

UL 44

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Thermoset-Insulated Wires and Cables

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Underwriters Laboratories Inc. (UL)
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UL Standard for Safety for Thermoset-Insulated Wires and Cables, UL 44

Sixteenth Edition, Dated July 15, 2005

Revisions: This Standard contains revisions through and including November 30, 2005.

Summary of Topics

These revisions to UL 44 include editorial changes and a correction to the crushing test for Types XHHW, XHHW-2, and XHH to specify the intended use of two flat plates instead of a flat plate and a rod.

The revised requirements are substantially in accordance with UL's Proposal(s) on this subject dated September 2, 2005.

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

As indicated on the title page (page1), this UL Standard for Safety has been adopted by the Department of Defense.

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

The master for this Standard at UL's Northbrook Office is the official document insofar as it relates to a UL service and the compliance of a product with respect to the requirements for that product and service, or if there are questions regarding the accuracy of this Standard.

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The requirements in this Standard are now in effect, except for those paragraphs, sections, tables, figures, and/or other elements of the Standard having future effective dates as indicated in the preface. The prior text for requirements that have been revised and that have a future effective date are located after the Standard, and are preceded by a "SUPERSEDED REQUIREMENTS" notice.

New product submittals made prior to a specified future effective date will be judged under all of the requirements in this Standard including those requirements with a specified future effective date, unless the applicant specifically requests that the product be judged under the current requirements. However, if the applicant elects this option, it should be noted that compliance with all the requirements in this Standard will be required as a condition of continued Listing and Follow-Up Services after the effective date, and understanding of this should be signified in writing.

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This Standard consists of pages dated as shown in the following checklist:

Page	Date
1-5	November 30, 2005
6-79	July 15, 2005
80	November 30, 2005
81-102	July 15, 2005
103-104	November 30, 2005
105-186	July 15, 2005

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Association of Standardization and Certification
NMX-J-451-ANCE-2005
Third Edition



Canadian Standards Association
CSA C22.2 No. 38-05
Eighth Edition



Underwriters Laboratories Inc.
UL 44
Sixteenth Edition

Thermoset-Insulated Wires and Cables

July 15, 2005

(Title Page Reprinted: November 30, 2005)



ANSI/UL 44-2005

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The most recent designation of ANSI/UL 44 as an American National Standard (ANSI) occurred on November 18, 2005.

This ANSI/UL Standard for Safety, which consists of the Sixteenth Edition, with revisions through November 30, 2005, is under continuous maintenance, whereby each revision is ANSI approved upon publication. Comments or proposals for revisions on any part of the Standard may be submitted to UL at any time. Proposals should be submitted via a Proposal Request in UL's On-Line Collaborative Standards Development System (CSDS) at <http://csds.ul.com>.

The Department of Defense (DoD) has adopted UL 44 on April 5, 1985. The publication of revised pages or a new edition of this Standard will not invalidate the DoD adoption.

CONTENTS

Preface	7
1 Scope	9
2 Definitions	9
3 General	10
3.1 Units of measure	10
3.2 Reference publications	10
4 Construction	14
4.1 Conductors	14
4.2 Insulation	18
4.3 Jackets or fibrous coverings over single conductors	19
4.4 Shielding (optional)	20
4.5 Multiple-conductor cables	20
4.6 Color coding	21
4.7 Fillers	22
4.8 Jacket separators	22
4.9 Jackets	22
4.10 Evaluation of new materials – establishment of dry temperature rating of alternative insulation and jacketing materials for use in this standard	23
4.11 Assemblies that include single-conductor thermoset-insulated wires	23
5 Test requirements	24
5.1 General	24
5.2 Conductor resistance	24
5.3 Tests of aluminum conductors	24
5.4 Long-term insulation resistance in water	25
5.5 Long-term insulation resistance in air for 90°C rated conductors	26
5.6 Capacitance and relative permittivity	26
5.7 Conductor corrosion	27
5.8 Insulation fall-in	27
5.9 Heat shock of thermoplastic jacket	27
5.10 Flexibility of separator under a thermoplastic jacket	27
5.11 Cold bend and cold impact	27
5.12 Deformation	28
5.13 Hot-creep elongation and hot-creep set	28
5.14 Flame and smoke	28
5.15 Weather resistance (optional)	32
5.16 Oil resistance (optional)	32
5.17 Gasoline and oil resistance (optional)	33
5.18 Crushing resistance	33
5.19 Dielectric breakdown after glancing impact	33
5.20 Durability of ink printing	33
5.21 Shrinkback	33
5.22 Evaluation of new materials – establishment of dry temperature rating	34
5.23 A-C spark test	34
5.24 Dielectric voltage-withstand in water	34
5.25 Insulation resistance in water at 15°C	34
5.26 Electrical continuity	35
6 Marking	35
6.1 Marking on product	35
6.2 Marking on package	38

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7 Deep-well submersible water-pump cable	38
7.1 General	38
7.2 Construction	39
7.3 Markings	40
7.4 Tests	42
8 Test methods	42
8.1 General	42
8.2 Conductor resistance	42
8.3 Test methods for aluminum conductors	42
8.4 Long-term insulation resistance in water	44
8.5 Long-term insulation resistance in air (for 90°C rated)	44
8.6 Capacitance and relative permittivity	44
8.7 Conductor corrosion	44
8.8 Insulation fall-in	44
8.9 Heat shock of thermoplastic jacket	44
8.10 Flexibility of separator under thermoplastic jacket	45
8.11 Cold bend and cold impact	45
8.12 Deformation	46
8.13 Hot creep	47
8.14 Flame	50
8.15 Weather resistance	76
8.16 Oil resistance	78
8.17 Gasoline resistance	79
8.18 Crushing resistance	80
8.19 Dielectric breakdown after glancing impact	81
8.20 Durability of ink printing	82
8.21 Shrinkback	83
8.22 Evaluation of new materials – establishment of dry temperature rating	84
8.23 A-C spark test	86
8.24 Dielectric voltage-withstand in water	88
8.25 Insulation resistance in water at 15°C	89
8.26 Electrical continuity	91
Tables	92
Figures	132

Annex A (normative) – Conductor types covered by this Standard (See Clause 1.2)

Annex B (informative) – Summary of requirements (See Clause 1.1)

Annex C (normative) – Chemical composition of recognized ACM, AA 8000 series aluminum alloy conductor materials (See Clause 1.1)

Annex D (normative) – Copper-clad aluminum conductors (See Clause 4.1.3)

D.1 General	158
D.2 Sizes and stranding	158
D.3 Conductor resistance	158
D.4 Physical properties	158
D.5 Marking requirements	158

Annex E (informative) – Metric sizes (See Clause 4.1.5)**Annex F (normative) – Protective coverings other than jackets (See Clauses 4.3.1 and 4.9.1.1)**

F.1 General	162
F.2 Tapes	162
F.3 Cotton braids	162
F.3.1 General	162
F.3.2 Coverage	163
F.4 All-glass and glass/cotton braids	166
F.4.5 Glass content	166
F.5 Cotton wraps and servings	167
F.5.2 Coverage	167
F.6 Glass wraps	169
F.7 Braids and wraps	169
F.8 Saturation of fibrous coverings other than tapes	169
F.9 Finish	170

Annex G (normative for Canada) – Color identification of circuit conductors (See Clauses 4.6.2, 4.6.3 and 7.2.4)**Annex H (normative) – Evaluation of materials having characteristics differing from those in Tables 11 or 20 (See Clauses 4.10 and 8.22.4)****Annex I (normative) – Formulas for calculating insulation resistance of types having parameters other than as specified in this Standard (See Clause 5.4.1.2)****Annex J (normative) – Alternative national markings (See Clauses 6.1.1 and 7.3.2)****Annex K (normative) – Requirements for Types RW75, R90, and RW90 rated 5000 V (See Table 1)**

K.1 General	181
K.2 Construction	181
K.2.1 Conductors	181
K.2.2 Conductor shielding	181
K.2.3 Insulation	181
K.2.4 Jackets	181
K.3 Tests	181
K.3.1 Long-term insulation resistance in water	181
K.3.2 Insulation resistance in air for Type R90, rated 5000 V	182
K.3.3 Dielectric voltage-withstand in water	182
K.3.4 Insulation Resistance in Water at 15°C	182
K.3.5 Resistivity of extruded semiconducting shielding	182

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Preface

This is the common ANCE, CSA, and UL standard for Thermoset-Insulated Wires and Cables. It is the Third edition of NMX-J-451-ANCE, the Eighth edition of CSA C22.2 No. 38, and the Sixteenth edition of UL 44. This edition of CSA C22.2 No. 38 supersedes the previous edition published in 1995. This edition of UL 44 supersedes the previous edition published in 1999.

This common standard was prepared by the Association of Standardization and Certification (ANCE), the Canadian Standards Association (CSA), and Underwriters Laboratories Inc. (UL). The efforts and support of the Technical Harmonization Committee for Electrical Wires and Cables, of the Council on the Harmonization of Electrotechnical Standards of the Nations of the Americas (CANENA), are gratefully acknowledged.

This standard was reviewed by the CSA Subcommittee on C22.2 No. 38, under the jurisdiction of the CSA Technical Committee on Wiring Products and the CSA Strategic Steering Committee on Requirements for Electrical Safety, and has been formally approved by the CSA Technical Committee. This standard was reviewed and approved by the Committee de Normalization of ANCE (CONANCE). This standard was reviewed by UL's Standards Technical Panel (STP) for Power Cables, STP 83.

This standard will be submitted to the Standards Council of Canada (SCC) for approval as a National Standard of Canada.

This standard has been approved by the American National Standards Institute (ANSI) as an American National Standard.

A UL standard is current only if it incorporates the most recently adopted revisions, all of which are itemized on the transmittal notice that accompanies the latest set of revised requirements.

Where reference is made to a specific number of specimens to be tested, the specified number is to be considered a minimum quantity.

Note: *Although the intended primary application of this standard is stated in its scope, it is important to note that it remains the responsibility of the users of the standard to judge its suitability for their particular purpose.*

Level of harmonization

This standard uses the IEC format but is not based on, nor shall it be considered equivalent to, an IEC standard. This standard is published as an equivalent standard for ANCE, CSA, and UL.

An equivalent standard is a standard that is substantially the same in technical content, except as follows: Technical national differences are allowed for codes and governmental regulations as well as those recognized as being in accordance with NAFTA Article 905, for example, because of fundamental climatic, geographical, technological, or infrastructural factors, scientific justification, or the level of protection that the country considers appropriate. Presentation is word for word except for editorial changes.

Reasons for differences from IEC

This standard provides requirements for insulated wires and cables for use in accordance with the electrical installation codes of Canada, Mexico, and the United States. At present there is no IEC standard for wires and cables for use in accordance with these codes. Therefore, this standard does not employ any IEC standard for base requirements.

Interpretations

The interpretation by the standards development organization of an identical or equivalent standard is based on the literal text to determine compliance with the standard in accordance with the procedural rules of the standards development organization. If more than one interpretation of the literal text has been identified, a revision is to be proposed as soon as possible to each of the standards development organizations to more accurately reflect the intent.

ANCE effective date

The effective date for ANCE will be announced through the Diario Oficial de la Federación (Official Gazette) and is indicated on the cover page.

CSA effective date

The effective date for CSA International will be announced through CSA Informs or a CSA certification notice.

UL effective date

As of July 15, 2005 all products Listed or Recognized by UL must comply with the requirements in this standard except for clauses, figures, and tables in the following list, which are effective as indicated in the list.

July 15, 2006: Clauses 5.13.1, 5.15.1, 6.2(e), 7.3.2(h) and Tables 20, 42, and 47.

January 15, 2007: Clauses 5.14.7, 6.1.9.1(e), 6.1.4, and 6.2(d).

Between July 15, 2005 and the effective dates indicated above, new product submittals to UL may be evaluated under all requirements in this standard or, if requested in writing, evaluated under presently effective requirements only. The presently effective requirements are contained in the fifteenth edition of UL 44.

A UL effective date is one established by Underwriters Laboratories Inc. and is not part of the ANSI approved standard.

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Thermoset-Insulated Wires and Cables

1 Scope

1.1 This Standard specifies the requirements for single-conductor and multiple-conductor thermoset-insulated wires and cables rated 600 V, 1000 V, 2000 V, and 5000 V, for use in accordance with the rules of the *Canadian Electrical Code (CEC)*, Part 1, CSA C22.1, in Canada, *Standard for Electrical Installations*, NOM-001-SEDE, in Mexico, and the *National Electrical Code (NEC)*, NFPA-70, in the United States of America.

See Annex A for the complete list of types covered by this Standard and the specific electrical codes for which they are intended, and Annex B for a summary of construction and test requirements for these types.

1.2 Table 1 provides a summary of the maximum conductor temperature, voltage ratings, and the number of insulated conductors for the types to which this Standard applies.

1.3 This Standard also specifies the requirements for submersible pump cables, with or without jackets, in Clause 7. No type-letter designations are assigned to these cables.

1.4 Products within this Standard may have applications not covered by the electrical codes listed in Clause 1.1.

2 Definitions

2.1 The following definitions apply in this Standard:

CP – a thermoset compound whose characteristic constituent is chlorosulfonated polyethylene.

CPE – a thermoset compound whose characteristic constituent is chlorinated polyethylene.

EPCV – a thermoset compound whose characteristic constituent is a co-vulcanizate of ethylene and propylene with polyethylene.

EP – a thermoset compound whose characteristic constituent is a copolymer of ethylene and propylene, or a terpolymer of ethylene, propylene, and a small amount of nonconjugated diene, or a blend of both.

Equipment-grounding conductor – a conductor that is defined in the *National Electrical Code* and the *Standard for Electrical Installations* as "Grounding Conductor, Equipment", and defined in the *Canadian Electrical Code*, Part I, as "Bonding conductor".

NBR/PVC – a thermoset compound whose characteristic constituents are acrylonitrile butadiene rubber and polyvinyl chloride.

Neoprene – a thermoset compound whose characteristic constituent is polychloroprene.

SBR/IIR/NR – designates a thermoset compound whose characteristic constituent is SBR (styrene and butadiene copolymer), IIR (butyl rubber), blends of SBR and IIR, or blends of SBR and/or IIR with NR (natural rubber).

Silicone (rubber) – a thermoset compound whose basic constituent is poly-organo-siloxane.

Thermoplastic – a jacket material that repeatedly can be softened by heating and hardened by cooling through a temperature range characteristic of the material, and that in the softened state can be shaped through the application of force.

Thermoset – an insulating or jacketing polymeric material which, when cross-linked, will not flow on subsequent heating. Cross-linking is accomplished either chemically or by irradiation.

XL – a thermoset compound whose characteristic constituent is cross-linked polyethylene, cross-linked polyvinyl chloride, cross-linked ethylene vinyl acetate, or blends thereof.

XL Filled an XL material in which the mass fraction of carbon black and/or mineral fillers is 10 percent or greater.

XL Unfilled – an XL material in which the mass fraction of carbon black and/or mineral fillers is less than 10 percent.

3 General

3.1 Units of measure

The unit of measure shall be SI. If a value for measurement is followed by a value in other units in parentheses, the second value represents a direct conversion or an alternative value. Except for conductor size, the first stated value is the requirement.

3.2 Reference publications

3.2.1 Where reference is made to ANCE, CSA, or UL Standards, such reference shall be considered to refer to the latest edition and all amendments published to that edition.

ANCE Standards

NOM-001-SEDE

Standard for Electrical Installations

NMX-E-034-SCFI

Plastics Industry – Carbon Black Contents on Polyethylene Materials – Test Method

NMX-J-008-ANCE

Tinned Soft or Annealed Copper Wire for Electrical Purposes – Specifications

NMX-J-012-ANCE

Wires and Cables – Concentric Lay Stranded Copper Conductors for Electrical Purposes – Specifications

NMX-J-013-ANCE

Wires and Cables – Rope Lay Stranded Copper Conductors Having Concentric Stranded Members for Electrical Purposes – Specifications

NMX-J-014-ANCE

Wires and Cables – Rope Lay Stranded Copper Conductors Having Bunch Stranded Members for Electrical Purposes – Specifications

NMX-J-032-ANCE

Wires and Cables – Concentric Lay Stranded Aluminum Cable for Electrical Purposes – Specifications

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NMX-J-036-ANCE

Soft or Annealed Copper Wire for Electrical Purposes – Specifications

NMX-J-040-ANCE

Determination of Moisture Absorption in Insulations and Jackets of Electrical Conductors – Test Method

NMX-J-066-ANCE

Determination of Diameters of Electrical Conductors – Test Method

NMX-J-177-ANCE

Determination of Thickness in Semiconductive Shielding, Insulations, and Jackets of Electrical Conductors – Test Method

NMX-J-178-ANCE

Ultimate Strength and Elongation of Insulation, Semiconductive Shielding, and Jackets of Electrical Conductors – Test Method

NMX-J-186-ANCE

Wires and Cables – Accelerated Aging in Forced Air Convection Oven of Semiconducting Shields, Insulations and Jackets of Electrical Conductors – Test Method

NMX-J-190-ANCE

Wires and cables – Thermal Shock Resistance of PVC Insulations and PVC Protective Coverings of Electrical Conductors – Test Method

NMX-J-191-ANCE

Heat Distortion of Semiconductive Shielding, Insulations and Protective Coverings of Electrical Conductors – Test Method

NMX-J-192-ANCE

Flame Test on Electrical Wires – Test Method

NMX-J-193-ANCE

Cold Bend of Thermoplastic Insulation and Protective Jackets, Used on Insulated Wire and Cable – Test Method

NMX-J-212-ANCE

Electrical Resistance, Resistivity and Conductivity – Test Method

NMX-J-294-ANCE

Insulation Resistance – Test Method

NMX-J-312-ANCE

Tensile Strength and Elongation by Strain of Wires for Electrical Conductors – Test Method

NMX-J-417-ANCE

Wire and Cables – Convection Laboratory Ovens for Evaluation of Electrical Insulation – Specifications and Test Methods

NMX-J-437-ANCE

Wires and Cables – Determination of Light Absorption Coefficient of Polyethylene Pigmented with Carbon Black – Test Method

NMX-J-498-ANCE

Vertical Tray – Flame Test – Test Method

CSA Standards

C22.1-02

Canadian Electrical Code, Part I

CSA C22.2 No. 0.3-01

Test Methods for Electrical Wires and Cables

CSA C22.2 No. 42-99 (R2002)

General Use Receptacles, Attachment Plugs and Similar Wiring Devices

CAN/CSA-C22.2 No. 48-M90 (R2000)

Nonmetallic-Sheathed Cables

UL Standards

UL 498

Standard for Attachment Plugs and Receptacles

UL 1567

Receptacles and Switches Intended for Use with Aluminum Conductors

UL 1581

Reference Standard for Electrical Wires, Cables, and Flexible Cords

UL 1685

Standard for Vertical-Tray Fire-Propagation and Smoke-Release Test for Electrical and Optical-Fiber Cables

3.2.2 This Standard refers to the following publications and, where such reference is made, it shall be to the edition listed below.

ASTM (American Society for Testing and Materials)

A 29-03

Steel Bars, Carbon and Alloy, Hot-Wrought and Cold-Finished, General Requirements for

B 3-01

Soft or Annealed Copper Wire

B 8-99

Concentric-Lay-Stranded Copper Conductors, Hard, Medium-Hard, or Soft

B 33-00

Tinned Soft or Annealed Copper Wire for Electrical Purposes

B 172-01

Rope-Lay-Stranded Copper Conductors Having Bunch-Stranded Members, for Electrical Conductors

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B 173-01

Rope-Lay-Stranded Copper Conductors Having Concentric-Stranded Members, for Electrical Conductors

B 189-95

Lead-Coated and Lead-Alloy-Coated Soft Copper Wire for Electrical Purposes

B 231-99

Standard Specification for Concentric-Lay-Stranded Aluminum 1350 Conductors

B 298-99

Standard Specification for Silver-Coated Soft or Annealed Copper Wire

B 355-95

Standard Specification for Nickel-Coated Soft or Annealed Copper Wire

B 835-00

Standard Specification for Compact Round Stranded Copper Conductors Using Single Input Wire Construction

B 836-00

Standard Specification for Compact Round Stranded Aluminum Conductors Using Single Input Wire Construction

D 1603-01

Standard Test Method for Carbon Black on Olefin Plastics

D 4218-96 (2001)

Standard Test Method for Determination of Carbon Black Content in Polyethylene Compounds by the Muffle-Furnace Technique

D 6370-99 (2003)

Standard Test Method for Rubber-Compositional Analysis by Thermogravimetry (TGA)

E 1131-03

Standard Test Method for Compositional Analysis by Thermogravimetry

IEC (International Electrotechnical Commission)

60228 (1978-01),

Conductors of insulated cables;

60228A (1993-01),

Conductors of insulated cables – Amendment No. 1.

IEEE (Institute of Electrical and Electronic Engineers)

1202-1991 (R1996)

IEEE Standard for Flame Testing of Cables for Use in Cable Tray in Industrial and Commercial Occupancies

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NFPA (National Fire Protection Association)

NFPA 70-2002
National Electrical Code

4 Construction

4.1 Conductors

4.1.1 General

Circuit and equipment-grounding conductors shall be of either copper, copper-clad aluminum, or aluminum.

4.1.2 Aluminum conductors

All conductors shall be of aluminum conductor material (ACM), AA 8000 series alloy.

Annex C provides the chemical composition of recognized aluminum alloy conductor materials.

4.1.2.1 In Mexico, thermoset-insulated aluminum conductors are limited to sizes 6 AWG and larger in accordance with NOM-001-SEDE, *Standard for Electrical Installations*.

4.1.3 Copper-clad aluminum conductors

In the United States, the requirements of Annex D shall apply to solid conductors or the individual wires of stranded conductors prior to stranding.

In Canada and Mexico, copper-clad aluminum conductors shall not be used in thermoset-insulated wires and cables.

4.1.4 Copper conductors

4.1.4.1 General

The requirements of Clauses 4.1.4.2 or 4.1.4.3 shall apply to solid conductors or the individual wires of stranded conductors prior to stranding. If the insulation adjacent to a copper conductor is of a material that corrodes unprotected copper, as determined by the requirement in Clause 5.7, or if a protective separator in compliance with Clause 4.1.8 is not provided, the solid conductor and each of the individual strands of a stranded conductor shall be separately covered with a coating as described in Clause 4.1.4.2.

4.1.4.2 Coated copper conductors

4.1.4.2.1 Each tin-coated conductor shall comply with the requirements of ASTM B 33 or NMX-J-008-ANCE; each wire in a lead-alloy-coated wire shall comply with the requirements of ASTM B 189; a nickel-coated wire shall comply with ASTM B 355 and a silver-coated wire shall comply with ASTM B 298. Conductors coated with other metals or alloys shall be subjected to special investigation.

In Mexico, the use of lead-alloy-coated wires is not permitted.

Note: In Mexico, the use of ASTM B 355 is recommended for nickel-coated wire, and the use of ASTM B 298 is recommended for silver-coated wire.

4.1.4.2.2 A metal coating, when not required, is appropriate for use on solid or individual wires (strands) or selected wires, such as the outer layer of wires of a stranded conductor. The metal coating when used shall comply with Clause 4.1.4.1.

4.1.4.3 Uncoated copper conductors

Each wire in an uncoated copper conductor shall comply with the requirements of ASTM B 3 or NMX-J-036-ANCE.

4.1.5 Sizes and stranding

4.1.5.1 Sizes

Conductors shall be of a size and assembly indicated for the finished wire type in Table 2.

Copper strands smaller than 0.0127 mm² (36 AWG) and aluminum strands smaller than 0.324 mm² (22 AWG) shall not be used. A compact stranded conductor shall not be segmented.

Note: Conductor sizes specified in IEC publications are not recognized in the CEC, NEC, or NOM-001-SEDE; however, these may be required for wires and cables intended for use outside of the codes. Information on these metric conductors is given in Annex E.

4.1.5.2 Stranding

The number of strands in the conductors shall be in accordance with Table 3.

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4.1.5.3 Compact

A compact-stranded conductor shall be a round conductor consisting of a central core surrounded by one or more helically laid wires, and formed into a smooth outermost layer by rolling, drawing, or other means. The lay length of every layer shall not be less than 8 times nor more than 16 times the outside diameter of the completed conductor except that, for sizes 33.6 mm² (2 AWG) and smaller, the maximum lay length shall be 17.5 times the outside diameter. The direction of lay of the outermost layer shall be left-hand, and it shall be reversed or unidirectional/unilay in successive layers.

4.1.5.4 Compressed

A compressed-stranded conductor shall be a round conductor consisting of a central core surrounded by one or more layers of helically laid wires with either the direction of lay reversed in successive layers or unilay or unidirectional lay. The direction of lay of the outer layer shall be left-hand in all cases. The strands of one or more layers shall be slightly compressed by rolling, drawing, or other means to change the originally round strands to various shapes that achieve filling of some of the spaces originally present between the strands.

4.1.5.5 Assembly of strands

A 19-wire combination round-wire unilay stranded conductor shall be round and shall consist of a straight central wire, an inner layer of six wires of the same diameter as the central wire, and an outer layer consisting of six wires with the same diameter as the central wire, alternated with six wires with a diameter of 0.732 times the diameter of the central wire. No particular assembly of the individual wires of any other stranded conductor is required. However, simple bunching (untwisted strands) shall not be used. The length of lay of the strands in a bunch-stranded conductor twisted as a single bunch shall not be greater than indicated in Table 4. The direction of lay of the strands in a bunch-stranded conductor shall be left-hand.

4.1.5.6 Length and direction of lay

Every stranded conductor other than a compact-stranded conductor, or a bunch-stranded conductor twisted as a single bunch, shall comply with the following:

- a) The direction of lay of the strands, members, or ropes in a 13.3 – 1010 mm² (6 AWG – 2000 kcmil) conductor other than a combination unilay or a compressed unilay or compressed unidirectional lay conductor shall be reversed in successive layers. Rope-lay conductors with bunch-stranded or concentric-stranded members shall be either unidirectional or reversed. All unidirectional lays and the outer layer of reversed lays shall be in the left-hand direction.
- b) For a bunch-stranded member of a rope-lay-stranded conductor in which the members are formed into rope-stranded components that are then cabled into the final conductor, the length of lay of the individual members within each component shall not be more than 30 times the outside diameter of one of those members.
- c) For a concentric-stranded member of a rope-lay-stranded conductor, the length of lay of the individual strands in a member shall be 8 – 16 times the outside diameter of the member. The direction of lay of the strands in each member shall be reversed in successive layers of the member.

- d) The length of lay of the strands in both layers of a 19-wire combination round-wire unilay-stranded copper or aluminum conductor shall be 8 – 16 times the outside diameter of the completed conductor. Otherwise, the length of lay of the strands in every layer of a concentric-lay-stranded conductor consisting of fewer than 37 strands shall be 8 – 16 times the outside diameter of the conductor.
- e) The length of lay of the strands in the outer two layers of a concentric-lay-stranded conductor consisting of 37 or more strands shall be 8 – 16 times the outside diameter of the conductor.
- f) The length of lay of the members or ropes in the outer layer of a rope-lay-stranded conductor shall be 8 – 16 times the outside diameter of that layer.

4.1.6 Diameter and cross-sectional area

4.1.6.1 The nominal diameters of solid and stranded conductors are shown in Tables 5 – 10. The minimum diameter for a stranded conductor is 98 percent of the nominal. The maximum diameter of any conductor is 101 percent of the nominal. Verification of the diameter shall be determined in accordance with the method described in UL 1581, Section 220, CSA C22.2 No. 0.3, Clause 4.1.1, or NMX-J-066-ANCE.

Conductor sizes in mm² (AWG/kcmil) covered by this Standard are shown in Table 5. The nominal cross-sectional area of a conductor identified in Table 5 is not a requirement.

4.1.6.2 In the United States, compressed unilay or compressed unidirectional lay copper conductors smaller in diameter than the requirement (0.98 x nominal in Table 8) for compressed concentric lay conductors shall be marked in accordance with Clause 6.1.6.

In Canada and the Mexico, this requirement does not apply.

4.1.7 Joints

A joint in a solid conductor or in one of the individual wires of a stranded conductor shall neither increase the diameter nor materially decrease the strength of the conductor or the individual wire. No more than one of the wires in a stranded conductor of 19 wires or less, or more than one of the wires in any given layer in a stranded conductor of more than 19 wires, shall be joined in any 0.3 m (1 ft) of conductor.

In a rope-lay-stranded conductor, which consists of a central core surrounded by one or more layers of stranded members (primary groups), each member shall be considered equivalent to a solid wire, and as such, may be spliced as a unit. These joints shall not be any closer together than two lay lengths.

A joint shall be allowed in a Class B stranded 2.08 mm² (14 AWG), 3.31 mm² (12 AWG), or 5.26 mm² (10 AWG) insulated copper conductor intended to be used in a multiple-conductor cable, with an overall covering. The joint (butt splice) shall be made by machine brazing or welding the entire conductor such that the resulting solid section of the stranded conductor is no longer than 13 mm (0.50 inch). In addition, the joint shall not increase the diameter of the conductor, there shall be no sharp points, and the distance between joints in a single conductor shall not average less than 1000 m (3280 ft) in any finished length of that single insulated conductor. A joint (butt splice) shall be made before or after insulating and prior to further processing. Where joints (butt splices) are made after insulating, the insulation applied over the joint shall be of the same insulation material used throughout the length of the conductor, or of another insulating material that meets or exceeds the electrical, physical, and mechanical requirements of this

Standard for the original insulating material. Joints in bare or insulated equipment-grounding conductors shall not be allowed. Insulated conductors with a joint (butt splice) shall not be surface marked with a type designation.

4.1.8 Separator

A separator of suitable material, when present between the conductor and the insulation, shall be of contrasting color to the conductor color, except that clear or green shall not be used. A white colored separator over aluminum complies with this requirement. The separator and the other wire or cable components shall not have any deleterious effect on one another.

4.2 Insulation

4.2.1 General

4.2.1.1 Conductors shall be insulated with one of the thermoset materials shown in Clause 4.2.1.2 and Table 19. The insulation shall meet all the requirements of this Standard. The insulation shall be applied directly over the conductor or over the separator, if provided, and shall fit tightly thereto. The insulation shall be free from pores, splinters, and other inhomogeneities visible with normal or corrected vision without magnification.

The physical properties of the insulation shall comply with Table 11, when determined in accordance with CSA C22.2 No. 0.3, Clause 4.3.1, UL 1581, Section 400, or NMX-J-178-ANCE and NMX-J-186-ANCE.

4.2.1.2 The following insulation materials are identified for use in this Standard:

- a) XL;
- b) EPCV;
- c) Composite Insulation;
 - i) Inner – EP, EPCV, or XL;
 - ii) Outer – EPCV, XL, CP, or CPE;
- d) EP;
- e) SBR/IIR/NR;
- f) Silicone; and
- g) CP, CPE.

See Clause 4.10 for performance requirements for insulation materials other than those identified for use in items a) – g).

4.2.2 Repairs

Where a repair is made in the insulation, the insulation applied to the repaired section shall be equivalent to that removed, and the repaired section of the finished conductor shall comply with the same electrical and thickness requirements specified in this Standard.

4.2.3 Thickness

The average and minimum insulation thicknesses shall be as shown in Tables 12 – 18, when measured in accordance with the methods shown in UL 1581, Section 240, CSA C22.2 No. 0.3, Clause 4.2.1, and NMX-J-177-ANCE.

4.2.4 Centering

The insulated conductor shall have a circular cross-section, with the insulation applied concentrically about the conductor or any separator (making the conductor plus any separator well centered in the insulation), fitting tightly on the conductor or over any separator. If the insulation is applied in more than one layer, adjacent layers shall be vulcanized, cured, or cross-linked into an integral mass, with the layers not separable. This mass shall be taken as a whole for all measurements and tests, with the exception that the thicknesses of the layers of composite insulation shall be measured separately.

4.2.5 Insulation strand penetration (fall-in)

The insulation shall not penetrate the stranded conductor in a manner that would hamper the free stripping of the insulation when tested in accordance with Clause 8.7.

4.3 Jackets or fibrous coverings over single conductors

4.3.1 A single-conductor wire and each conductor of any 2-conductor flat parallel cable, and each conductor of any multiple-conductor cable, shall have a protective covering of fibrous material or a jacket applied over the outer surface of the insulation, in accordance with Table 19. The temperature rating of the jacket shall be the same as that of the insulated conductor. Requirements for protective coverings other than jackets are covered in Annex F of this Standard. Physical property requirements for jackets shall comply with Table 20, when tested in accordance with CSA C22.2 No. 0.3, Clause 4.3.1, UL 1581, Section 400, or NMX-J-178-ANCE and NMX-J-186-ANCE. Jacket thickness requirements are shown in Tables 21 – 23.

4.3.2 The following materials are identified for use as jackets or coverings:

- a) Rubber-filled woven cotton tape;
- b) Polypropylene tape under a fibrous wrap or braid;
- c) Oriented polyethylene terephthalate tape under a fibrous wrap or braid;
- d) Fibrous braid;
- e) Fibrous wrap;
- f) Neoprene jacket;
- g) NBR/PVC jacket;

- h) CPE jacket;
- i) CP jacket;
- j) PVC jacket;
- k) XL jacket.

See Clause 4.10 for the performance requirements of jacket materials other than those identified for use in items a) – k).

4.4 Shielding (optional)

4.4.1 Shielding applied over a single conductor(s) or over an assembly of conductors shall consist of a braid, a helically applied flat copper tape, a longitudinally corrugated copper tape, or any combination thereof. For helically applied tapes, the overlap shall be a minimum of 12.5 percent or 6.35 mm (0.25 inch), whichever is greater. For longitudinally applied tapes, the minimum overlap shall be 12.5 percent of the width of the tape. Shielded single-conductor cables, not intended for use in multiple-conductor cables, shall be jacketed in accordance with Clause 4.3. Shielded multiple-conductor assemblies shall be jacketed in accordance with Clause 4.9.

4.5 Multiple-conductor cables

4.5.1 Lay of cabled conductors

4.5.1.1 The two or more conductors in a multiple-conductor round cable or assembly other than the assemblies covered in Clause 4.11 shall be cabled in accordance with Clauses 4.5.1.2 and 4.5.1.3.

4.5.1.2 The component wires or cables of a 2-conductor cable shall be assembled as follows:

- a) All cables in sizes larger than 13.3 mm² (6 AWG) twisted in accordance with Clause 4.5.1.3; and
- b) All cables in sizes 13.3 mm² (6 AWG) and smaller twisted in accordance with Clause 4.5.1.3 or parallel.

4.5.1.3 A multiple-conductor cable, other than 2-conductor parallel cable, shall have the finished insulated conductors cabled together with a length of lay not greater than indicated in Table 24. The direction of lay may be changed at intervals throughout the length of the cable. The intervals need not be uniform. In a cable in which the direction of lay is changed:

- a) Each area in which the lay is right- or left-hand for a minimum of five complete twists (full 360° cycles) shall have the insulated conductors cabled with a length of lay that is not greater than indicated in Table 24; and
- b) The length of each lay-transition zone (oscillated section) between these areas of right- and left-hand lay shall not exceed 1.8 times the maximum length of lay indicated in Table 24.

The overall diameter of the assembly, where required, shall be calculated as outlined in Clause 4.9.3.

If the assembly consists of a number of layers of insulated conductors, the direction of lay of the outer layer shall be either left-hand or right-hand and the direction of lay of the inner layers shall be reversed.

4.5.2 Equipment-grounding conductor

Equipment-grounding conductors shall not be smaller than the sizes shown in Table 25. Where multiple equipment-grounding conductors are employed, they shall have a combined area not less than the sizes given in Table 25. In cables containing more than one size of circuit conductor, the minimum equipment-grounding conductor size shall be determined by the size of the largest circuit conductor.

The equipment-grounding conductor shall be of the same flexible stranding class as that of the accompanying circuit conductors or of more flexible stranding.

4.6 Color coding

4.6.1 Color of insulated equipment-grounding conductor

4.6.1.1 An insulated conductor intended for use as an equipment-grounding conductor shall be finished to show the color green throughout the entire length and circumference of its outer surface, with or without one or more straight or helical, broken (non-continuous) or unbroken yellow stripes. See Clause 4.6.1.2 for details on stripes.

4.6.1.2 Stripes as specified in Clauses 4.6.1, 4.6.2, and 4.6.3 shall be of even or varying width and shall occupy a total of 5 – 70 percent of the calculated circumference of the outer surface of the finished insulated conductor, with no individual width less than 5 percent of that same circumference. The width shall be measured perpendicular to each stripe. Where broken stripes are appropriate, they shall consist of a series of identical marks and spaces, the length of each mark shall be at least 3 mm (1/8 inch), and the linear spacing between marks shall not be greater than 19 mm (3/4 inch).

4.6.2 Identification of ungrounded circuit conductor(s)

4.6.2.1 Each ungrounded circuit conductor shall be finished to show a color or combination of colors other than and in contrast with white, gray, or green. The outer surface so colored also complies with the intent of this requirement where it contains any one of the following added throughout the entire length of the cable in a color or combination of colors other than and in contrast with white, gray, and green:

- a) One or more broken or unbroken straight or helical stripes. See Clause 4.6.1.2 for details on stripes;
- b) An unbroken series of identical hash marks or other symbols with dimensions as specified for stripes and with regular spacing; and
- c) Numerals, letters, words, or a combination thereof that comply with this Standard.

4.6.2.2 In Canada, the color or combination of colors of the ungrounded and grounded circuit conductor(s) in a multiple-conductor cable shall also be in accordance with Annex G.

In Mexico and the United States, the requirements in Annex G do not apply.

4.6.2.3 The markings covered in Clauses 4.6.2 and 4.6.3 shall not conflict with and shall be readily distinguishable from any of the other required or optional markings covered in this Standard.

4.6.3 Identification of grounded circuit conductor(s)

4.6.3.1 An insulated conductor intended for use as a grounded circuit conductor shall be finished to show the color white or gray throughout the entire length and circumference of its outer surface, or shall be identified by three continuous straight or helical, unbroken white stripes on other than green insulation, along its entire length. Straight stripes shall be placed a nominal 120° apart. Where multiple grounded circuit conductors are used in a cable, no more than one shall employ white stripes. Additional conductors intended to be grounded circuit conductors shall be finished white (gray is not appropriate except in a 4-circuit-conductor cable) and shall have any one of the following throughout the length of the wire or cable in a color or combination of colors other than, and in contrast with, white, gray, or green.

See 4.6.1.2 for details on stripes.

4.7 Fillers

When used in a multiple-conductor cable or assembly, fillers shall not have any deleterious effect on other cable components.

4.8 Jacket separators

4.8.1 Where a thermoplastic jacket is used over insulation other than XL, a polymeric tape not less than 0.02 mm (0.8 mil) thick shall be incorporated under the jacket. The use of polymeric tape over XL insulation shall be optional. Where a thermoset jacket is used, a suitable separator applied between the insulation and the jacket shall be optional. The separator and other wire or cable components shall not have any deleterious effect on one another.

4.8.2 The tape shall be applied either helically or longitudinally to completely cover the underlying components and so that it has an overlap of not less than 25 percent of its width or 6.3 mm (0.25 inch), whichever is less.

4.9 Jackets

4.9.1 General

4.9.1.1 A multiple-conductor cable shall have a protective covering of fibrous material or a jacket applied over the cabled conductors in accordance with Table 19. Requirements for protective coverings, other than jackets, applied over cabled conductors are provided in Annex F of this Standard. Where a thermoplastic or thermoset jacket is required or applied, the jacket shall fit tightly and be applied over cabled conductors or over a jacket separator in compliance with Clause 4.8. The temperature rating of the jacket shall be 75°C. The use of a 90°C rated jacket is optional. The physical properties of the jacket shall comply with Table 20, when determined in accordance with CSA C22.2 No. 0.3, Clause 4.3.1, UL 1581, Section 400; or NMX-J-178-ANCE and NMX-J-186-ANCE. Requirements for jackets over individual conductors are described in Clause 4.3.

4.9.1.2 Materials identified for use as jackets are described in Clause 4.3.2. See Clause 4.10 for performance requirements for jacket materials other than those identified in Clause 4.3.2.

4.9.2 Jacket thicknesses

The average and minimum thicknesses of a jacket shall not be less than indicated in Table 26 when determined by the method described in CSA C22.2 No. 0.3, Clause 4.2.8, or UL 1581, paragraphs 260.1 – 260.8 or 280.1 – 280.3; or NMX-J-177-ANCE.

4.9.3 Diameter of conductor assembly under jacket

To calculate the diameter under the jacket, use the nominal and, where specified, the minimum average dimensions of the components in the assembly.

4.10 Evaluation of new materials – establishment of dry temperature rating of alternative insulation and jacketing materials for use in this standard

4.10.1 Materials having characteristics different from those specified in Table 11 or 20 shall be evaluated for the requested temperature rating in accordance with Clause 5.21. To be evaluated, insulations for use without jackets or additional coverings, the outer insulation layer of a composite insulation, and jackets shall have an initial absolute minimum tensile strength of not less than 6.8 MPa (1000 lbf/in²), and an absolute minimum elongation of 100 percent before aging. Insulations for use with jackets or additional coverings, or the inner layer of composite insulation, shall have an initial absolute minimum tensile strength of not less than 3.4 MPa (500 lbf/in²) and an absolute minimum elongation of 100 percent before aging.

4.10.2 The temperature rating and thickness of insulation and/or a jacket of materials having characteristics different from those specified in Table 11 or 20 shall be as required for the specific thermoset-insulated wire or cable type. The electrical, mechanical, and physical characteristics of the wire or cable using these materials shall meet all the requirements for an insulation or jacket material named in Clause 4.2.1.2 or 4.3.2 for the required temperature rating (see Annex H).

4.11 Assemblies that include single-conductor thermoset-insulated wires

4.11.1 When cabled into assemblies (length and direction of lay not specified), single-conductor wires that comply with the requirements in this Standard shall not be considered as cables and shall not include overall coverings. An open, helically applied binder or wrap, intended only to hold the assembly together, shall be optional.

Completed assemblies shall meet the requirements of Clause 4.11.2.

4.11.2 Completed assemblies shall meet the following requirements:

- a) Assemblies in which an uninsulated copper conductor is included shall be tested in accordance with Clause 5.22.
- b) Each assembly in which an uninsulated conductor is not included shall be tested in accordance with Clause 5.21 or Clause 5.22, with each layer in a multiple-layer assembly spark tested separately.
- c) Each 2.08 – 8.37 mm² (14 – 8 AWG) conductor in an assembly shall be individually tested for continuity in accordance with Clause 5.25 after the assembly is completed.

5 Test requirements

5.1 General

Every length of finished insulated conductor shall be capable of complying with the requirements of Clauses 5.2 – 5.25, as applicable.

5.2 Conductor resistance

5.2.1 The direct-current resistance of the conductor shall not be greater than specified in Tables 27 – 32 inclusive. For conductors for which the maximum resistance is not tabulated in Tables 27 – 32, the maximum resistance for a given size of the solid or stranded construction shall be determined by multiplying the maximum resistance tabulated in the tables for uncoated copper of the same size and construction by the ratio of 100 percent IACS (International Annealed copper Standard) to the percent conductivity as shown in the applicable conductor standard.

5.2.2 A twisted conductor assembly or multiple-conductor cable shall not exceed the value tabulated in Tables 27 – 32 as applicable, for a single conductor multiplied by whichever of the following factors is applicable:

- a) Cabled in one layer: 1.02;
- b) Cabled in more than one layer: 1.03; or
- c) Cabled as an assembly of other pre-cabled units: 1.04

5.2.3 Compliance shall be determined in accordance with Clause 8.2.

5.3 Tests of aluminum conductors

5.3.1 Physical properties

5.3.1.1 All aluminum conductors shall have a minimum elongation of 10 percent. Wires (strands) removed from a finished stranded conductor shall have a tensile strength of 98 – 159 MPa (14,250 – 23,100 lbf/in²). The tensile strength of all other conductors shall be 103 – 152 MPa (15,000 – 22,000 lbf/in²). See Clause 8.3.1.

5.3.1.2 Compliance with the requirements in Clause 5.3.1.1 for stranded conductors shall be determined either on wires taken prior to stranding into conductors, strands taken from a stranded conductor, or the stranded conductor as a whole, at the option of the manufacturer.

5.3.2 High-current heat cycling

5.3.2.1 In the United States and Canada, the results of the tests conducted in accordance with Clause 8.3.2 shall be considered acceptable if at least 24 thermocouples (26 thermocouples if one test jig is rejected before 51 cycles are completed) measure less than 175°C, with each temperature profile exhibiting thermal stability as defined in CSA C22.2 No. 42 or UL 498 (10°C being the maximum above average of all measurements).

In Mexico, this requirement does not apply. See Clause 4.1.2.1.

5.4 Long-term insulation resistance in water

5.4.1 Minimum acceptable value

5.4.1.1 The insulation, without the protective covering, of wet-rated single-conductor cable and of the individual single conductors of multiple-conductor cable shall have an insulation resistance at the rated temperature in tap water not less than specified in Tables 33 – 35 at any time during immersion, when tested in accordance with Clause 8.4. The period of immersion shall be 12 weeks or more if the insulation resistance during the last 6 weeks of the period is higher than 3 GΩ·m (10 MΩ·1000 ft). The period of immersion shall be 24 – 36 weeks if the insulation resistance is less than 3 GΩ·m (10 MΩ·1000 ft) but equals or exceeds the value indicated in Tables 33 – 35. An a-c voltage equal to the voltage rating of the wire (600 V, 1000 V, or 2000 V rms) shall be applied to the insulated conductor at all times other than while measuring the insulation resistance. These tests are accelerated tests.

5.4.1.2 The values in Tables 33 – 35 apply only to conductor types with the corresponding insulation thicknesses specified in this Standard. For other parameters of any material, the insulation resistance values shall be calculated by means of the formula in Annex I.

5.4.2 Maximum acceptable rate of decrease

5.4.2.1 During the extended immersion, the maximum decrease in insulation resistance per week, as determined from a curve (drawn to represent the average of actual values), for every continuous period of 3 weeks during the later half of the specified immersion time, shall not be more than 4 percent if and while the insulation resistance is 3 GΩ·m (10 MΩ·1000 ft) or more; and shall not be more than 2 percent if the insulation resistance is less than 3 GΩ·m (10 MΩ·1000 ft) but more than the value indicated in Tables 33 – 35. Any coil that shows a greater percent decrease in insulation resistance during the extended immersion period shall be allowed to be tested for additional 1-week immersion periods and judged on the basis of the results for every continuous period of 3 weeks during the last 12 weeks of immersion, provided that the final insulation resistance is not less than as specified in Tables 33 – 35.

5.5 Long-term insulation resistance in air for 90°C rated conductors

5.5.1 This test is not required on insulated conductors that meet the requirements of Clause 5.4.

5.5.2 Minimum acceptable value

5.5.2.1 The insulation on Type XHH, RHH, and R90 wires shall have an insulation resistance in air at $97 \pm 1^\circ\text{C}$ that is not less than indicated in Table 36 or 37, whichever is applicable, at any time during an extended period in an acceptable full-draft circulating-air oven, when tested in accordance with Clause 8.5 under the following conditions. The period in the oven shall be 12 weeks or more if the insulation resistance throughout the last 6 weeks of the period is $3 \text{ G}\Omega\cdot\text{m}$ ($10 \text{ M}\Omega\cdot 1000 \text{ ft}$) or higher. The period in the oven shall be 24 – 36 weeks if the insulation resistance is less than $3 \text{ G}\Omega\cdot\text{m}$ ($10 \text{ M}\Omega\cdot 1000 \text{ ft}$) but equals or exceeds the values in Table 36 or 37, whichever is applicable. An rms potential equal to the voltage rating of the wire shall be applied at all times other than while reading the insulation resistance.

5.5.2.2 The insulation resistance shall be measured between the conductor and an electrode consisting of graphite powder, a snug-fitting copper braid of minimum 90 percent coverage applied over the insulation, or an equivalent means.

5.5.3 Maximum acceptable rate of decrease

5.5.3.1 The maximum acceptable rate of decrease shall be the same as specified in Clause 5.4.2, except that the final insulation resistance shall not be less than specified in Table 36 or 37.

5.6 Capacitance and relative permittivity

5.6.1 Specimens of finished wire immersed in water at rated temperature, 75°C or 90°C , shall comply with each of the following, when tested in accordance with Clause 8.6:

- a) The relative permittivity determined after immersion for 24 h shall not be more than 10 for CP, silicone rubber, and CPE insulation and shall be 6 or less for all other insulations.
- b) The capacitance for CP, silicone rubber, and CPE insulations after immersion for 14 d shall be no more than 6 percent higher than the capacitance after 24 h immersion, and no more than 10 percent higher for all other insulations.
- c) The capacitance determined for CP, silicone rubber, and CPE insulations after 14 d immersion shall be no more than 2 percent higher than the capacitance determined after immersion for 7 d, and no more than 4 percent higher for all other insulations.

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5.7 Conductor corrosion

5.7.1 Bare unprotected copper conductor used without a separator under the insulation or jacket shall not show surface deterioration during visual examination, when tested in accordance with Clause 8.7.

5.8 Insulation fall-in

5.8.1 The stranded conductor shall be free of residual insulation or extruded conductor-shield material when tested in accordance with Clause 8.8.

5.9 Heat shock of thermoplastic jacket

5.9.1 A thermoplastic jacket shall not show any cracks after a specimen of finished wire or cable has been wound or bent around a mandrel having a diameter in accordance with Table 38, and while still on the mandrel, subjected to a temperature of $121 \pm 1^\circ\text{C}$ for a period of 1 h. For flat cable, the minor cross-sectional dimension of the cable shall be used in determining the mandrel diameter, and the cable shall be wound or bent flatwise around the mandrel. Compliance shall be determined in accordance with Clause 8.9.

5.10 Flexibility of separator under a thermoplastic jacket

5.10.1 A separator under a thermoplastic jacket, as required in Clause 4.8.1, shall not show cracks or open up after a specimen of the finished single-conductor wire or cable, or of the finished multiple-conductor cable, is wound at room temperature around a mandrel, when tested in accordance with Clause 8.10.

5.11 Cold bend and cold impact

5.11.1 Cold bend

5.11.1.1 After conditioning at a temperature of $-25 \pm 1^\circ\text{C}$ for 4 h, the insulation or jacket of a wire, cable, or assembly shall not show any cracks, nor shall any thread or threads of a fibrous covering of a wire, cable, or assembly show any breaks, when tested in accordance with Clause 8.11.1. The mandrel diameter shall be as specified in Table 39 for single conductors, and Table 40 for multiple-conductor cables. When the wire or cable is marked with the optional -40°C marking in accordance with Clause 6.1.8, conditioning shall be carried out at a temperature of $-40 \pm 1^\circ\text{C}$.

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5.11.2 Cold impact (optional)

5.11.2.1 Where required, the jacket and/or insulation on at least 8 out of 10 completed cable specimens shall not crack or rupture, nor shall any thread or threads of a fibrous covering break, when tested at -40°C in accordance with Clause 8.11.2.

5.12 Deformation

5.12.1 The thickness of XL insulation shall not decrease more than 30 percent for conductor sizes 2.08 – 107.2 mm² (14 – 4/0 AWG) or 15 percent for conductor sizes 127 – 1010 mm² (250 – 2000 kcmil) when subjected for 30 min, at a temperature of $131^{\circ}\text{C} \pm 1^{\circ}\text{C}$, to the load specified in Table 41, and tested in accordance with Clause 8.12, except that the test specimens shall be unconditioned.

5.12.2 The thickness of a jacket of thermoplastic material shall not decrease more than 50 percent when subjected to a temperature of $121 \pm 1^{\circ}\text{C}$ while under a load of 2000 g, when tested in accordance with Clause 8.12.

5.13 Hot-creep elongation and hot-creep set

5.13.1 Hot-creep elongation and hot-creep set of EP and EPCV insulation shall not exceed 50 percent and 5 percent respectively, after conditioning at $150 \pm 2^{\circ}\text{C}$ ($302.0 \pm 3.6^{\circ}\text{F}$) for 15 min in an air oven, when tested in accordance with Clause 8.13.

5.14 Flame and smoke

5.14.1 Horizontal specimen (XHH, XHHW, XHHW-2, RHH, RHW RHW-2, SA, SF, and SIS)

5.14.1.1 A finished wire or cable of any construction shall not convey flame along its length or to combustible materials in its vicinity when a specimen is subjected to the flame test described in Clause 8.14.1. The total length of char on the specimen shall not exceed 100 mm (4 inches), and the dripping particles emitted by the specimen during or after the application of flame shall not ignite the cotton on the floor of the enclosure, on the base of the burner, or on the wedge. Flameless charring of the cotton shall be ignored.

5.14.1.2 Type SIS conductors that comply with the requirements of Clause 5.14.1.1 shall be allowed to be marked FT2.

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5.14.2 Burning particles (dropping) test (R90, RW75, RW90, RWU75, and RWU 90)

5.14.2.1 XL insulation shall be such that when a specimen of single-conductor wire or cable without a covering or jacket is subjected to the burning particles (dropping) test, Clause 8.14.2, burning particles from the specimen shall not cause the newsprint to ignite (flame). The specimen shall be tested after allowing at least 3 weeks after manufacture. Earlier testing by the manufacturer is optional.

5.14.3 FT1 (optional)

5.14.3.1 A finished conductor, when tested in accordance with Clause 8.14.3, shall be considered to have met the requirements for this marking if:

- a) It does not convey flame.
- b) It does not continue to burn for more than 60 s after five 15 s applications of flame in the standard vertical flame test.
- c) The extended portion of the indicator is not burned more than 25 percent.

5.14.4 VW-1 (vertical-specimen) flame test (optional)

5.14.4.1 For a given size of a finished wire or cable to be marked VW-1, that size and 2.08 mm² (14 AWG) copper or 3.31 mm² (12 AWG) aluminum shall comply with the requirements of the horizontal flame test described in Clause 5.14.1, and shall be judged capable of not conveying flame along its length or in its vicinity when tested in accordance with Clause 8.14.4. If any specimen shows more than 25 percent of the indicator flag burned away or charred (soot that can be removed with a cloth or the fingers and brown scorching area shall be ignored) after any of the five applications of flame, the wire or cable shall be judged capable of conveying flame along its length. If any specimen emits flaming or glowing particles or flaming drops at any time that ignite the cotton on the burner, wedge, or floor of the enclosure (flameless charring of the cotton shall be ignored), the wire or cable shall be judged capable of conveying flame to combustible materials in its vicinity. If any specimen continues to flame longer than 60 s after any application of the gas flame, the wire or cable shall be judged capable of conveying flame to combustible materials in its vicinity.

5.14.5 Vertical-tray (optional)

Finished single conductors shall not exhibit damage that reaches the upper end of any of two sets of specimens when subjected to the flame test indicated in Clause 8.14.5 for the specified period.

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5.14.6 FT4 vertical-tray (optional)

Finished single conductors shall not exhibit charred material beyond a length exceeding 1.5 m (5 ft) from the flame impingement when tested in accordance with Clause 8.14.6 for the specified period.

Conductors meeting this requirement need not be subjected to the test described in Clause 5.14.5.

5.14.7 ST1 limited smoke (optional)

5.14.7.1 General

When tested in accordance with Clause 8.14.7, each finished insulated single conductor shall meet the test criteria in Clauses 5.14.5 or 5.14.6. Limits are specified for each fire test to make the following tests equally acceptable for the purpose of quantifying the smoke. The cable manufacturer shall specify, for testing each "ST1" (limited smoke) cable construction, either the vertical flame exposure described in Clause 8.14.7.1 or the vertical flame exposure described in Clause 8.14.7.2.

For a range of sizes to be marked "ST1", typically the smallest conductor in the range, the smallest conductor employing the same insulation thickness as the largest conductor in the range, and an intermediate conductor shall be selected for testing. Individual conductor sizes may be tested.

5.14.7.2 Vertical-tray flame exposure

Finished insulated single conductors shall exhibit the following properties when tested in accordance with Clause 8.14.7.1:

- a) The cable damage height for each set of specimens shall be less than 2.44 m (8 ft) when measured from the bottom of the cable tray.
- b) The total smoke released in 20 min for each set of specimens shall not exceed 95 m².
- c) The peak smoke release rate for each set of specimens shall not exceed 0.25 m²/s.
- d) The values of cable damage height, total smoke released, and peak smoke release rate obtained from one set of specimens shall not differ by more than 15 percent from the values obtained from the second set of specimens. If any of the values differ by more than 15 percent between the two sets of specimens, a third set of specimens shall be tested as described in Clause 8.14.7.1. The values obtained from the third set of specimens shall be within the limits in items a), b), and c).

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5.14.7.3 FT4 vertical-tray flame exposure

Finished insulated single conductors shall exhibit the following properties when sets of specimen lengths are tested in accordance with Clause 8.14.7.2:

- a) The cable damage height for each set of specimens shall be less than 1.50 m when measured from the bottom of the cable tray.
- b) The total smoke released in 20 minutes for each set of specimens shall not exceed 150 m².
- c) The peak smoke release rate for each set of specimens shall not exceed 0.40 m²/s.
- d) The values of cable damage height, total smoke released, and peak smoke release rate obtained from one set of specimens shall not differ by more than 15 percent from the values obtained from the second set of specimens. If any of the values differ by more than 15 percent between the two sets of specimens, a third set of specimens shall be tested as described in Clause 8.14.7.2. The values obtained from the third set of specimens shall be within the limits in items a), b), and c).

5.14.8 LS (low smoke): Flame, smoke, and acid gas release (optional)

5.14.8.1 General

The requirements of Clauses 5.14.8.2 to 5.14.8.4 apply to types marked "LS".

5.14.8.2 Smoke emission

The components of cables shall be tested in accordance with the method described in Clause 8.14.8.1 to obtain the smoke emission performance. For cables up to 10 mm (0.40 inch) external diameter, the maximum specific optical density (DM) shall not be more than 500, and the value of smoke obscuration in the first four min (VOF₄) shall not be more than 400. For cables with an external diameter larger than 10 mm (0.40 inch), the maximum specific optical density (DM) shall not be more than 500, and the value of smoke obscuration in the first four minutes (VOF₄) shall not be more than 800. Tests shall be performed on die-cut specimens 2 mm (0.08 inch) in thickness.

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5.14.8.3 Fire propagation (RPI)

Finished cable samples shall be subjected to the test method described in Clause 8.14.8.2 for testing fire-propagation resistance of single or multiple conductors. The cables shall be considered in compliance if the damage produced by the test does not exceed the upper limit of the chimney of the testing equipment (0.80 m over the oven).

5.14.8.4 Halogen acid gas emission

Samples of nonmetallic components of cables shall have a maximum loss of mass in the form of acid gas emission not greater than 20 percent (by weight) of halogen acid gas (except hydrogen fluoride), produced by pyrolysis, when tested in accordance with the method described in Clause 8.14.8.3. Acid gas is expressed as percentage of the hydrogen chloride evolved during the test.

5.15 Weather resistance (optional)

5.15.1 For unfilled XL material to be marked SR, the insulation shall contain a minimum of 2.5 percent carbon black content, determined in accordance with Clause 8.15.3. To be marked SR, materials other than unfilled XL shall retain 80 percent of their initial tensile strength and elongation values after being subjected to 720 h xenon or carbon arc exposure in accordance with Clause 8.15.2.

5.16 Oil resistance (optional)

5.16.1 Oil resistance at 60°C

To be marked PR I, the retention of tensile strength and elongation of the insulation, or jacket where used, shall not be less than 50 percent of the unconditioned value after immersion of the finished wire in IRM 902 oil for 96 h at 100°C as described in Clause 8.16.1.

5.16.2 Oil Resistance at 75°C

To be marked PR II, the retention of tensile strength and elongation of the insulation, or jacket where used, shall not be less than 65 percent of the unconditioned value after immersion of the finished wire in IRM 902 oil for 60 d at 75°C, as described in Clause 8.16.2.

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5.17 Gasoline and oil resistance (optional)

5.17.1 To be marked GR I or GR II, insulation, or jackets where used, shall comply with the requirements of Clause 5.16.1 for GR I, or 5.16.2 for GR II, and the retention of tensile strength and elongation shall not be less than 65 percent after 30 d immersion in water saturated with equal volumes of iso-octane and toluene (ASTM Reference Fuel C) maintained at $23 \pm 1^\circ\text{C}$, in accordance with Clause 8.17.

5.18 Crushing resistance

5.18.1 An average of not less than 5338 N (1200 lbf) shall be necessary to crush finished solid 2.08 mm² (14 AWG) Type XHH, XHHW, and XHHW-2 wires, or not less than 8007 N (1800 lbf) to crush finished stranded 33.6 mm² (2 AWG) Type XHH, XHHW, and XHHW-2 wires, to the point that the conductor contacts the earth-grounded metal of the testing machine used in the test described in Clause 8.18.

5.18.2 The results of this test on 2.08 mm² (14 AWG) and 33.6 mm² (2 AWG) sizes shall be considered representative of the performance of all 2.08 – 1010 mm² (14 AWG – 2000 kcmil) Type XHH, XHHW, and XHHW-2 wires with the same insulation.

5.19 Dielectric breakdown after glancing impact

5.19.1 The average breakdown potential for six specimens of finished solid 2.08 mm² (14 AWG) Type XHH, XHHW, and XHHW-2 wires that have separately been subjected to a glancing impact of 2 J (18 in-lbf) shall not be less than 20 percent of the average breakdown potential of six adjacent specimens of the same wire not subjected to the impact. Testing shall be performed in accordance with Clause 8.19.

5.20 Durability of ink printing

5.20.1 Printing on the finished wire shall remain legible after being subjected to the test specified in Clause 8.20.

5.21 Shrinkback

5.21.1 This requirement applies to solid 2.08 – 5.26 mm² (14 – 10 AWG) XL insulated conductors only. No exposed end of the conductor shall exceed 3 mm (0.12 inch) in length after 24 h when evaluated in accordance with Clause 8.21. As an option, if the exposed conductor length exceeds 3 mm (0.12 inch), it shall not exceed 4 mm (0.16 inch) in length after 7d.

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5.22 Evaluation of new materials – establishment of dry temperature rating

For the insulation and jacketing materials identified in Clause 4.10, the projected elongation of the insulation shall not be less than 50 percent, and the projected tensile strength calculated for 300 d shall not be less than 2 MPa (300 lbf/in²) for jacketed insulation, and 4 MPa (600 lbf/in²) for unjacketed insulation and jackets, after being subjected to long-term aging in an air oven for a minimum of 150 d, in accordance with Clause 8.22.

5.23 A-C spark test

5.23.1 Every finished production length of single-conductor cable shall be subjected either:

- a) To the a-c spark test in accordance with this clause; or
- b) To the dielectric voltage-withstand in water test described in Clause 5.24, and the insulation resistance in water test at 15°C described in Clause 8.24.

In the event that option a) is chosen, the finished wire or cable shall be capable of complying with the tests referred to in option b).

5.23.2 The test shall be performed in accordance with Clause 8.23. The test potential shall be as shown in Table 42.

5.24 Dielectric voltage-withstand in water

5.24.1 Finished wires and cables, when tested in accordance with Clause 8.24, shall withstand, without breakdown of the insulation, the application of the appropriate test voltage after immersion in water for not less than 6 h before the test potential is applied, as follows:

- a) Wires or cables shall be subjected to the a-c test voltage of Table 43 for 60 s;
- b) Alternatively, wires and cables shall be subjected to a d-c test voltage of 3 times the a-c voltage specified in item a) for the same period.

5.25 Insulation resistance in water at 15°C

5.25.1 The insulation of single conductors shall have an insulation resistance not less than the values specified in Tables 44 – 46 inclusive. The apparatus and test method shall be in accordance with Clause 8.25. When the water temperature is other than 15°C, the correction factor determined by the method described in Clause 8.25.2 or Table 54 shall be used. The test shall be carried out following the test in Clause 5.24, while still immersed.

5.26 Electrical continuity

Each conductor shall be continuous. Test methods for electrical continuity are specified in Clause 8.26.

6 Marking

6.1 Marking on product

6.1.1 General

6.1.1.1 All markings on the finished product shall be visible and legible. Surface printing, indent printing, or embossed marking meet the intent of this requirement. The process shall not result in a thickness less than the minimum specified.

6.1.1.2 The marking legend shall be repeated at intervals not exceeding 1.0 m (40 inches), except for conductor size, which shall be repeated on the conductor or marker tape at intervals not exceeding 610 mm (24 inches).

6.1.1.3 For products intended for specific national applications, markings alternative to those required in this Clause are described in Annex J.

6.1.1.4 Clauses 6.1.2 – 6.1.7 describe required markings. Clauses 6.1.8 – 6.1.13 describe additional markings.

6.1.1.5 Markings on a product shall be optional when the product is intended for further processing into another cable product.

6.1.2 Manufacturer's identification

A finished wire or cable shall have a durable distinctive marking throughout its entire length by which the organization responsible for the product is readily identified.

6.1.3 Type designation

6.1.3.1 The type designation as described in Table 1 shall be marked as indicated in Clause 6.1.1. The use of the word "Type" shall be optional. Marking of the maximum operating dry and wet temperature rating of insulation, as applicable, shall be optional.

6.1.3.2 In the United States, multiple-conductor cables with Type RHH, RHW, RHW-2, SA, XHH, XHHW, or XHHW-2 conductors and an outer covering shall have a suffix after the type letters as follows:

- a) D – Cable in which two conductors are laid parallel; or
- b) M – Cable in which two or more conductors are cabled together

In Canada and Mexico, this requirement does not apply.

6.1.3.3 A wire or cable that complies with all of the requirements applicable to two or more types shall be allowed to be marked to so indicate – e.g., "R90 or XHHW".

6.1.4 Conductor size

The size of conductors shall be marked on the product, expressed in one of the following forms:

a) "mm² (AWG)" or "AWG (mm²)";

or

b) "mm² (kcmil)" or "kcmil (mm²)".

Either a comma or a period shall signify a decimal. For printing on products, the use of "mm²" in place of "mm²" shall be allowed.

6.1.5 Aluminum conductors

Aluminum conductors shall be marked "AL" or "ALUM". The additional marking "ACM" shall be optional.

6.1.6 Compact copper conductors

6.1.6.1 In the United States, compact-stranded copper conductors shall be marked "Compact Copper" or "Compact Cu" or "Cmpct Cu" after the conductor size.

In Canada and Mexico, this requirement does not apply.

6.1.7 Voltage marking

A wire or cable shall be marked with its voltage rating, using "V", "volts", or "VOLTS".

6.1.8 Low-temperature marking (optional)

A wire or cable meeting the requirements for –40°C cold bend and cold impact specified in Clause 5.11 may be marked "(–40C)".

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6.1.9 Flame test marking (optional)

6.1.9.1 General

Insulated conductors with the following markings shall have met the requirements of the corresponding clauses:

- a) "FT1": Clause 5.14.3;
- b) "VW-1": Clause 5.14.4;
- c) "CT": Clause 5.14.5 or 5.14.6 (see 6.1.9.2 for applicability);
- d) "FT4": Clause 5.14.6 or 5.14.7 using flame exposure in accordance with Clause 8.14.7.2;
- e) "ST1": Clause 5.14.7;
- f) "LS": Clause 5.14.8;
- g) "RPI": Clause 5.14.8.3; and
- h) "FT2": Clause 5.14.1.

Note: The FT1 or FT4 marking is required as specified in the CEC, Part I, and the National Building Code of Canada.

6.1.9.2 Cable tray use marking (optional)

6.1.9.2.1 Insulated conductors marked "CT" shall meet the requirements of either Clause 5.14.5 or Clause 5.14.6.

6.1.9.2.2 In the United States, this marking shall be allowed on single circuit conductors of size 53.5 mm² (1/0 AWG) and larger, and on equipment-grounding conductors of size 21.2 mm² (4 AWG) and larger.

In Mexico, the marking "CT" shall be allowed on all sizes of multiple conductors and to single circuit conductors 21.2 mm² (4 AWG) and larger.

In Canada, the marking "CT" is not recognized by the *Canadian Electrical Code, Part I*.

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6.1.10 Weather resistance

Wires or cables meeting the requirements of Clause 5.15 may be marked "SR".

6.1.11 Oil resistance

Wires or cables meeting the requirements of Clause 5.16.1 may be marked "PR I". Wires or cables meeting the requirements of Clause 5.16.2 may be marked "PR II".

6.1.12 Gasoline and oil resistance

Wires or cables meeting the requirements of Clauses 5.16.1 and 5.17 may be marked "GR I". Wires or cables meeting the requirements of Clauses 5.16.2 and 5.17 may be marked "GR II".

6.1.13 Shielded products

Products meeting the requirements of Clause 4.4 shall be marked "SHIELDED".

6.2 Marking on package

Each package of wire or cable shall be tagged or marked to indicate the following legibly:

- a) Manufacturer's identification;
- b) Date of manufacture, by month and year (a code is acceptable);
- c) Type designation;
- d) Conductor size in accordance with Clause 6.1.4;
- e) "ALUM" or "AL" after the conductor size [item (d) above], when an aluminum conductor is used. The additional marking "ACM" shall be optional. If compact stranding is used, "CMPCT" or the word "COMPACT" shall accompany "ALUM" or "AL" or "ACM";
- f) Voltage rating;
- g) In the United States, if stranded copper conductors are compact, the words "Compact Copper" or "Compact Cu" or "Cmpct Cu" shall appear after the conductor size [item (d) above]. The following statement shall also appear on the package: "Terminate with connectors identified for use with compact-stranded copper conductors";
- h) "SHIELDED" when applicable; and
- i) Optionally, the maximum operating dry and wet temperature rating of insulation.

7 Deep-well submersible water-pump cable

7.1 General

The construction of deep-well submersible water-pump cable shall consist of assemblies comprising two or more insulated circuit conductors having a wet rating and an optional insulated equipment-grounding conductor. The assemblies shall be with or without an overall jacket. A low-temperature rating of -40°C shall be optional. Either twisted or parallel configurations shall be permitted.

7.2 Construction

7.2.1 General

Except as indicated, the components of deep-well submersible water-pump cable shall comply with the requirements of Clauses 7.2 – 7.4 of this Standard.

7.2.2 Conductors

Circuit conductors shall consist of solid or stranded 2.08 – 33.6 mm² (14 – 2 AWG) copper, solid or stranded 3.31 – 33.6 mm² (12 – 2 AWG) aluminum, or stranded 42.4 – 253 mm² (1 AWG – 500 kcmil) copper or aluminum. The optional insulated equipment-grounding conductor shall be of the same construction as the circuit conductors, except that a copper equipment-grounding conductor shall be allowed with aluminum circuit conductors, or an aluminum equipment-grounding conductor shall be allowed with copper circuit conductors. The minimum sizes of equipment-grounding conductors shall be as specified in Table 25. All conductors shall comply with Clause 4.1 of this Standard.

7.2.3 Insulation

Insulated conductors shall be of the types provided in Clause 7.2.4.

7.2.4 Assembly

The conductors shall be assembled in one of the following ways:

- a) **CABLED WITH AN OVERALL JACKET** – This cable assembly shall have two or more insulated circuit conductors of one of the following types: RHW-2, XHHW-2, RHW, XHHW, RWU75, or RWU90. The insulated circuit conductors shall be cabled together with an optional insulated equipment-grounding conductor in either a right- or left-hand lay of unspecified length, with an overall jacket. The jacket shall comply with the thickness requirements of Table 47 and the physical properties requirements in Table 20.
- b) **CABLED WITHOUT AN OVERALL JACKET** – This cable assembly shall have 2 – 6 insulated circuit conductors of one of the following types: RHW-2, XHHW-2, RHW, XHHW, RWU75, or RWU90. The insulated conductors shall be cabled together helically with an optional insulated equipment-grounding conductor in either a right- or left-hand lay of unspecified length, without an overall jacket.
- c) **PARALLEL WITH INTEGRAL WEB WITHOUT AN OVERALL JACKET** – This cable assembly shall have two, three, or four circuit conductors of one of the following types: RHW-2, XHHW-2, RHW, XHHW, RWU75, or RWU90. The circuit conductors shall be laid flat and parallel together with any optional equipment-grounding conductor laid parallel on the same axis. The conductors shall be joined to one another with an interconnecting web. The conductor insulation shall be extruded simultaneously with the interconnecting web and shall be of the same compound. The minimum thickness of insulation at any point on any conductor, after separation, shall not be less than required for the specified wire type.
- d) **PARALLEL WITH AN OVERALL JACKET AND INTEGRAL FILLERS OR WEBS** – This cable assembly shall have two, three, or four insulated circuit conductors of the following types: RHW-2, XHHW-2, RHW, XHHW, RWU75, or RWU90. The circuit conductors shall be laid parallel on the same axis, together with an optional insulated equipment-grounding conductor, and having an overall jacket that shall be extruded to form either an interconnecting web of

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unspecified thickness between the conductors, or fillers that are integral with the jacket. The degree to which the integral fillers fill the valleys between the conductors is not specified, except that the fill shall maintain the stability of the flat construction.

7.2.5 Polarity identification of conductors

7.2.5.1 Polarity identification of conductors other than the grounding or grounded conductor shall be provided by means of contrasting colors or stripes other than white, gray, or green; by ridges; by stripes; or by word printing. Grounded circuit conductors shall be colored white or gray or shall have white or gray stripes.

In Canada, the color of the conductors shall also be in accordance with Annex G.

In Mexico and the United States, the requirements in Annex G do not apply.

7.2.5.2 The equipment-grounding conductor shall be colored green or green with yellow stripes.

7.2.5.3 In the case of a flat cable that includes an insulated equipment-grounding conductor, the grounding conductor shall be identified as such, either as indicated in Clause 7.2.5.1 or by means of legible, durable ink printing of "GROUNDING ONLY" or equivalent on the outer surface of the finished conductor.

7.2.6 Jackets

7.2.6.1 Jackets shall comply with the requirements of Clause 4.9.1.

7.2.6.2 The average and minimum thicknesses of a jacket shall not be less than indicated in Table 47 when determined by the method described in CSA C22.2 No. 0.3, Clause 4.2.8, or UL 1581, paragraphs 260.1 – 260.8 or 280.1 – 280.3, or NMX-J-177-ANCE. The diameter over the assemblies described in Clause 7.2.3, for the purpose of determining jacket thickness, shall be obtained as specified in Clause 4.9.3.

7.3 Markings

7.3.1 Markings on product

7.3.1.1 Deep-well submersible water-pump cable shall be legibly and durably marked to indicate the following:

- a) The manufacturer's identification in accordance with Clause 6.1.2;
- b) The number of circuit conductors (in the case of jacketed constructions);
- c) The conductor size in accordance with Clause 6.1.4;
- d) The word AL or ALUM, if aluminum conductors are used. The additional marking "ACM" shall be optional;
- e) The designation "SUBMERSIBLE PUMP CABLE" (required on jacketed constructions, optional on conductors of non-jacketed constructions);
- f) The nominal voltage rating in accordance with Clause 6.1.7;

- g) The low-temperature rating marking in accordance with Clause 6.1.8 for cables complying with Clause 7.4.3;
- h) The type designation of individual conductors, either on the conductor insulation surface or the outer jacket; and
- i) Optional markings specified in Clause 6.1 as applicable.

7.3.1.2 The markings in Clause 7.3.1.1 shall be surface ink-printed, indented, or embossed at intervals not exceeding 0.6 m (24 inches). Indent markings shall be such that the minimum specified thickness of the jacket or insulation is maintained.

7.3.1.3 For products intended for specific national applications, markings alternative to those required in this Clause are described in Annex J.

7.3.2 Markings on package

Each packaged coil or reel of cabled or parallel assembly, and of jacketed cables, shall be tagged or marked to indicate the following legibly:

- a) The manufacturer's identification in accordance with Clause 6.1.2;
- b) The month and year of manufacture;
- c) The designation "SUBMERSIBLE PUMP CABLE";
- d) The conductor size in accordance with Clause 6.1.4;
- e) AL or ALUM, if aluminum conductors are used. The additional marking "ACM" shall be permitted;
- f) The nominal voltage rating in accordance with Clause 6.1.7;
- g) The low-temperature rating marking in accordance with Clause 6.1.8 for cables in compliance with Clause 7.4.3;
- h) In the United States and Canada, the notation "For Wiring Only Between Equipment Located at Water Well Heads and Motors of Installed Deep-Well Submersible Water Pumps";

In Mexico, this requirement does not apply; and
- i) The type designation of the individual conductors.

For products intended for specific national applications, markings alternative to those required in this clause are described in Annex J.

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7.4 Tests

7.4.1 General

In addition to the tests performed on each insulated conductor according to its type as specified in Clause 5, and the spark test specified in Table 42, the completed cable shall be subjected to the tests in Clauses 7.4.2 – 7.4.4.

7.4.2 Dielectric withstand

The finished assembly or cable shall withstand the a-c voltage as specified in Clause 5.23. For a flat or twisted assembly, the test voltage shall be applied between each conductor and tap water in which the assembly has been immersed for 6 h.

7.4.3 Cold impact

A cabled assembly with Type RWU75 or RWU90 conductors shall comply with the requirements in Clause 5.11.2. This test is optional for cabled assemblies with other conductor types.

7.4.4 Electrical Continuity

Each conductor shall be continuous when tested in accordance with Clause 8.26.

8 Test methods

8.1 General

The test methods are presented in Clauses 8.2 – 8.25.

8.2 Conductor resistance

8.2.1 Compliance shall be determined with the apparatus and method described in CSA C22.2 No. 0.3, Clause 4.1.2, UL 1581, Section 220, or NMX-J-212-ANCE.

8.3 Test methods for aluminum conductors

8.3.1 Physical properties

Compliance shall be determined with the apparatus and method described in CSA C22.2 No. 0.3, Clause 4.1.3, UL 1581, Section 10, or NMX-J-312-ANCE.

8.3.2 High-current heat cycling

8.3.2.1 Thirty-one samples of insulated solid size 3.31 mm² (12 AWG) wire, of length 610 – 685 mm (24 – 27 inches) each and fabricated from the aluminum conductor material, shall be secured to a test piece as shown in Figures 1 and 2, consisting of 15 test jigs (duplex receptacle terminals) and having the following characteristics:

- a) One terminal baseplate as shown in Figure 3 shall be made out of 0.76 ±0.03 mm 70/30 ASTM sheet brass, Rockwell B 82-86 hardness.
- b) Screws shall be made of carbon steel AISI* 1010 meeting the requirements of ASTM A 29 and located at 21.4 mm centers. See Figure 4 for screw description.
- c) The other terminal baseplate (neutral side) shall be the same as described in item a) but in addition shall have immersion tin plating of less than 0.003 mm thickness.
- d) The two binding-head screws, size No. 8-32, used on the white terminal baseplate shall be zinc-plated a minimum of 0.003 mm thick and have a chromate conversion coating.
- e) The other two binding-head screws, size No. 8-32, in the yellow side (line) of the jig shall be zinc-plated a minimum of 0.003 mm thick and brass-finished.

Screws shall be free-running when finger torque is applied until the head of the screw engages with the wire.

The wire shall be connected to form a 3/4 loop under the head of the screw as specified in CAN/CSA-C22.2 No. 48 or UL 1567. Terminal screws shall be torqued to 0.68 N and held for 30 s. Jigs shall be connected together at terminal screws A and B by means of a 610 – 685 mm (24 – 27 inch) piece of aluminum conductor material (ACM) wire. Terminal screws C and D of each jig shall be connected by a 610 – 685 mm (24 – 27 inch) piece of the ACM wire. One thermocouple (Type J No. 30 AWG iron constantan) shall be cemented or soldered as per Figure 2, attached at the midpoint (on the breakoff tab) of each terminal baseplate between the screws. These jigs shall then be connected to a 40 A, 60 Hz constant-current supply and subjected to 500 cycles of operation, with each cycle consisting of 3.5 h ON and 0.5 h OFF. Care shall be taken not to disturb the connecting wires after applying the torque.

*American Iron and Steel Institute.

8.3.2.2 Temperature measurements shall be taken in accordance with the method specified in CAN/CSA-C22.2 No. 48 or UL 1567, after temperature stability has been attained. Thermal stability shall be as defined in CAN/CSA-C22.2 No. 48.

8.3.2.3 Where a temperature exceeds 175°C (one thermocouple measurement) within the first 50 cycles of test, the result shall not be counted in the overall performance rating. The device shall be removed and replaced by two new test jigs. These shall be inserted into the circuit in such a manner as not to disturb the wire connections or the other test jigs. The results shall be considered acceptable if temperatures measured by the 26 thermocouples are less than 175°C, with each thermocouple profile exhibiting thermal stability as described in Clause 5.3.2.

8.4 Long-term insulation resistance in water

Compliance shall be determined with the apparatus and method specified in UL 1581, paragraphs 920.1 – 920.6, CSA C22.2 No. 0.3, Clause 4.28.2, or NMX-J-294-ANCE.

8.5 Long-term insulation resistance in air (for 90°C rated)

Compliance shall be determined with the apparatus and method specified in UL 1581, paragraphs 920.1 – 920.6, CSA C22.2 No. 0.3, Clause 4.28.2, or NMX-J-294-ANCE, modified as described in Clauses 5.4 and 5.5, using 3 or more 15 m (50 ft) coils.

8.6 Capacitance and relative permittivity

Compliance shall be determined with the apparatus and method specified in UL 1581, Section 1020, CSA C22.2 No. 0.3, Clause 4.28.4, or NMX-J-040-ANCE.

8.7 Conductor corrosion

A copper conductor removed from unaged specimens of the finished wire or cable and from specimens aged at elevated temperature, as described in Table 11, for the particular insulation being employed shall not show any evidence of corrosion (normal oxidation or discoloration of the copper not caused by the insulation or by any separator shall be disregarded) when subjected to a visual examination. The examination shall be made with normal or corrected vision without magnification.

8.8 Insulation fall-in

A 75 mm (3 inch) length of the insulation shall be stripped from a sample length of the finished stranded conductor, and the outer surface of the conductor shall be cleaned with a wire brush to remove the visible insulation. The outermost strands shall then be peeled back and examined for the presence of residual insulation or extruded conductor-shield material on the portions of these strands that were not accessible to the wire brush or on the remainder of the conductor beneath these strands.

8.9 Heat shock of thermoplastic jacket

Compliance with Clause 5.9.1 shall be determined with the apparatus and according to the method described in CSA C22.2 No. 0.3, Clause 4.23.1, UL 1581, Section 540, or NMX-J-190-ANCE.

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