3.1 Definitions

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 enforcing the rules. Electrical devices, which carry NRTL approval, are normally acceptable.

3.1.4 bending radius: The minimum radius at which a cable can be bent normally 8 times the diameter for armored cable and 6 times the diameter for unarmored.

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

3.1.8 current: The rate of transfer of electricity.

3.1.9 CWCMC: *See:* MC cable.

⁹NFPA publications are available from Publications Sales, National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101, USA (<http://www.nfpa.org/>).

¹⁰UL standards are available from Global Engineering Documents, 15 Inverness Way East, Englewood, CO 80112, USA (<http://global.ihs.com/>).

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

3.1.17 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 this recommended practice.

3.1.18 jacketed cable: Cable with a nonmetallic protective covering.

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

3.1.20 metal-clad (MC) cable: Continuously corrugated metal-clad cable as defined by Article 334 of the NEC and UL 1569.

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

3.1.20.1 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 of IEEE Std 1580-2001 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.

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

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

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

Table 1—Vibration limitations

Frequency range (Hz)	Amplitude (mm)
4–15	0.763 ± 0.152
16–25	0.508 ± 0.102
26–33	0.254 ± 0.051
34–40	0.128 ± 0.025
40–50	$0.076 + 0.000 - 0.025$

3.1.21 medium voltage (MV) cable: Medium voltage single or multiphase solid dielectric insulated conductor or cable rated 2001 V or higher as defined by NEC Article 326.

3.1.22 oil-resistant: Ability to withstand exposure to oil as defined by UL 83, Safety Standard for Thermoplastic Insulated Wires.

3.1.23 shipboard cable, marine: Armored or nonarmored cable constructed in accordance with this recommended practice, and certified as “Shipboard Cable, Marine” by a nationally recognized testing laboratory (NRTL).

3.1.24 sunlight-resistant: Ability to withstand exposure to direct sunlight as defined by UL 62, Flexible Cord and Fixture Wire.

3.2 Abbreviations and acronyms

ABS	American Bureau of Shipping
AHJ	Authority having jurisdiction
AWG	American Wire Gauge
CDA	Copper Development Association
CWCMC	Continuous Corrugated Metal Clad
ICEA	Insulated Cable Engineers Association
NRTL	Nationally recognized testing laboratory
PE	Polyethylene
PVC	Polyvinylchloride
USCG	United States Coast Guard

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:

4.1 Code of federal regulations

- a) Title 30, Part 250, Oil and Gas and Sulfur Operation in the Outer Continental Shelf (US Department of the Interior, Minerals Management Service).
- b) Title 33, Subchapter N, Outer Continental Shelf Activities, Parts 140–147 (USCG).
- c) Title 46, Shipping Subchapter I-A, Parts 107–108, Mobile Offshore Drilling Units (USCG).
- d) 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 tinned or alloy coated where necessary to ensure compatibility with primary insulation.

5.1.2 Composition

Conductors should be manufactured in accordance with the most current edition of following American National Standards: ASTM B3, B8, B33, B172, B173, B174, B189, and B496.

Metric conductors meeting IEC 60228 are also allowed.

5.1.3 Stranding

The construction requirements and nominal resistance of standard Class B concentric conductors are found in Table 10. 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. Compact stranded conductors may not be used in areas subjected to vibration or flexing.

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 shielding

Conductor shielding should be used on conductors of cables rated above 2000 V.

Conductor shielding should be an extruded semiconducting compound to a minimum thickness of 0.305 mm. 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. A semiconducting nonmetallic tape with a minimum thickness of 0.0635 mm may be used over the conductor and under the extruded semiconducting layer.

Extruded conductor shielding should have a maximum volume resistivity of 100 000 Ω -cm at room temperature and at the maximum normal operating temperature of the cable. Extruded conductor shielding 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 for 168 hours, minimum 100%
- b) Brittleness temperature, not warmer than -10 °C

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 rated at 105 °C meeting UL 1072 may be used.

Table 2—Insulation types

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

5.3.2 Properties

The physical and electrical properties of Type(s) T, T/N, E, X, LSE, LSX, 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 average thickness of T, T/N, E, X, LSE, LSX, S, and P insulation should not be less than the values given in Table 15. The minimum thickness at any point should not be less than 90% of the minimum average.

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.

These cables should contain the metallic shield of 5.18.4, 5.18.5, 5.18.6, and 5.18.7.

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 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 cloth 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 the same coverage as listed in 5.14.2. Silicone insulation requires the glass braid covering the insulation to be coated with a suitable anti-fraying coating.

5.7 Conductor identification

Conductor identification of distribution and control cables should be an Arabic number plus a number to be printed on single-colored insulation. Example: “1-ONE,” “2-TWO,” etc. or “1-BLACK,” “2-WHITE,” etc., per color code Table 22 or Table 23. The legend shall be repeated at intervals not exceeding 8 cm. The characters shall be clear and legible. Colored insulation may be used as an alternate. If an insulated conductor is functioning as a grounding conductor (normally not a current carrying conductor) in a distribution system, then it shall be colored as green or green and yellow.

Conductor identification of signal cable:

- 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 and start from the center of the cable.
- 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 and start from the center of the cable.

5.8 Cabling

Conductors, pairs, triads, or groups of conductors should be cabled in concentric layers (see Table 3).

Table 3—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

5.9 Fillers

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

5.10 Composite cables with optical fibers

Cables covered in Clause 5 may include optical fiber members.

5.11 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.

5.11.1 Individually shielded components and overall shielding

5.11.1.1 Shield types and drains

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

The size of the drain wire should be no smaller than two gauge sizes less than the instrumentation or signal circuit conductor size.

Where a braided coated or bare copper shield is used, it should be constructed using a minimum of 34 AWG wire.

5.11.1.2 Shield identification

Cables with individual and overall shielding should be identified as such in accordance with 5.19.1.2.

5.12 Cable jackets

5.12.1 General

The jacket should be thermoplastic Type T (PVC) or TPO (TPPO), thermosetting Type CP (CSPE), CPE, N (PCP), or L (XLPO) complying with the requirements of Table 16 or Table 17. The manufacturer should perform type tests and periodic testing to ensure jacket materials meet these requirements. The temperature rating of a jacket shall be not less than 15 °C lower than the temperature rating of the insulation.

5.12.2 Thickness of overall jacket

The 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 average values shown.

5.13 Marker

A durable printing or embossing on the jacket or a marker under the cable jacket should provide cable identification. Marker material should be suitable for its service. Marking should give the following information at intervals not exceeding 1 m:

- a) Manufacturer
- b) Cable designations (see 5.19)
- c) Voltage rating
- d) The listing (or classification) mark of an independent product testing and certification organization

- e) Applicable specification and the year of the standard, e.g., IEEE Std 1580-2001
- f) Other information that does not confuse or mislead may be added to the marking (such as the year of manufacture)

Only cable that is in total conformance with the requirements of this recommended practice should be marked “IEEE Std 1580-2001.”

5.14 Armor

5.14.1 General

Armor should be basket-weave type braid or continuous corrugated metal. The armor is not to be used as a shield or ground conductor.

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 $\pm$ 0.01 mm, and should be free from cracks, splits, or other flaws. The wire should be commercial bronze, aluminum, 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 4.

Table 4—Braid angle and coverage

Diameter over jacket (mm)	Percent coverage		Braid angle	
	Min	Max	Min	Max
0–15.24	88	94	30	60
15.25–25.4	88	94	35	60
25.41–38.1	88	94	40	70
38.11–50.8	88	94	45	70
50.81 and larger	88	94	50	80

Where 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

The maximum number of ends per carrier should conform to the values shown in Table 5.

Table 5—Maximum ends per carrier

Cable diameter under armor (mm)	Maximum number of ends per carrier	
	One over-one under	Two over-two under
0–10.16	8	5
10.17–20.32	12	8
20.33–38.1	15	10
38.11 and larger	20	10

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 and a minimum elongation of 2% in 254 mm.

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 Continuous corrugated metal armor

This armor should be a continuous 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 continuous 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 5.12. The overall sheath will increase the cable diameter and weight. 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 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	—
Jacket (Table 16, Table 17, and Table 18)	X	X ^d	—
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	—	—
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 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 product certification organization.

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

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

^ePST for flammability and when invoked for smoke, acid gas, and toxicity tests 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 cold impact test per clause 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.

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 described in 5.17.1.1, 5.17.1.2, 5.17.1.3, or 5.17.1.4. The test should be in accordance with IEEE Std 4.

5.17.1.1 Unshielded or unarmored cable

Each reel of single conductor unshielded or unarmored cable should be immersed in water for at least 6 hours. 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 5 conductors

For cables having more than 5 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 should comply with the partial discharge test requirements of UL 1072. 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 or 25 °C. Maximum resistance values should be in accordance with the appropriate standards referenced in 5.1.2.

5.17.4 Insulation resistance test¹¹

Each reel of finished cable should have an insulation resistance measured between each conductor and ground (metallic sheath, metallic shield, metallic armor, or water).

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.

¹¹For a parallel treatment using English units, see Annex C.

5.17.4.1 Method of test

Compliance with the insulation resistance test is determined in accordance with the method described in subclause 4.28.2 of CSA Standard C22.2 No. 03 or UL 1581. The insulation resistance constant K for a test at 15.6 °C is obtained in Table 12, Table 13, or Table 14 for the specific insulation under test.

The current should be measured after one minute with a continuous direct-current 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 different from 15.6 °C, the measured value should be multiplied by the proper correction factor, M , obtained in Table 21. This factor appears in the formula for insulation resistivity.

$$R = KM \log_{10} \frac{D}{d}$$

where

R = Insulation resistivity (MΩ·km)

K = insulation resistance constant (from Table 12, Table 13, or Table 14) (MΩ·km)

M = Temperature correction factor to 15.6 °C

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 formula

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

where

R = insulation resistivity (MΩ·km)

R_{meas} = measured insulation resistance (MΩ)

L = length of the test sample (m)

5.17.4.2 Test procedure for determining the multiplying-factor column for adjusting insulation resistance

5.17.4.2.1 Samples

Two samples, conveniently of a No. 14, 12, or 10 AWG solid conductor with a 1.14 mm wall of insulation, are to be selected as representative of the insulation under consideration. The samples are to be of a length (at least 60 m) 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 60 cm above the surface of the water to reduce electrical leakage. The samples are to be left in the water at room temperature for 16 hours before adjusting the bath temperature to 10.0 °C or before transferring the samples to a 10.0 °C 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 then is 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 10.0, 16.1, 22.2, 27.8, and 35.0 °C and returning, 27.8, 22.2, 16.1, and 10.0 °C. 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 35.0 °C 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 15.6 °C is then to be read from the graph.

5.17.4.2.6 Results

The resistivity coefficient C for a 1 °C change in temperature is to be calculated to two decimal places by dividing the insulation resistance at 15.0 °C read from the graph by the insulation resistance at 16.0 °C. The temperature correction factor M required to correct to the standard test temperature of 15.6 °C is then calculated from the following formula:

$$M = C^{(t - 15.6)}$$

where

t is the actual test temperature in degrees Celsius.

The columns of Table 21 give M for various values of C and t .

5.17.5 Flammability test

All cable constructions covered in Clause 5 should be flame retardant and should meet IEEE Std 1202-1991.

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 “-LS” (limited smoke) marking. Cable damage height may not exceed 1.5 m as measured from the lower edge of the burner face and total smoke release may not exceed 150 m² with a peak rate of smoke release not to exceed 0.40 m²/s.

Cables designated fire resistant (-FS), in addition to meeting the flame test of IEEE Std 1202-1991, 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.

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 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.
- 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 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 lengths of cable should be immersed in a 20% (by weight) common salt (sodium chloride) solution at $60\text{ }^{\circ}\text{C} \pm 1\text{ }^{\circ}\text{C}$ for 240 hours. The cable should be immersed in a U-bend such that each leg of the U-bend of the cable is 30 cm 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.

5.17.8 Cable immersion in oil test

Cable should be tested in accordance with the following procedure:

Three 1.1 m jacketed lengths of cable should be immersed in IRM 902 oil at $100\text{ }^{\circ}\text{C} \pm 1\text{ }^{\circ}\text{C}$ for 96 hours or as an alternative at $60\text{ }^{\circ}\text{C} \pm 1\text{ }^{\circ}\text{C}$ for 60 days. The cable should be immersed in the oil in a U-bend such that each leg of the U-bend is 30 cm above the surface of the oil.

After immersion in oil, 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.