UL 83

Thermoplastic-Insulated Wires and Cables

UL Standard for Safety for Thermoplastic-Insulated Wires and Cables, UL 83

Sixteenth Edition, Dated July 28, 2017

Summary of Topics:

This revision of ANSI/UL 83 dated April 10, 2020 includes the modification of Requirements for Conductor Stranding Marking on Product; 6.1.5, Table 42

Text that has been changed in any manner or impacted by UL's electronic publishing system is marked with a vertical line in the margin.

The new and revised requirements are substantially in accordance with Proposal(s) on this subject dated December 20, 2019.

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Association of Standardization and Certification
NMX-J-010-ANCE-2017
Sixth Edition

CSA Group
CSA C22.2 No. 75-17
Eleventh Edition

Underwriters Laboratories Inc.
UL 83
Sixteenth Edition

Thermoplastic-Insulated Wires and Cables

July 28, 2017

(Title Page Reprinted: April 10, 2020)

ANSI/UL 83-2020

Commitment for Amendments

This standard is issued jointly by the Association of Standardization and Certification (ANCE), the Canadian Standards Association (operating as "CSA Group"), and Underwriters Laboratories Inc. (UL). Comments or proposals for revisions on any part of the standard may be submitted to ANCE, CSA Group, or UL at any time. Revisions to this standard will be made only after processing according to the standards development procedures of ANCE, CSA Group, and UL. CSA Group and UL will issue revisions to this standard by means of a new edition or revised or additional pages bearing their date of issue. ANCE will incorporate the same revisions into a new edition of the standard bearing the same date of issue as the CSA Group and UL pages.

ISBN 978-1-4883-0433-0 © 2017 Canadian Standards Association

This Standard is subject to review withinin five years from the date of publication, and suggestions for its improvement will be referred to the appropriate committee. To submit a proposal for change, please send the following information to inquiries@csagroup. org and include "Proposal for change" in the subject line: Standard designation (number); relevant clause, table, and/or figure number; wording of the proposed change; and rationale for the change.

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This ANSI/UL Standard for Safety consists of the Sixteenth Edition including revisions through April 10, 2020. The most recent designation of ANSI/UL 83 as an American National Standard (ANSI) occurred on April 10, 2020. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, Title Page (front and back), or the Preface.

The Department of Defense (DoD) has adopted UL 83 on February 27, 1984. The publication of revised pages or a new edition of this Standard will not invalidate the DoD adoption.

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PREFACE

This is the harmonized ANCE, CSA Group, and UL Standard for Thermoplastic-Insulated Wires and Cables. It is the Sixth edition of NMX-J-010-ANCE, the Eleventh edition of CAN/CSA-C22.2 No. 75, and the Sixteenth edition of UL 83. This edition of NMX-J-010-ANCE supersedes the previous edition published March 28, 2014. This edition of CAN/CSA-C22.2 No. 75 supersedes the previous edition published March 28, 2014. This edition of UL 83 supersedes the previous edition published March 28, 2014. This harmonized standard has been jointly revised on April 10, 2020. For this purpose, CSA Group and UL are issuing revision pages dated April 10, 2020, and ANCE is issuing a new edition dated April 10, 2020.

This harmonized standard was prepared by the Association of Standardization and Certification, (ANCE), CSA Group 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 is considered suitable for use for conformity assessment within the stated scope of the standard.

The present Mexican Standard was developed by the CT 20 Conductores from the Comite de Normalizacion de la Asociacion de Normalizacion y Certificacion, A.C., CONANCE, with the collaboration of the SC 20B Conductores para Baja Tensión.

This standard was reviewed by the CSA Integrated Committee on Fixed Installation Wires and Cable, 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 has been developed in compliance with Standards Council of Canada requirements for National Standards of Canada. It has been published as a National Standard of Canada by CSA Group.

Application of Standard

Where reference is made to a specific number of samples 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 is it considered equivalent to, an IEC standard. This standard is published as an equivalent standard for ANCE, CSA Group, 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.

Thermoplastic-Insulated Wires and Cables

1 Scope

1.1 This Standard specifies the requirements for 600 V single-conductor, thermoplastic-insulated wires and cables, for use as follows:

a) In Canada, in accordance with CSA C22.1, *Canadian Electrical Code (CE Code)*, *Part I;*

b) In Mexico, in accordance with NOM-001-SEDE, *Standard for Electrical Installations;* and

c) In the United States, in accordance with ANSI/NFPA 70, *National Electrical Code (NEC)*.

Note: See Annex A for the complete list of wire types and voltage ratings covered by this Standard and the specific electrical codes for which they are intended.

1.2 This Standard also specifies the requirements for submersible-pump cables, with or without jackets (see Section 7). No type-letter designations are assigned to these cables.

1.3 In Mexico, the requirements for multiple-conductor thermoplastic-insulated and -jacketed cables rated 600 V are specified in Annex B.

In Canada and the United States, requirements for multiple-conductor thermoplastic-insulated and -jacketed cables are covered in other standards.

1.4 Products for which this Standard provides requirements might have applications not described in the electrical codes listed in Clause 1.1.

2 General

2.1 Units of measure

Values stated without parentheses are the requirement. Values in parentheses are explanatory or approximate information. This applies to all values with the exception of conductor size.

2.2 Reference publications

Where reference is made to any Standards, such reference shall be considered to refer to the latest editions and revisions thereto available at the time of printing, unless otherwise specified.

Secretary of Energy

NOM-001-SEDE,
Standard for Electrical Installations

ANCE Standards

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 Conductors – Specifications

NMX-J-014-ANCE,
Wires and Cables – Rope Lay Stranded Copper Conductors Having Bunch Stranded Members for Electrical Applications

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 on Electrical Conductors – Test Method

NMX-J-093-ANCE,
Wire and Cables – Determination of the Resistance to Fire Propagation on Electrical Conductors – Test Methods

NMX-J-177-ANCE,
Determination of Thickness of 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,
Accelerated Aging in Forced-Convection Ovens of Semiconductive Shielding, Insulations and Jackets of Electrical Conductors – Test Method

NMX-J-189-ANCE,
Electrical Products – Wires and Cables – Room Temperature Flexibility Test for PVC Insulated Electrical Conductors – Test Method

NMX-J-190-ANCE,
Heat Shock Resistance of PVC Insulations and 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-194-ANCE,
Wires and Cables – Oil Immersion Aging for Insulations and Jackets of Electrical Conductors – Test Method

NMX-J-212-ANCE,
Electrical Resistance, Resistivity and Conductivity – Test Method

NMX-J-293-ANCE,
Wires and Cables – Alternating Current and Direct Current Dielectric Voltage Withstand – Test Method

NMX-J-294-ANCE,
Insulation Resistance – Test Method

NMX-J-297-ANCE,
Wires and Cables – Flexible Cords Copper Conductors for Electrical and Electronic Applications – Specifications

NMX-J-472-ANCE,
Electrical Products – Wires and Cables – Determination of the Amount of Halogen Acid Gas Evolved During the Controlled Combustion of Polymeric Materials Taken from Electrical Cables – Test Method

NMX-J-473-ANCE,
Wires and Cables – Spark Test – Test Method

NMX-J-474-ANCE,
Electrical Products – Wires and Cables – Determination of Specific Optical Density of Smoke Generated by Electrical Wires and Cables – Test Methods

NMX-J-498-ANCE,
Wires and Cables – Vertical Tray Flame Test – Test Method

NMX-J-516-ANCE,
Wires and Cables – Weather Resistance of Insulation of Jacket of Electrical Conductors – Test Method

NMX-J-553-ANCE,
Wires and Cables – Weather Resistance of Insulation or Jacket of Electrical Conductors – Test Method

NMX-J-556-ANCE,
Wire and Cable Test Methods

CSA Group Standards

C22.1-15,
Canadian Electrical Code, Part I

CAN/CSA C22.2 No. 0,
General Requirements – Canadian Electrical Code, Part II

CAN/CSA C22.2 No. 2556,
Wire and Cable Test Methods

UL Standards

UL 2556
Wire and Cable Test Methods

ASTM (American Society for Testing and Materials) Standards

B3-13,
Standard Specification for Soft or Annealed Copper Wire

B8-11,
Standard Specification for Concentric-Lay-Stranded Copper Conductors, Hard, Medium-Hard, or Soft

B33-10,
Standard Specification for Tinned – Coated Soft or Annealed Copper Wire for Electrical Purposes

B172-10,
Standard Specification for Rope-Lay-Stranded Copper Conductors Having Bunch-Stranded Members, for Electrical Conductors

B173-10,
Standard Specification for Rope-Lay-Stranded Copper Conductors Having Concentric-Stranded Members, for Electrical Conductors

B174-10,
Standard Specification for Bunch-Stranded Copper Conductors for Electrical Conductors

B801-07(2012),
Standard Specification for Concentric-Lay-Stranded Conductors of 8000 Series Aluminum Alloy for Subsequent Covering or Insulation

B835-04(2009),
Standard Specification for Compact Round Stranded Copper Conductors Using Single Input Wire Construction

B836-00(2011),
Standard Specification for Compact Round Stranded Aluminum Conductors Using Single Input Wire Construction

B901-04(2011),
Standard Specification for Compressed Round Stranded Aluminum Conductors Using Single Input Wire Construction

B902-13,
Standard Specification for Compressed Round Stranded Copper Conductors, Hard, Medium-Hard, or Soft Using Single Input Wire Construction

IEC (International Electrotechnical Commission) Standards

60228 (2004-11),
Conductors of insulated cables

NFPA (National Fire Protection Association) Publication

NFPA 70-2014,
National Electrical Code

2.3 Summary of requirements

As a guide to users of this Standard, a summary of requirements is provided in Annex C.

2.4 General requirements

In Canada, general requirements applicable to this standard are given in CAN/CSA-C22.2 No. 0.

3 Definitions

3.1 The following definitions apply in this Standard:

Equipment-grounding conductor – a conductor that is defined in Mexico, in NOM-001-SEDE, and in the United States, in the *NEC*, as "Grounding Conductor, Equipment", and in Canada, in the *CE Code, Part I*, as "Bonding conductor".

PVC – a thermoplastic compound whose characteristic constituent is polyvinyl chloride or a copolymer of vinyl chloride and vinyl acetate.

Thermoplastic – a polymeric material that can repeatedly be softened by heating and hardened by cooling and that in the softened state can be shaped through the application of force.

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

In Canada and the United States, aluminum conductors shall be of aluminum conductor material (ACM), AA 8000 series alloy.

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

In Mexico, aluminum conductors shall not be used in thermoplastic-insulated wires and cables in accordance with NOM-001-SEDE.

4.1.3 Copper-clad aluminum conductors

In the United States, the requirements of Annex E 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 thermoplastic-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.

4.1.4.2 Bare copper conductors

Each wire in a bare copper conductor shall comply with the requirements of ASTM B3 or NMX-J-036-ANCE.

4.1.4.3 Tin-coated copper conductors

Each wire in a tin-coated conductor shall comply with the requirements of ASTM B33 or NMX-J-008-ANCE. Overcoating of 2.08 mm^2 (14 AWG), 3.31 mm^2 (12 AWG), and 5.26 mm^2 (10 AWG) stranded copper conductor with a layer of tin shall be optional.

4.1.5 Sizes and stranding

4.1.5.1 Sizes

Conductor sizes and stranding shall be as shown in Table 1.

Note: IEC conductor sizes are not recognized in the CE Code, Part I, NEC, or NOM-001-SEDE; however, these sizes can be required for wires and cables intended for use outside of the codes. As a guide to users of this Standard, information on IEC conductors is provided in Annex F.

4.1.5.2 Stranding

4.1.5.2.1 General

4.1.5.2.1.1 The minimum number of wires (strands) in a conductor shall be in accordance with Table 2.

4.1.5.2.1.2 Copper strands smaller than 0.0127 mm^2 (36 AWG) and aluminum strands smaller than 0.324 mm^2 (22 AWG) shall not be used. A compact-stranded conductor shall not be segmented.

4.1.5.2.2 Concentric

A concentric conductor shall be a round conductor consisting of a round central core surrounded by one or more layers of helically laid round wires all having the same diameter.

4.1.5.2.3 Compact

A compact-stranded conductor shall be a round conductor consisting of a central core surrounded by one or more layers of helically laid wires, and formed into a smooth outermost layer by rolling, drawing, or other means. The lay length of every layer shall be not less than 8 times nor more than 16 times the outside diameter of the completed conductor, except that for sizes 33.6 mm^2 (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.

4.1.5.2.4 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.

4.1.5.2.5 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 shall be 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 as indicated in Table 3. The direction of lay of the strands in a bunch-stranded conductor shall be left-hand.

4.1.5.2.6 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 mm^2 (6 AWG – 2000 kcmil) conductor, other than a compressed unilay single input wire, 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.

The length of lay shall be determined in accordance with the test, Length of lay, in UL 2556, CSA C22.2 No. 2556, or NMX-516-ANCE

4.1.6 Diameter and cross-sectional area

4.1.6.1 The nominal diameters of solid and stranded conductors are shown in Table 4 – Table 9. There are no diameter requirements for conductor classes not referenced in Table 4 – Table 9. See Clause 5.2 for conductor resistance requirements. The minimum diameter for stranded conductors is 98 percent of the nominal. The maximum diameter is 101 percent of the nominal. The diameter shall be determined in accordance with the test, Conductor diameter, in UL 2556, CSA C22.2 No. 2556, or NMX-J-066-ANCE.

4.1.6.2 Conductor sizes in mm^2 (AWG/kcmil) covered by this Standard are shown in Table 4. The nominal cross-sectional area of a conductor identified in Table 4 is not a requirement.

4.1.7 Joints

4.1.7.1 A joint (butt splice) where allowed 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.

4.1.7.2 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. Not more than one of the wires in a stranded conductor of 19 wires or less, nor 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.

4.1.7.3 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, shall be spliced as a unit. These joints shall not be any closer together than 2 lay lengths.

4.1.7.4 A joint shall be allowed in a Class B stranded 2.08 mm^2 (14 AWG), 3.31 mm^2 (12 AWG), 5.26 mm^2 (10 AWG), or 8.37 mm^2 (8 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. 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 between the conductor and the insulation shall be optional. The separator shall be of contrasting color to the conductor color, except that clear or green shall not be used. White-colored separator over aluminum conductors shall be optional. The separator and the other wire or cable components shall not have any deleterious effect on each other.

4.2 Insulation

4.2.1 General

4.2.1.1 Conductors shall be insulated for their entire length with PVC or other thermoplastic material meeting 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 without magnification to normal or corrected-to-normal vision.

4.2.1.2 If the insulation is applied in more than one layer, the interface between the layers shall be free of voids visible without magnification to normal or corrected-to-normal vision, and all layers shall be taken together for all measurements and tests.

4.2.2 Repairs

4.2.2.1 Where a repair is made in the insulation, the insulation applied to the repaired section shall be equivalent to that removed.

4.2.2.2 In Canada and the United States, the repaired section of the finished conductor shall comply with the same electrical and thickness requirements specified in this Standard.

In Mexico, repairs to finished conductors are not permitted.

4.2.3 Colored insulation

4.2.3.1 When colored insulation is required, either the insulation shall be colored throughout its thickness or a thin colored coating of suitable material shall be applied to the surface of the insulation. The coating material shall not have an adverse effect on the properties of the insulation. If the coating is of an extruded type, it shall be considered as part of the insulation and shall comply with all requirements.

4.2.3.2 Polarity identification of circuit conductors other than the grounding or grounded conductor shall be provided by means of contrasting colors 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 three continuous white stripes on a background of other than green or green with yellow stripes. Longitudinal white stripes shall be spaced nominally 120 degrees apart. The equipment-grounding conductor shall be colored green or green with continuous or broken yellow stripes.

4.2.3.3 Stripes as specified in Clause 4.2.3.2 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).

4.2.4 Thickness and centering

4.2.4.1 The minimum average thickness and the minimum thickness at any point of the insulation shall be as shown in Table 10. Compliance shall be determined in accordance with the test, Thickness, in UL 2556, CSA C22.2 No. 2556, or NMX-J-177-ANCE.

4.2.4.2 The insulation shall have a circular cross-section, with the insulation applied concentrically about the conductor and fitting tightly on the conductor or over any separator.

4.2.5 Physical properties of insulation

4.2.5.1 General

The tensile strength and ultimate elongation of PVC insulation, before and after aging, shall be as specified in Table 11.

4.2.5.2 Test requirement

Compliance with Clause 4.2.5.1 shall be determined in accordance with the test, Physical properties (ultimate elongation and tensile strength), in UL 2556, CSA C22.2 No. 2556, or NMX-J-556-ANCE.

4.2.5.3 Evaluation of alternative insulation materials for use in this Standard (see Annex G)

4.2.5.3.1 Alternative insulation materials for products shall be evaluated in accordance with the test, Dry temperature rating of new materials (long-term aging test), in UL 2556, CSA C22.2 No. 2556, or NMX-J-556-ANCE.

4.2.5.3.2 Materials having characteristics different from those specified in Table 11 shall be evaluated for the requested temperature rating in accordance with Clause 5.21. To be evaluated, materials shall have an initial absolute minimum tensile strength of not less than 6.8 MPa (1000 lbf/in^2), and an absolute minimum elongation of 100 percent before aging.

4.2.5.3.3 The temperature rating and thickness of those materials having characteristics different from those specified in Table 11 shall be as required for the specific thermoplastic-insulated wire or cable type. The electrical, mechanical, and physical characteristics of the wire or cable using these materials shall be such that the materials meet the specified requirements for PVC for the temperature rating.

4.2.5.3.4 Insulation material complying with Clause 4.2.5.3.2 shall then be evaluated to establish requirements for its specific physical properties in Table 12.

4.3 Nylon jacket

4.3.1 General

Types THHN, THWN, TWN75, THWN-2, and T90 Nylon shall have a jacket of nylon extruded tightly over the insulation. The use of nylon jackets on other types to which this Standard applies shall be optional. Where utilized, nylon jackets shall comply with all applicable requirements. Jacket materials other than nylon meeting the requirements of this Standard shall be acceptable.

4.3.2 Thickness

The minimum jacket thickness at any point shall be as shown in Table 13, and shall be measured in accordance with UL 2556, CSA C22.2 No. 2556, or NMX-J-177-ANCE.

4.4 Assemblies that include thermoplastic-insulated single conductors

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 cables, and do not include overall coverings. An open, skeleton tape or wrap intended only to hold the assembly together shall be allowed. Such assemblies shall be allowed to include other single-conductor wires or cables not covered in this Standard. An assembly shall be without a bare or covered aluminum conductor, but a bare copper conductor – size is not specified – that is coated with tin or other metal shall be optional. A bare, coated copper conductor shall not be covered. The completed assembly shall meet the following requirements:

a) Assemblies in which a bare, coated copper conductor is included shall be tested for dielectric voltage-withstand as indicated in Clause 5.23, except that immersion in water shall be for at least 1 h.

b) Each assembly in which a bare conductor is not included shall either be tested as indicated in Clause 5.23 (1 h or longer immersion) or be spark tested as indicated in Clause 5.22, with each layer in a multiple-layer assembly sparked separately.

c) Each 2.08 – 8.37 mm^2 (14 AWG – 8 AWG) conductor in an assembly shall be individually tested for continuity after the assembly is completed.

5 Test requirements

5.1 General

Every length of finished insulated conductor shall be capable of meeting the test requirements set out in 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 as specified in Table 14 – Table 23 inclusive. For conductors for which the maximum resistance is not tabulated in Table 14 – Table 23 , 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 The DC resistance, when measured on a single conductor within a twisted conductor assembly or multiple-conductor cable shall not exceed the value tabulated in Table 14 – Table 23 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 the test, DC resistance, in UL 2556, CSA C22.2 No. 2556, or NMX-J-212-ANCE.

5.3 Tests on aluminum conductors

5.3.1 Physical properties

5.3.1.1 All aluminum conductors shall have a minimum elongation at break 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/in^2). The tensile strength of all other conductors shall be 103 – 152 MPa (15,000 – 22,000 lbf/in^2). Compliance shall be determined in accordance with the test, Physical properties of conductors – Maximum tensile strength and elongation at break, in UL 2556 or CSA C22.2 No. 2556.

5.3.1.2 Compliance with the requirements in 5.3.1.1 for stranded conductors shall be determined either on wires taken prior to stranding into conductors, any strand(s) taken from a stranded conductor, or the stranded conductor as a whole, at the option of the manufacturer. In case of non-compliance, the results from specimens taken from a center strand only shall be considered for referee purposes.

5.3.2 High-current heat cycling [3.31 – 8.37 mm^2 (12 – 8 AWG) conductors only]

5.3.2.1 A minimum of 24 thermocouples (26 thermocouples if one test jig is rejected before 51 cycles are completed) shall measure less than 175°C, with each temperature profile exhibiting thermal stability.

5.3.2.2 Compliance shall be determined in accordance with the test, High-current heat cycling for aluminum conductors, in UL 2556 or CSA C22.2 No. 2556.

5.4 Short-term insulation resistance at elevated temperature in water

The resistance values shall not be less than those shown in Table 24 when tested in accordance with the test, Insulation resistance, in UL 2556, CSA C22.2 No. 2556, or NMX-J-556-ANCE, after immersion in water for at least 6 h at the same temperature as the temperature rating of the insulation.

5.5 Long-term insulation resistance in water – acceptance criteria

5.5.1 The insulation without 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 temperature specified in Clause 5.5.2 in tap water that is not less than specified in Table 24 at any time while immersed. The period of immersion shall be 12 weeks or more if the insulation resistance throughout the last 6 weeks of the initial 12–week immersion period is greater than 3 GΩ·m (10 MΩ·1000 ft). The period of immersion shall be at least 24 weeks and no more than 36 weeks, unless requested by the manufacturer, if the insulation resistance is less than 3 GΩ·m (10 MΩ·1000 ft) at any point during the last 6 weeks of the initial 12-week immersion period, but equals or exceeds the value specified in Table 24. An a-c voltage equal to the voltage rating of the wire (600 V rms) shall be applied to the insulated conductor at all times other than while measuring the insulation resistance.

In the case of nylon-jacketed wires, the nylon shall be removed prior to testing. These tests are accelerated tests. The values in Table 24 apply only to conductor types with the corresponding insulation thicknesses specified in this Standard.

5.5.2 The water shall be 50 ±1°C or 60 ±1°C for Types TW and TWU; 75 ±1°C for Types THW, THWN, THW-LS, THHW-LS, THHW, TW75, TWN75, and TWU75; and 90 ±1°C for Types THW-2 and THWN-2.

5.5.3 The maximum weekly decrease in insulation resistance as determined in Clause 5.5.4 shall not be more than 4 percent if the insulation resistance throughout the last 6 weeks of the immersion period 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 values specified in Table 24. If the results of the test do not meet either of these criteria, but are more than the values specified in Table 24, the period of immersion may be extended by one week intervals at the request of the manufacturer, subject to the minimum test period established in 5.5.1. If the insulation resistance falls below the values specified in Table 24, the test shall be discontinued and considered a failure.

5.5.4 The maximum weekly decrease in insulation resistance shall be calculated as the slope of a least squares best fit straight line curve drawn through a three-week moving average of the last six weeks of raw test data. Each three-week moving average data point for the least squares best fit straight line curve shall be calculated as the average of the raw data for the current week and the previous two weeks (for example, the week 12 data point would be the average of the weeks 10, 11 and 12 raw data values).

5.5.5 Compliance with 5.5.1– 5.5.4 shall be determined in accordance with the test, Long-term insulation resistance (Method 1), in UL 2556, CSA C22.2 No. 2556, or NMX-J-556-ANCE.

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

5.6.1 General

This test shall not be required on insulated conductors that meet the requirements of Clause 5.5.

5.6.2 Acceptance criteria

5.6.2.1 The 90° C rated insulation of the individual conductors without covering shall have insulation resistance in air at 97 ±1° C that is not less than specified in Table 25 at any time during an extended period in an acceptable full-draft circulating-air oven. The period in the oven shall be 12 weeks or more, if the insulation resistance throughout the last 6 weeks of the initial 12-week period in the oven is greater than 3 GΩ·m (10 MΩ·1000 ft). The period in the oven shall be at least 24 weeks and no more than 36 weeks, unless requested by the manufacturer if the insulation resistance is less than 3 GΩ·m (10 MΩ·1000 ft) at any point during the last 6 weeks of the initial 12-week period in the oven, but equals or exceeds the value specified in Table 25. An a-c voltage equal to the voltage rating of the wire (600 V rms) shall be applied to the insulated conductor at all times other than while measuring the insulation resistance. In the case of nylon-jacketed wires, the nylon shall be removed prior to testing. These tests are accelerated tests. The values in Table 25 apply only to conductor types with the corresponding insulation thicknesses specified in this Standard.

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

5.6.2.3 The maximum weekly decrease in insulation resistance as determined in Clause 5.6.2.4 shall not be more than 4 percent if the insulation resistance throughout the last 6 weeks of the period in the oven is 3 GΩ-m (10 MΩ-1000 ft) or more, and shall not be more than 2 percent if the insulation resistance at any point during the last 6 weeks of the initial 12-week period in the oven is less than 3 GΩ-m (10 MΩ-1000 ft), but more than the values specified in Table 25. If the results of the test do not meet either of these criteria, but are more than the values specified in Table 25, the period of immersion may be extended by one week intervals at the request of the manufacturer, subject to the minimum test period established in 5.5.3. If the insulation resistance falls below the values specified in Table 25, the test shall be discontinued and considered a failure.

5.6.2.4 The maximum weekly decrease in insulation resistance shall be calculated as the slope of a least squares best fit straight line curve drawn through a three-week moving average of the last six weeks of raw test data. Each three-week moving average data point for the least squares best fit straight line curve shall be calculated as the average of the raw data for the current week and the previous two weeks (for example, the week 12 data point would be the average of the weeks 10, 11 and 12 raw data values).

5.6.2.5 Compliance with 5.6.2.1 – 5.6.2.4 shall be determined in accordance with the test, Long-term insulation resistance (Method 2), in UL 2556, CSA C22.2 No. 2556, or NMX-J-556-ANCE.

5.7 Capacitance and relative permittivity of wet rated ("W" type) wires

Specimens of finished wire immersed in water at the wet-rated temperature, 60 ±1° C, 75 ±1° C, or 90 ±1° C, shall comply with each of the following, in accordance with the test, Capacitance and relative permittivity, in UL 2556, CSA C22.2 No. 2556, or NMX-J-040-ANCE:

a) The relative permittivity determined after immersion for 24 h shall not be more than 10.

b) The capacitance determined for all insulations after immersion for 14 d shall not be more than 10 percent higher than the capacitance after 24 h immersion.

c) The capacitance determined for all insulations after the 14 d immersion shall not be more than 5 percent higher than the capacitance determined after immersion for 7 d.

In the case of nylon-jacketed wires, the nylon shall be removed prior to testing.

5.8 Flexibility at room temperature after aging

The insulation and nylon jacket (if present) shall not show any cracks, either on the surface or internally, when wound around a mandrel of the diameter specified in Table 26, Column B, at room temperature, in accordance with the test, Flexibility at room temperature after aging, in UL 2556, CSA C22.2 No. 2556, or NMX-J-189-ANCE, after aging in an air oven as specified in Table 11.

5.9 Heat shock

5.9.1 Neither the insulation nor the nylon jacket (if present) shall show any cracks, on the surface or internally, after a specimen of finished wire or cable is wound around a mandrel after conditioning in an air-circulating oven for 1 hour to a temperature of 121 ±1°C. For single conductors the mandrel diameter shall be as specified in Column A of Table 26. Compliance shall be determined in accordance with the test, Heat Shock, in UL 2556, CSA C22.2 No. 2556, or NMX-J-190-ANCE.

5.9.2 For 42.4 mm^2 (1 AWG) and smaller, the specimen shall be tightly wound for four adjacent turns around the mandrel, and both ends of the specimen shall be securely held in place. For 53.5 mm^2 (1/0 AWG) and larger, a U-bend shall be made between the specimen in contact with the mandrel for not less than 180 degrees.

5.10 Cold bend and cold impact

5.10.1 Cold bend

5.10.1.1 After conditioning at a temperature of −25 ±1°C for 4 h, the insulation and nylon covering (if present) shall not show any cracks when tested in accordance with the test, Cold bend, in UL 2556, CSA C22.2 No. 2556, or NMX-J-193-ANCE, modified as indicated in Clause 5.10.1.2. The mandrel diameter shall be as specified in Column B of Table 26. Conditioning at a temperature of −40 ±1°C shall be optional.

5.10.1.2 In the case of 85.0 mm^2 (3/0 AWG) or smaller conductors, the specimen shall be tightly wound for four adjacent turns around the mandrel, and the winding shall be done at a uniform rate of approximately 4 s per turn. For sizes 107 mm^2 (4/0 AWG) and larger, a 180 degree U-bend shall be performed.

5.10.1.3 When the wire or cable is marked with the optional "−40C" marking in accordance with Clause 6.1.9, conditioning shall be carried out at a temperature of −40 ±1°C.

5.10.2 Cold impact (optional)

The insulation and jacket, where present, on at least 8 out of 10 complete cable specimens shall not crack or rupture when tested at −40°C in accordance with the test, Cold impact, in UL 2556, CSA C22.2 No. 2556, or NMX-J-556-ANCE.

5.11 Deformation

5.11.1 The thickness of 60°C, 75°C, and 90°C rated insulations shall not decrease by more than 50, 30, and 30 percent, respectively, when subjected to the load specified in Table 29 and tested in accordance with the test, Deformation, in UL 2556, CSA C22.2 No. 2556, or NMX-J-191-ANCE.

5.11.2 Nylon-jacketed conductors shall be maintained at 136 ±1°C during the test, with the nylon left in place. Measurements shall be made over the nylon. Except as shown in Clause 5.11.3, all other conductors shall be maintained at 121 ±1°C during the test.

5.11.3 In Mexico, Types THHW and THHW-LS conductors shall be maintained at 136 ±1°C during the test.

5.12 Flame and smoke

5.12.1 Vertical flame

When tested in accordance with the test, FV-1/Vertical Flame, in UL 2556, CSA C22.2 No. 2556, or NMX-J-192-ANCE, a specimen of a wire or cable shall not flame longer than 60 s following five 15 s applications of the test flame, the period between applications being 15 s. 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.

5.12.2 FT1

In Canada, when tested in accordance with the test, FT1, in UL 2556, CSA C22.2 No. 2556, or NMX-J-193-ANCE, a finished conductor shall not convey flame or continue to burn for more than 60 s after five 15 s applications of the test flame. If more than 25 percent of the extended portion of the indicator is burned, the conductor shall be considered to have conveyed flame.

In the United States and Mexico, compliance with this requirement shall be optional.

5.12.3 FV-2/VW-1 (optional)

5.12.3.1 Vertical specimen

5.12.3.1.1 For a given size of a finished wire or cable to be marked VW-1, that size and 2.08 mm^2 (14 AWG) copper or 3.31 mm^2 (12 AWG) aluminum shall comply with the requirements of the horizontal flame test described in Clause 5.12.3.2, and with the requirements of Clause 5.12.3.1.2 when tested in accordance with the test FV-2/VW-1, in UL 2556, CSA C22.2 No. 2556, or NMX-J-192-ANCE.

5.12.3.1.2 Each specimen shall be judged not capable of conveying flame along its length or in its vicinity if the following conditions apply:

a) The specimen does not show 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;

b) The specimen does not emit 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); and

c) The specimen does not continue to flame longer than 60 seconds after any application of the gas flame.

5.12.3.2 Horizontal specimen

Each size of a given construction of a finished wire that is marked VW-1 or FV-2, in addition to complying with Clause 5.12.3.1, shall be capable of not conveying flame along its length or in its vicinity when a specimen is subjected to the test in FT2/FH/Horizontal flame, in UL 2556, CSA C22.2 No. 2556, or NMX-J-192-ANCE. The total length of the char in the specimen shall not exceed 100 mm (4 inches), and the dripping particles emitted by the specimen during or after the application of the flame shall not ignite the cotton on the floor of the enclosure, on the base of the burner, or on the wedge.

5.12.4 Vertical tray (optional)

Finished single conductors shall not exhibit damage that reaches the upper end of any of two sets of specimen, when subjected for the specified period to the test, Method 1 – Vertical tray, in UL 2556, CSA C22.2 No. 2556, or NMX-J-498-ANCE.

5.12.5 FT4 vertical tray (optional)

Finished single conductors shall not exhibit charred material beyond a length exceeding 1.5 m from the flame impingement, when tested for the specified period in accordance with the test, Method 2 – FT4, in UL 2556, CSA C22.2 No. 2556, or NMX-J-498-ANCE.

5.12.6 ST1 limited-smoke (optional)

5.12.6.1 General

When tested in accordance with the test, ST1 limited smoke, in UL 2556, CSA C22.2 No. 2556, or NMX-J-498-ANCE, each finished insulated single conductor shall comply with the requirements in Clauses 5.12.4 or 5.12.5. Limits are specified for each fire test to make the following tests equally acceptable for the purpose of quantifying generation of the smoke. The cable manufacturer shall specify, for testing each ST1 (limited-smoke) cable construction, either the vertical flame exposure described in the Vertical tray flame test – Method 1 – Vertical tray, or in the Vertical tray flame test – Method 2 – FT4 in UL 2556, CSA C22.2 No. 2556, or NMX-J-556-ANCE.

Typically, for a range of sizes to be marked ST1, 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. Testing of individual conductor sizes shall be optional.

5.12.6.2 Vertical tray flame exposure

Finished insulated single conductors shall exhibit the following properties when tested in accordance with the Vertical tray flame test – Method 1 – Vertical tray in UL 2556, CSA C22.2 No. 2556, or NMX-J-498-ANCE:

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 m^2.

c) The peak smoke release rate for each set of specimens shall not exceed 0.25 m^2/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 UL

2556, CSA C22.2 No. 2556, or NMX-J-498-ANCE. The values obtained from the third set of specimens shall be within the limits specified in (a), (b), and (c).

5.12.6.3 FT4 vertical tray flame exposure

Finished insulated single conductors shall exhibit the following properties when sets of specimen lengths are tested in accordance with the Vertical tray flame test – Method 2 – FT4 in UL 2556, CSA C22.2 No. 2556, or NMX-J-498-ANCE:

a) The cable damage height for each set of specimens shall be less than 1.50 m when measured from the lower edge of the burner face.

b) The total smoke released in 20 min for each set of specimens shall not exceed 150 m^2.

c) The peak smoke release rate for each set of specimens shall not exceed 0.40 m^2/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 UL 2556, CSA C22.2 No. 2556, or NMX-J-498-ANCE. The values obtained from the third set of specimens shall be within the limits specified in (a), (b), and (c).

5.12.7 LS (low-smoke): Flame, smoke, and acid-gas release

5.12.7.1 General

The requirements of Clauses 5.12.7.2 – 5.12.7.4 apply to Types THW-LS and THHW-LS and shall be mandatory for all other types marked "LS".

5.12.7.2 Smoke emission

The components of cables shall be tested in accordance with the test, Smoke emission in UL 2556, CSA C22.2 No. 2556, or NMX-J-474-ANCE 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 minutes (VOF_4) 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 (VOF_4) shall not be more than 800.

5.12.7.3 Fire propagation (RPI)

Finished cable samples shall be subjected to the test method described in UL 2556, CSA C22.2 No. 2556, or NMX-J-093-ANCE 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).

5.12.7.4 Halogen acid gas emission

Samples of nonmetallic materials of cables when tested in accordance with the method described in UL 2556, CSA C22.2 No. 2556, or NMX-J-472-ANCE shall have a maximum loss of mass, in the form of acid-gas emission produced by pyrolysis, not greater than 20 percent. Acid gas shall be expressed as percentage of the hydrogen chloride evolved during the test.

5.13 Weather (sunlight) resistance (optional)

To be marked SR, the insulation of a single wet-rated conductor having no outer jacket or covering, the outer jacket of a multiconductor cable, and the insulation and nylon jacket of nylon-jacketed conductors of a completed single wire or a multiconductor cable shall retain at least 80 percent of their unconditioned tensile strength and elongation values, after conditioning for 720 h in a specified weather-resistance apparatus. The rate of separation shall be 0.85 mm/s (2 in/min) for the testing of the nylon jacket.

Compliance shall be determined in accordance with the applicable clauses of the test, Physical properties – weather (sunlight) resistance, in UL 2556, CSA C22.2 No. 2556, or NMX-J-553-ANCE.

5.14 Oil resistance (optional)

5.14.1 Oil resistance at 60°C

5.14.1.1 To be marked PR I, tensile strength and elongation of the insulation shall not be less than 50 percent of the unconditioned value after immersion of the finished wire in IRM 902 oil for 96 hours at 100° C. Compliance shall be determined in accordance with the applicable clauses of the test, Oil resistance, in UL 2556, CSA C22.2 No. 2556, or NMX-J-194-ANCE.

5.14.1.2 Specimens of wire shall be immersed without removal of the nylon or outer jacket, if present. After immersion, each specimen shall be cut in half at the center of the U bend to provide two specimens for physical tests from each length immersed. The nylon jacket shall be removed prior to the physical tests.

5.14.2 Oil resistance at 75°C

5.14.2.1 To be marked PR II, in addition to complying with the requirements of Clause 5.14.1, the retention of tensile strength and elongation of the insulation shall be not less than 65 percent of the unconditioned value after immersion of the finished wire or cable in IRM 902 oil for 60 d at 75° C. Compliance shall be determined in accordance with the applicable clauses of the test, Oil resistance, in UL 2556, CSA C22.2 No. 2556, or NMX-J-194-ANCE.

5.14.2.2 Specimens of wire shall be immersed without removal of the nylon jacket, if present. After immersion, each specimen shall be cut in half at the center of the U bend to provide two specimens for physical tests from each length immersed. The nylon jacket shall be removed prior to the physical tests.

5.15 Gasoline and oil resistance (optional)

5.15.1 To be marked GR I or GR II, the retention of tensile strength and elongation of wet rated insulated conductors found to be in compliance with the requirements of Clause 5.14.1 or 5.14.2, respectively, 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 ±1°C. Compliance shall be determined in accordance with the applicable clauses of the test, Gasoline resistance, in UL 2556, CSA C22.2 No. 2556, or NMX-J-194-ANCE.

5.15.2 Specimens shall be immersed without removal of the nylon jacket, if present. After immersion for the specified length of time, each specimen shall be cut in half at the center of the U bend to provide two specimens for physical tests from each length immersed. The nylon jacket shall be removed prior to the physical tests.

5.16 Abrasion resistance (nylon-jacketed types or insulations other than PVC)

The insulation and nylon jacket (if present) on solid 2.08 mm^2 (14 AWG) conductors shall not wear through to expose the conductor on any of 6 specimens subjected to 800 cycles of abrasion by means of a weight that exerts a force of 3.3 ±0.1 N or 340 ±13 gf (12.0 ±0.5 ozf), in accordance with the procedure described in the test, Abrasion resistance, in UL 2556, CSA C22.2 No. 2556, or NMX-J-556-ANCE.

5.17 Crush resistance (nylon-jacketed types or insulations other than PVC)

An average of not less than 1000 N (225 lbf) shall be necessary to crush solid 2.08 mm^2 (14 AWG) insulated conductors until contact is established between the conductor of the specimen and the earth-grounded flat steel plate or steel rod when a specimen of the finished wire is subjected to the crushing procedure described in the test, Crush resistance – Method 2, in UL 2556, CSA C22.2 No. 2556, or NMX-J-556-ANCE.

5.18 Impact resistance (nylon-jacketed types or insulations other than PVC)

A free-falling steel weight that impacts with an energy of 2.7 J (2 ft-lbs) upon the insulation and nylon jacket (if present) of a solid 2.08 mm^2 (14 AWG) specimen shall not expose the conductor or cause triggering of the indicator in more than two out of ten specimens when tested in accordance with the test, Impact resistance, in UL 2556, CSA C22.2 No. 2556, or NMX-J-556-ANCE.

5.19 Durability of ink printing

5.19.1 The printing on the finished wire shall remain legible after being subjected to the test, Durability of ink printing, in UL 2556, CSA C22.2 No. 2556 or NMX-J-556-ANCE. Finished nylon jacketed wire that has ink printing clearly legible through the nylon jacket need not be tested.

5.19.2 One of two specimens shall be conditioned in a forced air oven at the rated temperature of the specimen for 24 h; the other shall be left at room temperature for 24 h.

5.20 Color coating

5.20.1 Surface (ink or paint) coated thermoplastic-insulated wire shall comply with the requirements in Clauses 5.20.2 – 5.20.4, when tested in accordance with the test, Color coating, in UL 2556, CSA C22.2 No. 2556, or NMX-J-556-ANCE.

5.20.2 The surface-coated thermoplastic-insulated conductor shall comply with the tensile strength and ultimate elongation requirements before and after the air-oven aging applicable to the insulation.

5.20.3 The coating shall not flake off of the surface of the insulation when samples of the wire are flexed at room temperature in the manner described in the test, Color coating, in UL 2556, CSA C22.2 No. 2556, or NMX-J-556-ANCE both before and after the air-oven aging applicable to the insulation.

5.20.4 The surface coating shall not migrate when tested in accordance with the test, Color coating, in UL 2556, CSA C22.2 No. 2556, or NMX-J-556-ANCE.

5.21 Long-term aging of insulation

5.21.1 The absolute elongation of insulation material referenced in Clause 4.2.5.3 shall be not less than 50 percent after being subjected to long-term aging in an air oven in accordance with the test, Dry temperature rating of new materials (long-term aging test), in UL 2556, CSA C22.2 No. 2556, or NMX-J-556-ANCE.

5.21.2 The minimum unaged and aged tensile and ultimate elongation values for the compound shall be established at 85 percent of the average measured value of the six specimens.

5.21.3 The applicable test duration and temperature shall be in accordance with Table 12.

5.22 A-C spark test

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

a) To the a-c spark test in accordance with the test, Spark, in UL 2556, CSA C22.2 No. 2556, or NMX-J-473-ANCE. The test potential shall be as shown in Table 40; or

b) To the dielectric voltage-withstand in water test described in Clause 5.23, and the insulation resistance in water test at 15°C described in Clause 5.24.

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

5.23 Dielectric voltage-withstand in water

5.23.1 The insulation of single conductors, when tested in accordance with the test, Dielectric voltage-withstand – Method 1 (in water), in UL 2556, CSA C22.2 No. 2556, or NMX-J-293-ANCE shall withstand, without breakdown, the application of the appropriate test voltage after immersion in water for not less than 1 h before the test potential is applied, as follows:

a) The ac test voltage specified in Table 41 for 1 minute;

b) Alternatively, a DC test voltage of 3 times the AC test voltage specified in Table 41 for the same period.

5.24 Insulation resistance in water at 15°C

Following compliance with Clause 5.23, while still immersed, the insulation of single conductors shall have an insulation resistance, corrected to 15°C, if necessary, of not less than the values specified in Table 30 when tested at the prevailing water temperature. The apparatus and test method shall be in accordance with the test, Insulation resistance, in UL 2556, CSA C22.2 No. 2556, or NMX-J-294-ANCE. Unless the spark test specified in Clause 5.22 is carried out, each length of finished cable shall be subjected to this test.

5.25 Electrical continuity

Each conductor shall be continuous when tested in accordance with either Method 1 or Method 2 described in the test, Continuity, in UL 2556, CSA C22.2 No. 2556, or NMX-J-556-ANCE.

6 Marking

Advisory Note: In Canada, there are two official languages, English and French, and in Mexico, the official language is Spanish. Annex H provides translations in French and Spanish of the English markings specified in this Standard. Markings required by this Standard may have to be provided in other languages to conform with the language requirements of the country where the product is to be used.

6.1 Marking on product

6.1.1 General

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

6.1.1.2 Marking on a product shall be optional when the product is intended for use in a product covered by another end-product standard (further processing).

6.1.1.3 The marking legend shall be repeated at intervals not exceeding 1.0 m (40 inches), except for conductor size, which shall be repeated at intervals not exceeding 610 mm (24 inches).

6.1.1.4 Required markings are described in Clauses 6.1.2 – 6.1.8. Optional markings are described in Clauses 6.1.9 – 6.1.13.

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 A wire or cable that complies with all the requirements of two or more types shall be allowed to be marked to so indicate – e.g., THHN T90 NYLON or THHN/THWN.

6.1.4 Conductor size

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

a) mm^2 (AWG);

b) AWG (mm^2);

c) mm^2 (kcmil);

d) kcmil (mm^2);

e) AWG; or

f) kcmil.

In Mexico, items (a) and (c) apply.

In Canada, items (a), (b), (c), and (d) apply.

In the United States, items (a), (b), (c), (d), (e), and (f) apply.

The use of either a comma or a period signifies a decimal. For printing on products, the use of mm2 in place of mm^2 shall be allowed.

The mm^2 marked shall be the nominal cross-sectional area in square millimeters shown in Table 4.

6.1.5 Conductor stranding

A wire or cable employing stranded conductors that are more finely stranded than Class B or C stranding (including Class B and Class C compact) shall be marked with the conductor class or classes. For conductor class, refer to Clause 4.1. For the number of strands on Class B or C conductors, see Table 42.

Note: *A wire or cable employing SIW or combination unilay stranding need not be marked.*

6.1.6 Aluminum conductors

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

6.1.7 Compact copper conductors

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.

6.1.8 Voltage marking

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

6.1.9 Low-temperature marking (optional)

A wire or cable marked "−40°" shall meet the requirements for −40°C cold bend and cold impact specified in Clause 5.10.

6.1.10 Flame test marking (optional)

6.1.10.1 General

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

a) "FT1": Clause 5.12.2 applies;

b) "VW-1" or "FV-2": Clause 5.12.3 applies;

c) "CT": Clause 5.12.4 or Clause 5.12.5 applies (see Clause 6.1.10.2 for applicability);

d) "FT4" or "FT4/IEEE 1202": Clause 5.12.5 or Clause 5.12.6 applies, using the FT4 Vertical-Tray Flame exposure;

e) "ST1": Clause 5.12.6 applies;

f) "LS": Clause 5.12.7 applies; and

g) "RPI": Clause 5.12.7.3 applies.

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

6.1.10.2 Cable-tray use marking (optional)

6.1.10.2.1 Insulated conductors marked "CT" shall meet the requirements of either Clause 5.12.4 or Clause 5.12.5.

6.1.10.2.2 In the United States, this marking shall be allowed on single circuit conductors of size 53.5 mm^2 (1/0 AWG) and larger, and equipment-grounding conductors of size 21.2 mm^2 (4 AWG) and larger.

6.1.10.2.3 In Mexico, the marking "CT" shall be allowed on single circuit conductors 21.2 mm^2 (4 AWG) and larger.

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

6.1.11 Weather resistance (optional)

Wires or cables marked "SR" shall meet the requirements of Clause 5.13. When marked "SR", the additional markings "Sunlight Resistant" or "Sun Res" shall be allowed.

6.1.12 Oil resistance (optional)

Wires or cables marked "PR I" shall meet the requirements of Clause 5.14.1. Wires or cables marked "PR II" shall meet the requirements of Clause 5.14.2.

6.1.13 Gasoline and oil resistance (optional)

Wires or cables marked "GR I" shall meet the requirements of Clauses 5.14.1 and 5.15. Wires or cables marked "GR II" shall meet the requirements of Clauses 5.14.2 and 5.15.

6.2 Marking on package

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

a) Manufacturer's identification;

b) Type designation;

c) Conductor size, in accordance with Clause 6.1.4;

d) "AL" after the conductor size (item c), when aluminum conductor is used. The additional marking "ACM" shall be optional;

e) If compact stranding is used, the word "COMPACT" or "CMPCT";

f) In the United States, if stranded copper conductors are compacted, the words "Compact Copper" or "Compact Cu" or "Cmpct Cu" shall be included adjacent to the conductor size (item c). The following statement shall also appear on the package: "Terminate with connectors identified for use with compact-stranded copper conductors";
In Canada and Mexico, this requirement does not apply.

g) Voltage rating(s);

h) Maximum operating dry and wet temperature ratings of insulation shall be optional.

6.3 Month and year of manufacture

The month and year of manufacture shall be included among the package markings described in Clause 6.2 or shall be included among the product markings described in Clause 6.1. The use of a code shall be allowed.

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, with or without an overall jacket. These cables shall be of the twisted or parallel configuration.

Note: *In Canada the −40°C rating is required as specified in the CE Code, Part I.*

7.2 Construction

7.2.1 Conductors

Circuit conductors shall consist of solid or stranded 2.08 – 33.6 mm^2 (14 – 2 AWG) copper, solid or stranded 3.31 – 33.6 mm^2 (12 – 2 AWG) aluminum ACM, or stranded 42.4 – 253 mm^2 (1 AWG – 500 kcmil) copper or aluminum ACM. The optional insulated equipment-grounding conductor shall be of the same construction as the circuit conductor, and of a size that is not smaller than indicated in Table 31, except that a copper equipment-grounding conductor shall be allowed with aluminum circuit conductors, as described in Table 31. An aluminum equipment-grounding conductor shall be allowed with copper circuit conductors, as described in Table 32. All of the conductors shall comply with Clause 4.1.

7.2.2 Insulation

7.2.2.1 Insulated conductors of the types listed in Groups I, II, and III of Table 33, assemblies (a), (b), and (d) of Clause 7.2.3, shall comply with the requirements of Sections 1 – 6 of this Standard. Insulated conductors of the types listed in Groups I and III, assembly (c), shall have an integral insulation-jacket consisting of the sum of the thickness of insulation of Table 10 corresponding to the types listed, plus the thickness of integral jacket from Table 34.

7.2.2.2 The insulation and integral jacket shall be of the same compound as the listed product and shall comply with the applicable requirements of Sections 1 – 6, and the assembly shall comply with the requirements of Clause 7.4.

7.2.2.3 Polyethylene-insulated conductors of Group IV, assembly (d) of Clause 7.2.3 shall be insulated with unfilled polyethylene and shall comply with Table 35 and Table 36 and the applicable test methods of this Standard.

7.2.3 Assembly

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

a) CABLED WITH OVERALL JACKET: this cable assembly has two or more insulated circuit conductors from Group I, II, III, or IV of Table 33 and 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 37 and the physical properties specified in Table 39.

b) CABLED WITHOUT OVERALL JACKET: this cable assembly has from two to six insulated circuit conductors from Group I of Table 33 with an individual jacket in accordance with Table 34, or from Group III of Table 33, and 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 OVERALL JACKET: this cable assembly has two, three, or four circuit conductors from Group I of Table 33 with an integral jacket from Table 34, or from Group III of Table 33, together with any optional equipment- grounding conductor laid parallel on the same axis. The conductors are joined to one another with an interconnecting web. The conductor insulation, or integral insulation, and jacket 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 OVERALL JACKET WITH INTEGRAL FILLERS OR WEBS: this cable assembly has two, three, or four insulated circuit conductors from Group I, II, III, or IV of Table 33 laid parallel on the same axis, together with an optional insulated equipment-grounding conductor and an overall jacket that complies with the thickness requirements of Table 37, and the requirements for physical properties specified in Table 39.

The jacket shall be extruded to form either an interconnecting web of 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.

7.2.4 Polarity identification of circuit conductors

Polarity identification of circuit conductors other than the grounding or grounded conductor shall be provided by means of contrasting colors 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 stripes. The equipment-grounding conductor shall be colored green or green with yellow stripes.

In the case of a flat cable that includes an insulated equipment-grounding conductor, the grounding conductor shall be identified by means of legible, durable ink printing, that reads "GND" or ⏚ on the outer surface of the finished conductor. The additional words "GROUNDING ONLY" shall be allowed.

7.3 Marking

Advisory Note: In Canada, there are two official languages, English and French, and in Mexico, the official language is Spanish. Annex H provides translations in French and Spanish of the English markings specified in this Standard. Markings required by this standard may have to be provided in other languages to conform with the language requirements of the country where the product is to be used.

7.3.1 Marking on product

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

a) The manufacturer's identification;

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", if aluminum conductors are used. The additional marking "ACM" shall be optional;

e) The designation "SUBMERSIBLE PUMP CABLE" as applicable (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 "−40°C", for cables complying with Clause 7.4.4;

h) The type designation of individual conductors, either on the conductor insulation surface or the outer jacket. In the case of polyethylene-insulated conductors, the marking "PE 75C" shall be applied on the outer jacket;

i) For other than polyethylene-insulated conductors, marking of the maximum operating dry and wet temperature rating of insulation as applicable shall be optional; and

j) Optional markings specified in Clause 6.1 as applicable.

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

7.3.2 Marking on package

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

a) Manufacturer's name;

b) Month and year of manufacture;

c) Product designation "SUBMERSIBLE PUMP CABLE";

d) Conductor size in accordance with Clause 6.1.4;

e) "AL", if aluminum conductors are used. The additional marking "ACM" shall be optional;

f) Nominal voltage rating, in accordance with Clause 6.1.7;

g) The low-temperature rating "−40°C", for cables in compliance with Clause 7.4.4;

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 marking does not apply;

i) Type designation of the individual conductors. In the case of polyethylene-insulated cables, the marking "PE 75C" shall be applied on the jacket.

j) For other than polyethylene-insulated conductors, marking of the maximum operating dry and wet temperature rating of insulation as applicable shall be optional.

7.4 Tests

7.4.1 General

In addition to the tests performed on each insulated conductor according to its type as specified in Section 5, or in the case of polyethylene-insulated conductors as specified in Table 36, and the spark test specified in the Table 35, the completed cable shall be subjected to the tests set out in Clauses 7.4.2 − 7.4.5.

7.4.2 Dielectric withstand

7.4.2.1 A finished unjacketed assembly or cable shall withstand the a-c voltage specified in Clause 5.23 when tested in accordance with the test, Dielectric voltage-withstand – Method 1 (in water), in UL 2556, CSA C22.2 No. 2556, or NMX-J-293-ANCE, or in the case of polyethylene cables, Table 35. For each assembly, the test voltage shall be applied between each conductor while immersed in tap water. A flat assembly shall be immersed for 6 h, twisted assemblies for 1 h. Spark testing in accordance with Clause 5.22 is also acceptable.

7.4.2.2 For a jacketed multiconductor cable, the test shall be conducted in accordance with the test, Dielectric voltage-withstand – Method 2 (in air) of UL 2556, CSA C22.2 No. 2556, or NMX-J-293-ANCE.

7.4.3 Insulation resistance

The finished assembly of polyethylene-insulated conductor with jacket, and the cables of assembly c) in Clause 7.2.3, shall withstand an insulation resistance test applied between each conductor while the remaining conductors are connected together and connected to ground. Polyethylene-insulated conductors shall have an insulation resistance not less than that calculated for a constant K of 15,000 GΩ·m at 15°C.

7.4.4 Heat shock

7.4.4.1 For cable assemblies with an overall jacket, the insulation and jacket shall not show any cracks, on the surface or internally, after a specimen of finished cable assembly is wound around a mandrel after conditioning in an air-circulating oven for 1 h to a temperature of 121 ± 1°C.

7.4.4.2 The mandrel diameter and the number of turns shall be as specified in Table 29. 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 the test, Heat shock, in UL 2556, CSA C22.2 No. 2556, or NMX-J-190-ANCE.

7.4.5 Cold bend

For cable assemblies with an overall jacket, the insulation and nylon covering jacket (if present) and jacket shall not show any cracks when tested in accordance with the test, Cold bend, in UL 2556, CSA C22.2 No. 2556, or NMX-J-193-ANCE. The mandrel diameter and number of turns shall be as specified in Table 30.

In Canada, conditioning shall be at a temperature of −40 ±1°C.

7.4.6 Cold impact

In Canada, a cable with an overall jacket, and the conductors of a cabled assembly, tested individually, shall comply with the requirements in Clause 5.10.2.

In the United States and Mexico, compliance with this requirement shall be optional.

7.4.7 Electrical continuity

Each conductor shall be continuous when tested in accordance with the test, Continuity, in UL 2556, CSA C22.2 No. 2556, or NMX-J-556-ANCE.

7.4.8 FT1 flame test

In Canada, a finished cable assembly with an overall jacket shall meet the requirements of Clause 5.12.2.

7.4.9 Deformation

The thickness of the jacket on a cable assembly with an overall jacket shall not decrease more than 50 percent when subjected to a temperature of 121 ±1°C while under a load of 2000 g. Compliance shall be determined In accordance with the test, Deformation, in UL 2556, CSA C22.2 No. 2556, or NMX-J-498-ANCE

7.4.10 Durability of printing

A finished cable assembly with an overall jacket shall meet the requirements of Clause 5.19.

Tables

Table 1
Conductor sizes and stranding

(See Clauses 4.1.5.1, 6.1.3.1, B1.2, and E2.)

Wire type	Metal	Conductor size range		Type of stranding
		mm^2	AWG or kcmil	
THHN or T90 Nylon THWN-2, THWN or TWN75	Copper	2.08 – 507	14 – 1000	Concentric, compressed, and rope lay
	Copper	2.08 – 507	14 – 1000	Compact
	Copper	2.08 – 107	14 – 4/0	Solid and combination unilay
	Copper	2.08 – 13.3	14 – 6	Bunched
	Aluminum	3.31 – 507	12 – 1000	Concentric and compressed
	Aluminum	3.31 – 507	12 – 1000	Compact
	Aluminum	3.31 – 107	12 – 4/0	Solid
	Aluminum	13.3 – 107	6 – 4/0	Combination unilay
TW, TWU, TWU75, THW or TW75, THW-2, THW-LS, THHW, THHW-LS	Copper	2.08 – 1010	14 – 2000	Concentric, compressed, and rope lay
	Copper	2.08 – 507	14 – 1000	Compact
	Copper	2.08 – 107	14 – 4/0	Solid and combination unilay
	Copper	2.08 – 13.3	14 – 6	Bunched
	Aluminum	3.31 – 1010	12 – 2000	Concentric and compressed

Table 1 Continued on Next Page

Table 1 Continued

Wire type	Metal	Conductor size range		Type of stranding
		mm²	AWG or kcmil	
	Aluminum	3.31 – 507	12 – 1000	Compact
	Aluminum	3.31 – 107	12 – 4/0	Solid
	Aluminum	13.3 – 107	6 – 4/0	Combination unilay

Table 2
Conductor stranding

(See Clauses 4.1.5.2.1 and E2.)

Sizes of wire		Minimum number of strands[b]		
mm²	AWG or kcmil	Combination unilay	Compact stranded	All others
2.08 – 8.37	14 – 8	19[a]	7	7
13.3 – 33.6	6 – 2	19	7	7
42.4 – 107	1 – 4/0	19	18	19
127 – 253	250 – 500	–	35	37
279 – 507	550 – 1000	–	58	61
557 – 760	1100 – 1500	–	–	91
811 – 1010	1600 – 2000	–	–	127

[a] *Copper only.*

[b] *In Canada and the United States, single input strands shall be in accordance with ASTM B801, ASTM B835, ASTM B836, ASTM B901, and ASTM B902. In Mexico, the lesser number of strands in a conductor shall be as shown in this table and as specified in NMX-J-012-ANCE or NMX-J-014-ANCE.*

Table 3
Length of lay of strands in a bunch-stranded conductor twisted as a single bunch[a]

(See Clause 4.1.5.2.4.)

Size of conductor		Maximum acceptable length of lay	
mm²	AWG	mm	in
2.08	14	44	1-3/4
3.31	12	51	2
5.26	10	64	2-1/2
8.37	8	70	2-3/4
13.3	6	86	3-3/8
larger than 13.3	larger than 6	16 times the conductor diameter	

[a] *Includes the following bunch-stranded constructions twisted as a single bunch under Classes I, K, and M:*

Conductor size		***Number of strands in single bunch***		
mm²	*AWG*	*Class I*	*Class K*	*Class M*
2.08	*14*	–	*41*	*104*
3.31	*12*	–	*65*	–
5.26	*10*	*26*	*104*	–
8.37	*8*	*41*	–	–
13.3	*6*	*65*	–	–

Note: *Nominal strand configuration and number of wires are found in ASTM B174 or NMX-J-297-ANCE.*

Table 4
Diameters over solid conductors and cross-sectional area for all solid and stranded conductors

(See Clauses 4.1.6 and 6.1.4.)

Size of conductor		Nominal diameter of solid conductor		Nominal cross-sectional area of conductor	
mm^2	AWG or kcmil	mm	mils	mm²	cmil or kcmil
2.08	14 AWG	1.63	64.1	2.08	4110 cmil
3.31	12	2.05	80.8	3.31	6530
5.26	10	2.588	101.9	5.261	10380
8.37	8	3.264	128.5	8.37	16510
13.3	6	4.115	162.0	13.3	26240
21.2	4	5.189	204.3	21.2	41740
26.7	3	5.827	229.4	26.67	52620
33.6	2	6.543	257.6	33.6	66360
42.4	1	7.348	289.3	42.4	83690
53.5	1/0	8.252	324.9	53.5	105600
67.4	2/0	9.266	364.8	67.4	133100
85.0	3/0	10.40	409.6	85.0	167800
107	4/0	11.68	460.0	107	211600
127	250 kcmil	–	–	127	250 kcmil
152	300	–	–	152	300
177	350	–	–	177	350
203	400	–	–	203	400
228	450	–	–	228	450
253	500	–	–	253	500
279	550	–	–	279	550
304	600	–	–	304	600
329	650	–	–	329	650
355	700	–	–	355	700
380	750	–	–	380	750
405	800	–	–	405	800
456	900	–	–	456	900
507	1000	–	–	507	1000
557	1100	–	–	557	1100
608	1200	–	–	608	1200
633	1250	–	–	633	1250
659	1300	–	–	659	1300
709	1400	–	–	709	1400

Table 4 Continued on Next Page

Table 4 Continued

Size of conductor		Nominal diameter of solid conductor		Nominal cross-sectional area of conductor	
mm^2	AWG or kcmil	mm	mils	mm²	cmil or kcmil
760	1500	–	–	760	1500
811	1600	–	–	811	1600
861	1700	–	–	861	1700
887	1750	–	–	887	1750
912	1800	–	–	912	1800
963	1900	–	–	963	1900
1010	2000	–	–	963	1900

Table 5
Diameters over round compact-stranded conductors

(See Clause 4.1.6.1.)

Conductor size		Nominal diameter	
mm^2	AWG or kcmil	mm	inch
3.31	12	2.16	0.085
5.26	10	2.72	0.107
8.37	8	3.40	0.134
13.3	6	4.29	0.169
21.2	4	5.41	0.213
26.7	3	6.02	0.238
33.6	2	6.81	0.268
42.4	1	7.59	0.299
53.5	1/0	8.53	0.336
67.4	2/0	9.55	0.376
85.0	3/0	10.74	0.423
107	4/0	12.07	0.475
127	250 kcmil	13.21	0.520
152	300	14.48	0.570
177	350	15.65	0.616
203	400	16.74	0.659
228	450	17.78	0.700
253	500	18.69	0.736
279	550	19.69	0.775
304	600	20.65	0.813
329	650	21.46	0.845

Table 5 Continued on Next Page

Table 5 Continued

Conductor size		Nominal diameter	
mm^2	AWG or kcmil	mm	inch
355	700	22.28	0.877
380	750	23.06	0.908
405	800	23.83	0.938
456	900	25.37	0.999
507	1000	26.92	1.060

Table 6
Diameters over round compressed concentric-lay-stranded conductors for Classes B, C, and D

(See Clause 4.1.6.1.)

Conductor size		Nominal diameter	
mm^2	AWG or kcmil	mm	inches
2.08	14 AWG	1.80	0.071
3.31	12	2.26	0.089
5.26	10	2.87	0.113
8.37	8	3.61	0.142
13.3	6	4.52	0.178
21.2	4	5.72	0.225
26.7	3	6.40	0.252
33.6	2	7.19	0.283
42.4	1	8.18	0.322
53.5	1/0	9.19	0.362
67.4	2/0	10.3	0.405
85.0	3/0	11.6	0.456
107	4/0	13.0	0.512
127	250 kcmil	14.2	0.558
152	300	15.5	0.611
177	350	16.8	0.661
203	400	17.9	0.706
226	450	19.0	0.749
253	500	20.0	0.789
279	550	21.1	0.829
304	600	22.0	0.866
329	650	22.9	0.901
355	700	23.7	0.935
380	750	24.6	0.968
405	800	25.4	1.000
456	900	26.9	1.060

Table 6 Continued on Next Page

Table 6 Continued

Conductor size		Nominal diameter	
mm^2	AWG or kcmil	mm	inches
507	1000	28.4	1.117
557	1100	29.8	1.173
608	1200	31.1	1.225
633	1250	31.8	1.250
659	1300	32.4	1.275
709	1400	33.6	1.323
760	1500	34.8	1.370
811	1600	35.9	1.415
861	1700	37.1	1.459
887	1750	37.6	1.480
912	1800	38.2	1.502
963	1900	39.2	1.542
1010	2000	40.2	1.583

Table 7
Diameters over round compressed single input wire and unidirectional or unilay-stranded conductors for Class B

(See Clause 4.1.6.1.)

Conductor size		Nominal diameter	
mm^2	AWG	mm	inches
3.31	12[a]	2.26	0.089
5.26	10[a]	2.87	0.113
8.37	8[a]	3.61	0.142
13.3	6[a]	4.52	0.178
21.2	4[a]	5.72	0.225
26.7	3[a]	6.40	0.252
33.6	2[a]	7.19	0.283
42.4	1 AWG	7.95	0.313
53.5	1/0	8.94	0.352
67.4	2/0	10.03	0.395
85.0	3/0	11.25	0.443
107	4/0	12.65	0.498
127	250 kcmil	13.77	0.542
152	300	15.09	0.594
177	350	16.28	0.641
203	400	17.40	0.685
226	450	18.47	0.727
253	500	19.46	0.766
279	550	20.42	0.804

Table 7 Continued on Next Page

Table 7 Continued

Conductor size		Nominal diameter	
mm^2	AWG	mm	inches
304	600	21.34	0.840
329	650	22.20	0.874
355	700	23.04	0.907
380	750	23.85	0.939
405	800	24.61	0.969
456	900	26.11	1.028
507	1000	27.53	1.084
557	1100	28.88	1.137
608	1200	30.15	1.187
633	1250	30.78	1.212
659	1300	31.39	1.236
709	1400	32.56	1.282
760	1500	33.71	1.327
811	1600	34.82	1.371
861	1700	35.89	1.413
887	1750	36.42	1.434
912	1800	33.71	1.327
963	1900	37.95	1.494
1010	2000	38.94	1.533

[a] Applies to single input wire only.

Table 8
Diameter over round concentric-lay-stranded conductors for Classes B, C, and D

(See Clause 4.1.6.1.)

Conductor size		Nominal diameter	
mm^2	AWG or kcmil	mm	inches
2.08	14 AWG	1.85	0.0727
3.31	12	2.32	0.0915
5.26	10	2.95	0.116
8.37	8	3.71	0.146
13.3	6	4.67	0.184
21.2	4	5.89	0.232
26.7	3	6.60	0.260
33.6	2	7.42	0.292
42.4	1	8.43	0.332
53.5	1/0	9.45	0.372
67.4	2/0	10.62	0.418
85.0	3/0	11.94	0.470

Table 8 Continued on Next Page

Table 8 Continued

Conductor size		Nominal diameter	
mm^2	AWG or kcmil	mm	inches
107	4/0	13.41	0.528
127	250 kcmil	14.6	0.575
152	300	16.00	0.630
177	350	17.30	0.681
203	400	18.49	0.728
228	450	19.61	0.772
253	500	20.65	0.813
279	550	21.72	0.855
304	600	22.68	0.893
329	650	23.60	0.929
355	700	24.49	0.964
380	750	25.35	0.998
405	800	26.16	1.030
456	900	27.79	1.094
507	1000	29.26	1.152
557	1100	30.71	1.209
608	1200	32.08	1.263
633	1250	32.74	1.289
659	1300	33.38	1.314
709	1400	34.67	1.365
760	1500	35.86	1.412
811	1600	37.06	1.459
861	1700	38.20	1.504
887	1750	38.76	1.526
912	1800	39.32	1.548
963	1900	40.39	1.590
1010	2000	41.45	1.632

Table 9
Strand and conductor dimensions for 19-wire combination round-wire unilay-stranded conductors

(See Clause 4.1.6.1.)

Conductor size		Nominal strand dimensions								Nominal conductor diameter E = 3A + 2C	
		Large strand				Small strand					
		Diameter (A)		Cross-sectional area		Diameter (C)		Cross-sectional area			
mm²	AWG	mm	inch	mm²	cmil	mm	inch	mm²	cmil	mm	inch
2.08	14	0.4	0.0159	0.128	253	0.3	0.0117	0.069	137	1.80	0.071
3.31	12	0.5	0.0201	0.205	404	0.4	0.0147	0.109	216	2.29	0.090
5.26	10	0.6	0.0253	0.324	640	0.5	0.0185	0.173	342	2.87	0.113
8.37	8	0.8	0.0319	0.515	1018	0.6	0.0234	0.277	548	3.63	0.143
13.3	6	1.0	0.0402	0.818	1616	0.7	0.0294	0.437	864	4.55	0.179
21.2	4	1.3	0.0507	1.301	2570	0.9	0.0371	0.696	1376	5.74	0.226
26.7	3	1.4	0.0570	1.644	3249	1.1	0.0417	0.880	1739	6.45	0.254
33.6	2	1.6	0.0640	2.073	4096	1.2	0.0468	1.108	2190	7.26	0.286
42.4	1	1.8	0.0718	2.609	5155	1.3	0.0526	1.400	2767	8.15	0.321
53.5	1/0	2.1	0.0807	3.296	6512	1.5	0.0591	1.768	3493	9.14	0.360
67.4	2/0	2.3	0.0906	4.154	8208	1.7	0.0663	2.225	4396	10.26	0.404
85.0	3/0	2.6	0.1017	5.234	10343	1.9	0.0745	2.809	5550	11.53	0.454
107	4/0	2.9	0.1142	6.600	13042	2.1	0.0836	3.537	6989	12.95	0.510

Table 10
Insulation thickness, minimum average and minimum at any point

(See Clauses 4.2.4 and 7.2.2.)

Conductor size		TWU, TWU75				THW, TW75, THW-2, THW-LS, THHW, THHW-LS, TW				THHN, T90 Nylon, THWN-2, THWN, TWN75			
		Minimum average		Minimum at any point		Minimum average		Minimum at any point		Minimum average		Minimum at any point	
mm²	AWG or kcmil	mm	mils	mm	mils	mm	mils	mm	mils	mm	mils	mm	mils
2.08 – 3.31	14 – 12	1.52	60	1.37	54	0.76	30	0.69	27	0.38	15	0.33	13
5.26	10	1.52	60	1.37	54	0.76	30	0.69	27	0.51	20	0.46	18
8.37	8	2.03	80	1.83	72	1.14	45	1.02	40	0.76	30	0.69	27
13.3	6	2.03	80	1.83	72	1.52	60	1.37	54	0.76	30	0.69	27
21.2 – 33.6	4 – 2	2.03	80	1.83	72	1.52	60	1.37	54	1.02	40	0.91	36
42.4 – 107	1 – 4/0	2.41	95	2.18	86	2.03	80	1.83	72	1.27	50	1.14	45
127 – 253	250 – 500	2.79	110	2.51	99	2.41	95	2.18	86	1.52	60	1.38	54
279 – 507	550 – 1000	3.18	125	2.84	112	2.79	110	2.51	99	1.78	70	1.60	63
557 – 1010	1100 – 2000	3.55	155	3.20	139	3.18	125	2.84	112	–	–	–	–

Table 11
Physical properties of PVC insulation

(See Clauses 4.2.5.1, 4.2.5.3.2, 4.2.5.3.3, 5.8, and G1.)

Minimum properties	TW, TWU	TWU75	THW or TW75	THW-2	THW-LS	THHW, THHN, THWN-2, THHW-LS, T90 Nylon	THWN or TWN75
Before aging: Tensile strength, MPa (lbf/in^2)	10.3 (1500)	12.4 (1800)		13.8 (2000)			
Elongation, percent, minimum increase in distance between 25 mm (1 inch) gauge marks	100	150					
After aging: at 100°C, 7d							
Retention of tensile strength, percent	Min. 65	–					
Retention of elongation, percent	65/45[a]	–					
After aging: at 121°C, 7d							
Retention of tensile strength, percent	–	75		–	75	–	75
Retention of elongation, percent	–	65/45[a]		–	65/45[a]	–	65/45[a]
After aging: at 136°C, 7d							
Retention of tensile strength, percent	–			75	–	75	–
Retention of elongation, percent	–			65/45[a]	–	65/45[a]	–

[a] *The 45 percent applies only to samples aged in die-cut form.*

Table 12
Worksheet for determination of physical properties of insulation having characteristics different from those indicated in Table 11[a]

(See Clauses 4.2.5.3.4 and 5.21.3.)

Condition of specimens at time of measurement	Minimum ultimate elongation [25 mm (1 inch) benchmarks]	Minimum tensile strength
Unaged	b	b
Insulation from wires rated 90°C (covering, if present, removed before aging): Aged in a full-draft circulating-air oven for 168 h at 136 ± 1° C	b	b

Table 12 Continued on Next Page

Table 12 Continued

Condition of specimens at time of measurement	Minimum ultimate elongation [25 mm (1 inch) benchmarks]	Minimum tensile strength
Insulation from wires rated 75°C (covering, if present, removed before aging): Aged in a full-draft circulating-air oven for 168 h at 121 ± 1° C	b	b
Insulation from wires rated 60°C (covering, if present, removed before aging): Aged in a full-draft circulating-air oven for 168 h at 100 ± 1° C	b	b

[a] *See Clause 4.2.5.3.2, which establishes that the initial values of tensile strength and elongation shall be at least 6.8 MPa (1000 lbf/in^2) and 100 percent, respectively.*

[b] *Values as determined in accordance with Annex D of UL 2556, CSA C22.2 No. 2556, or NMX-J-178-ANCE.*

Table 13
Thickness of jacket over Types THHN, THWN, TWN75, THWN-2, and T90 nylon

(See Clause 4.3.2.)

Conductor size (AWG or kcmil)		Minimum thickness at any point	
mm^2	AWG or kcmil	mm	mils
2.08 – 5.26	14 – 10	0.10	4
8.37 – 13.3	8 – 6	0.13	5
21.2 – 33.6	4 – 2	0.15	6
42.4 – 107	1 – 4/0	0.18	7
127 – 253	250 – 500	0.20	8
279 – 507	550 – 1000	0.23	9

Table 14
Maximum direct-current resistance at 20°C of solid conductors of aluminum and bare copper

(See Clauses 5.2.1, 5.2.2, and E3.)

Size of conductor		Aluminum		Bare copper	
mm^2	AWG	Ohms per km	Ohms per 1000 ft	Ohms per km	Ohms per 1000 ft
2.08	14	–	–	8.45	2.57
3.31	12	8.71	2.65	5.31	1.62
5.26	10	5.48	1.67	3.34	1.02
8.37	8	3.45	1.05	2.10	0.641
13.3	6	2.17	0.661	1.32	0.403
21.2	4	1.36	0.416	0.832	0.254
26.7	3	1.08	0.330	0.660	0.201
33.6	2	0.857	0.261	0.523	0.159
42.4	1	0.680	0.207	0.415	0.126
53.5	1/0	0.539	0.164	0.329	0.100

Table 14 Continued on Next Page

Table 14 Continued

Size of conductor		Aluminum		Bare copper	
mm^2	AWG	Ohms per km	Ohms per 1000 ft	Ohms per km	Ohms per 1000 ft
67.4	2/0	0.428	0.130	0.261	0.0795
85.0	3/0	0.339	0.103	0.207	0.0631
107	4/0	0.269	0.0820	0.16	0.0500

Table 15
Maximum direct-current resistance at 20°C of aluminum and bare copper conductors – concentric-stranded Classes B, C, and D; compact-stranded; and compressed-stranded

(See Clauses 5.2.1, 5.2.2, and E3.)

Size of conductor		Aluminum		Bare copper	
mm^2	AWG or kcmil	Ohms per km	Ohms per 1000 ft	Ohms per km	Ohms per 1000 ft
2.08	14 AWG	–	–	8.62	2.62
3.31	12	8.88	2.71	5.43	1.65
5.26	10	5.59	1.70	3.41	1.04
8.37	8	3.52	1.07	2.14	0.653
13.3	6	2.21	0.674	1.35	0.411
21.2	4	1.39	0.424	0.848	0.259
26.7	3	1.10	0.336	0.673	0.205
33.6	2	0.875	0.267	0.534	0.163
42.4	1	0.693	0.211	0.423	0.130
53.5	1/0	0.550	0.168	0.335	0.102
67.4	2/0	0.436	0.133	0.266	0.0811
85.0	3/0	0.346	0.106	0.211	0.0643
107	4/0	0.274	0.0836	0.167	0.0510
127	250 kcmil	0.232	0.0708	0.142	0.0432
152	300	0.194	0.0590	0.118	0.0360
177	350	0.166	0.0505	0.101	0.0308
203	400	0.145	0.0442	0.0885	0.0270
228	450	0.129	0.0393	0.0787	0.0240
253	500	0.116	0.0354	0.0709	0.0216
279	550	0.106	0.0322	0.0644	0.0196
304	600	0.0967	0.0295	0.0590	0.0180
329	650	0.0893	0.0272	0.0545	0.0166
355	700	0.0829	0.0253	0.0506	0.0154
380	750	0.0774	0.0236	0.0472	0.0144
405	800	0.0725	0.0221	0.0443	0.0135

Table 15 Continued on Next Page

Table 15 Continued

Size of conductor		Aluminum		Bare copper	
mm^2	AWG or kcmil	Ohms per km	Ohms per 1000 ft	Ohms per km	Ohms per 1000 ft
456	900	0.0645	0.0197	0.0393	0.0120
507	1000	0.0580	0.0177	0.0354	0.0108
557	1100	0.0528	0.0161	0.0322	0.00981
608	1200	0.0484	0.0147	0.0295	0.00899
633	1250	0.0464	0.0142	0.0283	0.00863
659	1300	0.0447	0.0136	0.0272	0.00823
709	1400	0.0415	0.0126	0.0253	0.00771
760	1500	0.0387	0.0118	0.0236	0.00719
811	1600	0.0363	0.0111	0.0221	0.00674
861	1700	0.0341	0.0104	0.0208	0.00635
887	1750	0.0332	0.0101	0.0202	0.00617
912	1800	0.0322	0.00983	0.0197	0.00600
963	1900	0.0306	0.00931	0.0186	0.00568
1010	2000	0.0290	0.00884	0.0177	0.00540

Note: *Nominal strand configuration and number of wires are found in ASTM B8 or NMX-J-012-ANCE for copper conductors, and NMX-J-032-ANCE for aluminum conductors.*

Table 16
Maximum direct-current resistance at 20°C of copper conductors, concentric-stranded Class B with each strand coated with tin or a tin alloy and compressed-stranded Class B with each strand coated

(See Clauses 5.2.1 and 5.2.2.)

Size of conductor			
mm^2	AWG or kcmil	Ohms per km	Ohms per 1000 ft
2.08	14 AWG	8.96	2.73
3.31	12	5.64	1.72
5.26	10	3.55	1.08
8.37	8	2.23	0.680
13.3	6	1.40	0.428
21.2	4	0.882	0.269
26.7	3	0.700	0.213
33.6	2	0.555	0.169
42.4	1	0.440	0.134
53.5	1/0	0.349	0.106
67.4	2/0	0.277	0.0843
85.0	3/0	0.219	0.0669
107	4/0	0.172	0.0525

Table 16 Continued on Next Page

Table 16 Continued

Size of conductor			
mm^2	AWG or kcmil	Ohms per km	Ohms per 1000 ft
127	250 kcmil	0.147	0.0449
152	300	0.123	0.0374
177	350	0.105	0.0320
203	400	0.0911	0.0278
228	450	0.0810	0.0247
253	500	0.0729	0.0222
279	550	0.0669	0.0204
304	600	0.0614	0.0187
329	650	0.0561	0.0171
355	700	0.0520	0.0159
380	750	0.0486	0.0148
405	800	0.0455	0.0139
456	900	0.0405	0.0123
507	1000	0.0364	0.0111
557	1100	0.0331	0.0101
608	1200	0.0303	0.00925
633	1250	0.0292	0.00888
659	1300	0.0280	0.00854
709	1400	0.0260	0.00793
760	1500	0.0243	0.00740
811	1600	0.0228	0.00694
861	1700	0.0214	0.00653
887	1750	0.0208	0.00635
912	1800	0.0202	0.00617
963	1900	0.0192	0.00584
1010	2000	0.0182	0.00555

Note: *Nominal strand configuration and number of wires are found in ASTM B8 or NMX-J-012-ANCE.*

Table 17
Maximum direct-current resistance at 20°C of copper conductors concentric-stranded Classes C and D with each strand coated with tin or a tin alloy and compressed-stranded Classes C and D with each strand coated

(See Clauses 5.2.1 and 5.2.2.)

Size of conductor		Class C		Class D	
mm^2	AWG or kcmil	Ohms per km	Ohms per 1000 ft	Ohms per km	Ohms per 1000 ft
2.08	14 AWG	9.15	2.78	9.25	2.82
3.31	12	5.75	1.75	5.75	1.75
5.26	10	3.55	1.08	3.62	1.10
8.37	8	2.23	0.679	2.23	0.679
13.3	6	1.41	0.427	1.41	0.427
21.2	4	0.882	0.269	0.882	0.269
26.7	3	0.700	0.213	0.700	0.213
33.6	2	0.555	0.169	0.555	0.169
42.4	1	0.440	0.134	0.440	0.134
53.5	1/0	0.349	0.106	0.349	0.106
67.4	2/0	0.276	0.0844	0.276	0.0844
85.0	3/0	0.219	0.0669	0.219	0.0669
107	4/0	0.174	0.0530	0.174	0.0530
127	250 kcmil	0.147	0.0449	0.147	0.0449
152	300	0.122	0.0374	0.122	0.0374
177	350	0.105	0.0320	0.105	0.0320
203	400	0.0920	0.0280	0.0920	0.0280
228	450	0.0818	0.0249	0.0818	0.0249
253	500	0.0736	0.0224	0.0736	0.0224
279	550	0.0669	0.0204	0.0669	0.0204
304	600	0.0614	0.0187	0.0614	0.0187
329	650	0.0566	0.0172	0.0566	0.0172
355	700	0.0526	0.0160	0.0526	0.0160
380	750	0.0491	0.0150	0.0491	0.0150
405	800	0.0460	0.0141	0.0460	0.0141
456	900	0.0409	0.0124	0.0409	0.0124
507	1000	0.0364	0.0111	0.0368	0.0112
557	1100	0.0335	0.0102	0.0335	0.0102
608	1200	0.0307	0.00935	0.0307	0.00935
633	1250	0.0295	0.00898	0.0295	0.00898
659	1300	0.0284	0.00863	0.0284	0.00863
709	1400	0.0260	0.00794	0.0263	0.00802
760	1500	0.0243	0.00741	0.0246	0.00748
811	1600	0.0231	0.00702	0.0231	0.00702
861	1700	0.0216	0.00660	0.0216	0.00660
887	1750	0.0210	0.00642	0.0210	0.00642
912	1800	0.0202	0.00617	0.0205	0.00623
963	1900	0.0192	0.00584	0.0194	0.00591
1010	2000	0.0183	0.00555	0.0184	0.00561

Note: *Nominal strand configuration and number of wires are found in ASTM B8 or NMX-J-012-ANCE.*

Table 18
Maximum direct-current resistance at 20°C of 19-wire combination round-wire unilay-stranded copper conductors

(See Clauses 5.2.1 and 5.2.2.)

Size of conductor		Each strand coated		Each strand uncoated	
mm^2	AWG	Ohms per km	Ohms per 1000 ft	Ohms per km	Ohms per 1000 ft
2.08	14	9.15	2.78	8.62	2.62
3.31	12	5.75	1.75	5.43	1.65
5.26	10	3.55	1.08	3.41	1.04
8.37	8	2.23	0.679	2.14	0.654
13.3	6	1.41	0.427	1.35	0.412
21.2	4	0.882	0.269	0.848	0.259
26.7	3	0.700	0.213	0.673	0.205
33.6	2	0.555	0.169	0.534	0.163
42.4	1	0.440	0.134	0.423	0.129
53.5	1/0	0.349	0.106	0.335	0.102
67.4	2/0	0.277	0.0844	0.266	0.0811
85.0	3/0	0.219	0.0669	0.211	0.0643
107	4/0	0.172	0.05230	0.167	0.0510

Table 19
Maximum direct-current resistance at 20°C of 19-wire combination round-wire unilay-stranded aluminum conductors

(See Clauses 5.2.1 and 5.2.2.)

Size of conductor		Ohms per km	Ohms per 1000 ft
mm^2	AWG		
13.3	6	2.21	0.674
21.2	4	1.39	0.424
26.7	3	1.10	0.336
33.6	2	0.875	0.267
42.4	1	0.693	0.211
53.5	1/0	0.550	0.168
67.4	2/0	0.436	0.133
85.0	3/0	0.346	0.106
107	4/0	0.274	0.0836

Table 20
Maximum direct-current resistance at 20°C of solid copper conductors coated with tin or a tin alloy

(See Clauses 5.2.1 and 5.2.2.)

Conductor size			
mm^2	AWG	Ohms per km	Ohms per 1000 ft
2.08	14	8.78	2.68
3.31	12	5.53	1.68
5.26	10	3.48	1.06
8.37	8	2.16	0.659
13.3	6	1.36	0.415
21.2	4	0.856	0.261
26.7	3	0.679	0.207
33.6	2	0.538	0.164
42.4	1	0.427	0.130
53.5	1/0	0.337	0.103
67.4	2/0	0.267	0.0814
85.0	3/0	0.212	0.0655
107	4/0	0.168	0.0512

Table 21
Maximum direct-current resistance at 20°C of Class G and H stranded conductors

(See Clauses 5.2.1 and 5.2.2.)

Size of conductor		Bare copper				Coated copper[a]				Aluminum			
		Class G		Class H		Class G		Class H		Class G		Class H	
mm^2	AWG or kcmil	Ohms per km	Ohms per 1000 ft	Ohms per km	Ohms per 1000 ft	Ohms per km	Ohms per 1000 ft	Ohms per km	Ohms per 1000 ft	Ohms per km	Ohms per 1000 ft	Ohms per km	Ohms per 1000 ft
	AWG												
2.08	14	8.70	2.65	–	–	9.24	2.82	–	–	–	–	–	–
3.31	12	5.48	1.67	–	–	5.81	1.77	–	–	–	–	–	–
5.26	10	3.45	1.05	–	–	3.66	1.11	–	–	–	–	–	–
8.37	8	2.16	0.660	2.18	0.666	2.30	0.701	–	–	–	–	–	–
13.3	6	1.37	0.415	1.38	0.419	1.42	0.431	–	–	2.23	0.680	–	–
21.2	4	0.857	0.261	0.865	0.263	0.890	0.271	–	–	1.41	0.428	–	–
26.7	3	0.679	0.207	0.6866	0.209	0.707	0.215	–	–	1.11	0.340		
33.6	2	0.539	0.164			0.560	0.170			0.883	0.369	–	–
(No. of wires)		Class H only											
33.6	2 (133)			0.544	0.166			0.566	0.172			0.891	0.271
33.6	2 (259)			0.547	0.166			0.580	0.176			–	–
42.4	1	0.431	0.132	0.434	0.133	0.449	0.137	–	–	0.707	0.215	–	–
53.5	1/0	0.342	0.104	0.344	0.105	0.355	0.108	–	–	0.560	0.170	–	–
67.4	2/0	0.271	0.0826	0.272	0.0830	0.282	0.0860	–	–	0.445	0.136	–	–
85.0	3/0	0.215	0.0656			0.223	0.0681			0.353	0.107		

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Table 21 Continued

Size of conductor		Bare copper				Coated copper[a]				Aluminum			
		Class G		Class H		Class G		Class H		Class G		Class H	
mm²	AWG or kcmil	Ohms per km	Ohms per 1000 ft	Ohms per km	Ohms per 1000 ft	Ohms per km	Ohms per 1000 ft	Ohms per km	Ohms per 1000 ft	Ohms per km	Ohms per 1000 ft	Ohms per km	Ohms per 1000 ft
(No. of wires)		Class H only											
85.0	3/0 (259)			0.216	0.0659			0.0685	0.224			0.354	0.108
85.0	3/0 (427)			0.217	0.0662			0.0703	0.231			–	–
107	4/0 (259)			0.171	0.0522			0.0544	0.179			0.280	0.0857
107	4/0 (427)			0.172	0.0525			0.0546	0.180			0.283	0.0861
107	4/0	.170	.0520			.177	.0541			.279	.0853		
	kcmil												
127	250	.145	.0443	.146	.0445	.151	.0460	.0462	.152	.238	.0725	.239	.0728
152	300	.121	.0368	.121	.0370	.125	.0384	.0386	.126	.198	.0604	.199	.0607
177	350	.104	.0316	.104	.0317	.108	.0328	.0330	.108	.170	.0518	.170	.0520
203	400	.0917	.0276	.0911	.0277	.0942	.0288	.0289	.0948	.149	.0453	.149	.0455
226	450	.0806	.0246	.0810	.0247	.0838	.0255	.0257	.0843	.132	.0403	.133	.0405
253	500	.0725	.0221	.0729	.0222	.0755	.0230	.0232	.0758	.119	.0362	.119	.0364
279	550	.0663	.0202	.0669	.0204	.0690	.0210	.0212	.0696	.108	.0332	.110	.0335
304	600	.0607	.0186	.0613	.0187	.0631	.0193	.0195	.0638	.0996	.0304	.100	.0306
329	650	.0561	.0171	.0566	.0172	.0583	.0177	.0180	.0589	.0919	.0280	.0928	.0283
355	700	.0520	.0159	.0525	.0160	.0542	.0165	.0166	.0547	.0834	.0260	.0862	.0262
380	750	.0486	.0148	.0491	.0150	.0505	.0154	.0155	.0510	.0797	.0243	.0804	.0245
405	800	.0456	.0139	.0460	.0140	.0473	.0145	.0146	.0478	.0747	.0227	.0754	.0230
456	900	.0405	.0123	.0409	.0124	.0421	.0129	.0130	.0425	.0664	.0202	.0670	.0204
507	1000	.0364	.0111	.0368	.0112	.0379	.0115	.0116	.0382	.0598	.0183	.0603	.0184
608	1200	.0304	.00926	.0307	.00934	.0316	.00963	.00972	.0319	.0498	.0152	.0503	.0153
633	1250	.0292	.00888	.0295	.00897	.0303	.00924	.00933	.0306	.0478	.0146	.0482	.0147
659	1300	.0280	.00855	.0283	.00863	.0292	.00888	.00897	.0295	.0460	.0140	.0464	.0142
709	1400	.0260	.00794	.0263	.00801	.0270	.00825	.00833	.0273	.0426	.0131	.0430	.0132
760	1500	.0243	.00741	.0245	.00748	.0253	.00770	.00777	.0255	.0398	.0121	.0402	.0122
811	1600	.0230	.00701	.0230	.00701	.0239	.00729	.00729	.0239	.0377	.0115	.0377	.0115
861	1700	.0216	.00660	.0216	.00660	.0225	.00686	.00686	.0225	.0355	.0108	.0355	.0108
887	1750	.0210	.00641	.0210	.00641	.0218	.00666	.00666	.0218	.0345	.0105	.0345	.0105
912	1800	.0204	.00623	.0204	.00623	.0212	.00648	.00648	.0212	.0335	.0102	.0335	.0102
963	1900	.0194	.00591	.0194	.00591	.0201	.00614	.00614	.0201	.0317	.00968	.0317	.00968
1010	2000	.0184	.00561	.0184	.00561	.0192	.00583	.00583	.0192	.0302	.00919	.0302	.00919

[a] Each strand coated with tin.

Note: *Nominal strand configuration and number of wires are found in ASTM B173 or NMX-J-013-ANCE.*

Table 22
Maximum direct-current resistance at 20°C of Class M stranded conductors

(See Clauses 5.2.1 and 5.2.2.)

Size of conductor		Bare copper		Coated copper (each strand coated with tin or a tin alloy)	
mm^2	AWG or kcmil	Ohms per km	Ohms per 1000 ft	Ohms per km	Ohms per 1000 ft
2.08	14 AWG	8.61	2.62	9.25	2.82
3.31	12	5.53	1.68	5.94	1.81
5.26	10	3.48	1.06	3.73	1.14
8.37	8	2.18	0.666	2.35	0.715
13.3	6	1.39	0.423	1.49	0.455
21.2	4	0.873	0.266	0.937	0.286
26.7	3	0.699	0.213	0.744	0.226
33.6	2	0.554	0.169	0.595	0.182
42.4	1	0.440	0.134	0.472	0.144
53.5	1/0	0.349	0.106	0.374	0.114
67.4	2/0	0.276	0.0851	0.300	0.0913
85.0	3/0	0.221	0.0874	0.238	0.0724
107	4/0	0.175	0.0534	0.189	0.0574
127	250 kcmil	0.149	0.0453	0.159	0.0487
152	300	0.123	0.0377	0.133	0.0405
177	350	0.106	0.0323	0.114	0.0347
203	400	0.0928	0.0283	0.0997	0.0304
226	450	0.0825	0.0252	0.0858	0.0261
253	500	0.0743	0.0226	0.0798	0.0243
279	550	0.0675	0.0206	0.0725	0.0221
304	600	0.0619	0.0189	0.0664	0.0203
329	650	0.0571	0.0174	0.0613	0.0187
355	700	0.0530	0.0162	0.0569	0.0173
380	750	0.0495	0.0151	0.0531	0.0162
405	800	0.0464	0.0142	0.0499	0.0152
456	900	0.0413	0.0125	0.0443	0.0135
507	1000	0.0371	0.0113	0.0399	0.0121

Note: *Nominal strand configuration and number of wires are found in ASTM B172 or NMX-J-014-ANCE.*

Table 23
Maximum direct-current resistance at 20°C of Class I and K stranded conductors

(See Clauses 5.2.1 and 5.2.2)

Size of conductor		Class I						Class K			
		Bare copper		Coated copper		Aluminum		Bare copper		Coated copper	
mm^2	AWG or kcmil	Ohms per km	Ohms per 1000 ft	Ohms per km	Ohms per 1000 ft	Ohms per km	Ohms per 1000 ft	Ohms per km	Ohms per 1000 ft	Ohms per km	Ohms per 1000 ft
	AWG										
2.08	14	–	–	–	–	–	–	8.61	2.62	9.25	2.82
3.31	12	–	–	–	–	–	–	5.43	1.65	5.82	1.77
5.26	10	3.41	1.04	3.55	1.08	–	–	3.41	1.04	3.66	1.11
8.37	8	2.14	0.654	2.23	0.679	3.52	1.07	2.18	0.666	2.35	0.715
13.3	6	1.38	0.419	1.43	0.436	2.25	0.687	1.38	0.419	1.48	0.450
21.2	4	0.865	0.263	0.900	0.274	1.42	0.432	0.865	0.263	0.928	0.283
26.7	3	0.686	0.209	0.713	0.217	1.12	0.343	0.693	0.211	0.744	0.226
33.6	2	0.544	0.166	0.566	0.172	0.891	0.271	0.549	0.167	0.590	0.180
42.4	1	0.431	0.132	0.449	0.137	0.707	0.215	0.436	0.133	0.467	0.143
53.5	1/0	0.345	0.105	0.359	0.109	0.566	0.172	0.345	0.105	0.370	0.113
67.4	2/0	0.273	0.0834	0.285	0.0868	0.449	0.137	0.276	0.0843	0.297	0.0904
85.0	3/0	0.217	0.0662	0.225	0.0689	0.356	0.108	0.219	0.0668	0.236	0.0717
107	4/0	0.172	0.0525	0.180	0.0546	0.283	0.0861	0.173	0.0530	0.187	0.0569
	kcmil										
127	250	0.147	0.0449	0.153	0.0466	0.242	0.0735	0.147	0.0449	0.158	0.0481
152	300	0.122	0.0373	0.128	0.0389	0.201	0.0613	0.122	0.0373	0.132	0.0401
177	350	0.105	0.0320	0.109	0.0334	0.172	0.0525	0.106	0.0323	0.114	0.0347
203	400	0.0920	0.0280	0.0957	0.0292	0.151	0.0460	0.092	0.0283	0.0997	0.0304
226	450	0.0817	0.0249	0.0850	0.0259	0.134	0.0408	0.082	0.0252	0.0886	0.0270
253	500	0.0735	0.0224	0.0765	0.0234	0.120	0.0367	0.074	0.0226	0.0798	0.0243
279	550	0.0669	0.0204	0.0696	0.0212	0.110	0.0335	0.067	0.0206	0.0725	0.0221
304	600	0.0613	0.0187	0.0638	0.0195	0.100	0.0306	0.061	0.0189	0.0664	0.0203
329	650	0.0571	0.0174	0.0594	0.0182	0.0936	0.0286	0.057	0.0174	0.0613	0.0187
355	700	0.0530	0.0162	0.0552	0.0168	0.0870	0.0265	0.053	0.0162	0.0569	0.0173
380	750	0.0495	0.0151	0.0515	0.0157	0.0812	0.0248	0.049	0.0151	0.0531	0.0162
405	800	0.0464	0.0142	0.0482	0.0147	0.0761	0.0232	0.046	0.0142	0.0499	0.0152
456	900	0.0413	0.0125	0.0429	0.0131	0.0676	0.0206	0.041	0.0125	0.0443	0.0135
507	1000	0.0371	0.0113	0.0387	0.0117	0.0610	0.0186	0.037	0.0113	0.0399	0.0121
557	1100	0.0338	0.0103	0.0351	0.0107	0.0554	0.0168	–	–	–	–
608	1200	0.0310	0.00944	0.0322	0.00981	0.0507	0.0155	–	–	–	–
633	1250	0.0297	0.00906	0.0310	0.00941	0.0487	0.0149	–	–	–	–
659	1300	0.0286	0.00871	0.0297	0.00906	0.0468	0.0143	–	–	–	–
709	1400	0.0265	0.00809	0.0275	0.00840	0.0435	0.0133	–	–	–	–
760	1500	0.0248	0.00755	0.0257	0.00784	0.0406	0.0123	–	–	–	–
811	1600	0.0233	0.00708	0.0242	0.00735	0.0380	0.0116	–	–	–	–
861	1700	0.0218	0.00666	0.0227	0.00693	0.0358	0.0109	–	–	–	–
887	1750	0.0212	0.00647	0.0220	0.00672	0.0348	0.0106	–	–	–	–
912	1800	0.0206	0.00629	0.0214	0.00654	0.0339	0.0103	–	–	–	–
963	1900	0.0196	0.00596	0.0203	0.00619	0.0320	0.00977	–	–	–	–
1010	2000	0.0186	0.00566	0.0193	0.00589	0.0304	0.00928	–	–	–	–

Table 24
Minimum insulation resistance at elevated temperature in water

(See Clauses 5.4, 5.5.1, and 5.5.3.)

Conductor size		GΩ·m					MΩ·1000 ft				
		50 or 60°C test		75 or 90°C test			50 or 60°C test		75 or 90°C test		
mm^2	AWG or kcmil	TW	TWU	TWU75 (75°C test)	THW[a], THW-LS, THHW, THHW-LS or TW75 (75°C test), THW-2 (90°C test)	Type THWN or TWN75 (75°C test), THWN-2 (90°C test)	TW	TWU	TWU75 (75°C test)	THW[a], THW-LS, THHW, THHW-LS or TW75 (75°C test), THW-2 (90°C test)	Type THWN or TWN75 (75°C test), THWN-2 (90°C test)
2.08	14 AWG	0.030	0.042	0.042	0.030	0.035	0.095	0.138	0.138	0.095	0.115
3.31	12	0.025	0.036	0.036	0.025	0.030	0.080	0.118	0.118	0.080	0.095
5.26	10	0.025	0.030	0.030	0.025	0.035	0.065	0.098	0.098	0.065	0.100
8.37	8	0.025	0.032	0.032	0.025	0.035	0.070	0.105	0.105	0.070	0.100
13.3	6	0.025	0.027	0.027	0.025	0.030	0.070	0.089	0.089	0.070	0.085
21.2	4	0.020	0.022	0.022	0.020	0.030	0.060	0.072	0.072	0.060	0.085
26.7	3	0.020	0.020	0.020	0.020	0.025	0.050	0.066	0.066	0.050	0.080
33.6	2	0.015	0.0185	0.0185	0.015	0.025	0.050	0.061	0.061	0.050	0.070
42.4	1	0.020	0.0195	0.0195	0.020	0.025	0.055	0.064	0.064	0.055	0.075
53.5	1/0	0.020	0.0175	0.0175	0.020	0.025	0.050	0.057	0.057	0.050	0.070
67.4	2/0	0.015	0.0160	0.0160	0.015	0.020	0.045	0.052	0.052	0.045	0.065
85.0	3/0	0.015	0.0145	0.0145	0.015	0.020	0.040	0.048	0.048	0.040	0.055
107	4/0	0.015	0.0130	0.0130	0.015	0.020	0.035	0.043	0.043	0.035	0.050
127	250 kcmil	0.015	0.0140	0.0140	0.015	0.020	0.040	0.046	0.046	0.040	0.055
152	300	0.015	0.0130	0.0130	0.015	0.020	0.035	0.043	0.043	0.035	0.050
177	350	0.015	0.0120	0.0120	0.015	0.015	0.035	0.039	0.039	0.035	0.050
203	400	0.010	0.0110	0.0110	0.010	0.015	0.030	0.036	0.036	0.030	0.045
226	450	0.010	0.0105	0.0105	0.010	0.015	0.030	0.034	0.034	0.030	0.045
253	500	0.010	0.0100	0.0100	0.010	0.015	0.030	0.033	0.033	0.030	0.040
279	550	0.010	–	–	0.010	0.015	0.030	–	–	0.030	0.045
304	600	0.010	0.0105	0.0105	0.010	0.015	0.030	0.034	0.034	0.030	0.045
329	650	0.010	–	–	0.010	0.015	0.030	–	–	0.030	0.040
355	700	0.010	0.0100	0.0100	0.010	0.015	0.030	0.033	0.033	0.030	0.040
380	750	0.010	0.0097	0.0097	0.010	0.015	0.025	0.032	0.032	0.015	0.040
405	800	0.010	0.0094	0.0094	0.010	0.015	0.025	0.031	0.031	0.015	0.040
456	900	0.010	0.0089	0.0089	0.010	0.010	0.025	0.029	0.029	0.010	0.035
507	1000	0.010	0.0085	0.0085	0.010	0.010	0.025	0.028	0.028	0.010	0.030
557	1100	0.010	–	–	0.010	–	0.020	–	–	0.020	–

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Table 24 Continued

Conductor size		GΩ·m					MΩ·1000 ft				
		50 or 60°C test		75 or 90°C test			50 or 60°C test		75 or 90°C test		
mm^2	AWG or kcmil	TW	TWU	TWU75 (75°C test)	THW[a], THW-LS, THHW, THHW-LS or TW75 (75°C test), THW-2 (90°C test)	Type THWN or TWN75 (75°C test), THWN-2 (90°C test)	TW	TWU	TWU75 (75°C test)	THW[a], THW-LS, THHW, THHW-LS or TW75 (75°C test), THW-2 (90°C test)	Type THWN or TWN75 (75°C test), THWN-2 (90°C test)
608	1200	0.010	–	–	0.010	–	0.020	–	–	0.020	–
633	1250	0.010	0.0085	0.0085	0.010	–	0.020	0.028	0.028	0.020	–
659	1300	0.010	–	–	0.010	–	0.020	–	–	0.020	–
709	1400	0.010	–	–	0.010	–	0.020	–	–	0.020	–
760	1500	0.010	0.0078	0.0078	0.010	–	0.020	0.026	0.026	0.020	–
811	1600	0.010	–	–	0.010	–	0.020	–	–	0.020	–
861	1700	0.010	–	–	0.010	–	0.020	–	–	0.020	–
887	1750	0.010	0.0073	0.0073	0.010	–	0.015	0.024	0.024	0.015	–
912	1800	0.010	–	–	0.010	–	0.015	–	–	0.015	–
963	1900	0.010	–	–	0.010	–	0.015	–	–	0.015	–
1010	2000	0.005	0.0068	0.0068	0.005	–	0.015	0.022	0.022	0.015	–

[a] *The values in this column apply to Type THW or THW-2 wire with a single or double layer of insulation.*

Table 25
Minimum acceptable long-term insulation resistance in air of Types THHN and T90 at 97.0°C (206.6°F)

(See Clauses 5.6.2.1 and 5.6.2.3.)

Size of conductor		GΩ·m	MΩ·1000 ft
mm^2	AWG or kcmil		
2.08	14 AWG	0.080	0.260
3.31	12	0.070	0.220
5.26	10	0.070	0.230
8.37	8	0.075	0.235
13.3	6	0.060	0.185
21.2	4	0.065	0.200
26.7	3	0.060	0.185
33.6	2	0.050	0.160
42.4	1	0.055	0.180
53.5	1/0	0.050	0.160
67.4	2/0	0.045	0.145
85.0	3/0	0.040	0.130
107	4/0	0.040	0.115

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Table 25 Continued

Size of conductor		GΩ·m	MΩ·1000 ft
mm²	AWG or kcmil		
127	250 kcmil	0.040	0.130
152	300	0.040	0.115
177	350	0.035	0.110
203	400	0.035	0.100
226	450	0.035	0.100
253	500	0.030	0.095
279	550	0.035	0.100
304	600	0.035	0.100
329	650	0.030	0.095
355	700	0.030	0.090
380	750	0.030	0.090
405	800	0.030	0.090
456	900	0.030	0.080
507	1000	0.025	0.075

Table 26
Mandrel diameters[a]

(See Clauses 5.8, 5.9, and 5.10.1.)

Size of conductor		A (Heat shock)		B (Room temperature and cold bend)	
mm²	AWG	mm	inches	mm	inches
2.08	14	3	0.133	8	0.313
3.31	12	4	0.148	9	0.375
5.26	10	4	0.168	14	0.563
8.37	8	6	0.228	17	0.688
13.3	6	16	0.646	32	1.250
21.2	4	19	0.744	35	1.375
26.7	3	20	0.802	37	1.458
33.6	2	22	0.866	40	1.563
42.4	1	26	1.016	68	2.688
53.5	1/0	28	1.098	73	2.875
67.4	2/0	30	1.190	76	3.000
85.0	3/0	33	1.294	83	3.250
107	4/0	36	1.410	89	3.500
127	250 kcmil	100	3.940	160	6.304
152	300	107	4.215	171	6.744

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Table 26 Continued

Size of conductor		A (Heat shock)		B (Room temperature and cold bend)	
mm^2	AWG	mm	inches	mm	inches
177	350	114	4.475	182	7.160
203	400	120	4.710	191	7.536
228	450	125	4.935	201	7.904
253	500	131	5.145	209	8.232
279	550	140	5.515	280	11.030
304	600	145	5.715	290	11.430
329	650	150	5.895	299	11.790
355	700	154	6.070	308	12.140
380	750	159	6.245	317	12.490
405	800	163	6.410	326	12.820
456	900	171	6.725	342	13.450
507	1000	178	7.020	357	14.040
608	1200	197	7.745	393	15.490
633	1250	200	7.885	401	15.770
659	1300	204	8.025	408	16.050
709	1400	210	8.270	420	16.540
760	1500	216	8.510	432	17.020
811	1600	222	8.745	444	17.490
861	1700	228	8.970	456	17.940
887	1750	231	9.085	462	18.170
912	1800	233	9.190	467	18.380
963	1900	239	9.400	478	18.800
1010	2000	244	9.610	488	19.220

[a] When the mandrel specified is not available, a mandrel with a smaller diameter may be used. However, in the case of noncompliant result, the wire or cable shall be retested using the specified mandrel.

Table 27
Mandrel diameters for heat shock test for deep-well submersible water pump cable[a]

(See Clause 7.4.4.2.)

Overall diameter of wire		Number of adjacent turns	Diameter of mandrel as a multiple of the overall wire or cable diameter
mm	inches		
0 – 19.0	0 – 0.75	6	3
19.1 – 38.1	0.76 – 1.5	180 degree bend	8
Over 38.1	Over 1.5	180 degree bend	12

[a] Maximum mandrel diameter based on the calculated insulation diameter. For convenience, a mandrel of smaller diameter may be used to represent the specified size. In case of non-compliance, the specified mandrel shall be used.

Table 28
Mandrel diameters for cold bend test for deep-well submersible water pump cable[a]

(See Clause 7.4.5.)

Cable configuration	Mandrel diameter	Number of turns
Parallel	6 times overall minor cross-sectional axis	1/2 (180 degree bend)
Multiple-conductor, twisted	8 times overall diameter	1/2 (180 degree bend)

[a] When the mandrel specified is not available, a mandrel with a smaller diameter may be used. However, in the case of noncompliant results, the cable shall be retested using the specified mandrel.

Table 29
Deformation load requirements

(See Clause 5.11.1.)

Size of conductor		Load[a] exerted on a specimen by the foot of the rod	
mm²	AWG or kcmil	N	gf
2.08 – 8.37	14 – 8	4.90	500
13.3 – 42.4	6 – 1	7.35	750
53.5 – 107	1/0 – 4/0	9.81	1000
127 – 1010	250 – 2000	19.61	2000

[a] The specified load is not the weight to be added to each rod in the test apparatus but rather the total of the weight added and the weight of the rod. Because the weight of the rod varies from one apparatus to another, specifying the exact weight to be added to a rod to achieve the specified load on a specimen in all cases is impractical except for an individual apparatus.

Table 30
Minimum insulation resistance at 15°C in water

(See Clause 5.24.)

Conductor size		GΩ·m				MΩ·1000 ft			
mm²	AWG or kcmil	Type TW, TW75	Types TWU, TWU75	Types THW-2, THHW, THHW-LS, THW, TWN75, and THW-LS	Types THWN-2, THWN, THHN, and T90 Nylon	Type TW, TW75	Types TWU, TWU75	Types THW-2, THHW, THHW-LS, THW, TWN75, and THW-LS	Types THWN-2, THWN, THHN, and T90 Nylon
2.08	14 AWG	45	65	175	205	140	205	570	665
3.31	12	40	55	150	175	120	175	485	550
5.26	10	35	45	125	180	100	150	405	580
8.37	8	35	50	130	185	105	155	415	595
13.3	6	35	40	135	155	105	130	435	495
21.2	4	30	35	115	155	90	110	360	505
26.7	3	25	30	110	145	80	100	325	465
33.6	2	25	30	90	130	75	90	295	415
42.4	1	30	30	105	140	85	95	340	455

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Table 30 Continued

Conductor size		GΩ·m				MΩ·1000 ft			
mm^2	AWG or kcmil	Type TW, TW75	Types TWU, TWU75	Types THW-2, THHW, THHW-LS, THW, TWN75, and THW-LS	Types THWN-2, THWN, THHN, and T90 Nylon	Type TW, TW75	Types TWU, TWU75	Types THW-2, THHW, THHW-LS, THW, TWN75, and THW-LS	Types THWN-2, THWN, THHN, and T90 Nylon
53.5	1/0	25	25	95	130	75	85	310	415
67.4	2/0	25	25	85	115	70	80	280	370
85.0	3/0	20	20	80	105	60	70	250	330
107	4/0	20	20	70	95	55	65	225	300
127	250 kcmil	20	20	80	105	60	70	245	330
152	300	20	20	70	95	55	65	225	300
177	350	20	20	65	90	50	60	210	285
203	400	15	15	65	80	50	55	200	255
226	450	15	15	60	80	45	50	190	255
253	500	15	15	55	75	45	50	180	240
279	550	15	–	65	80	50	–	200	255
304	600	15	15	60	80	45	50	190	255
329	650	15	–	60	75	45	–	185	240
355	700	15	15	55	70	45	50	180	225
380	750	15	–	55	70	40	–	170	225
405	800	15	15	55	70	40	45	165	225
456	900	15	15	50	65	40	45	155	210
507	1000	15	15	50	60	35	40	150	195
557	1100	15	–	45	–	35	–	140	–
608	1200	10	–	45	–	30	–	135	–
633	1250	10	15	45	–	30	40	135	–
659	1300	10	–	45	–	30	–	135	–
709	1400	10	–	40	–	30	–	125	–
760	1500	10	10	40	–	30	40	125	–
811	1600	10	–	40	–	30	–	120	–
861	1700	10	–	40	–	30	–	120	–
887	1750	10	10	35	–	25	35	110	–
912	1800	10	–	35	–	25	–	110	–
963	1900	10	–	35	–	25	–	110	–
1010	2000	10	10	35	–	25	35	105	–

Note: *The K values at 15°C (60°F) are*

a) *For Type TW, TW75, TWU, and TWU75: 152 GW·m (500 MW·1000 ft);*

b) *For Type THW-2, THHW, THHW-LS, THW, and THW-LS: 610 GW·m (2000 MW·1000 ft); and*

c) *For Type THWN-2, TWN75, THWN, THHN, and T90 Nylon: 1220 GW·m (4000 MW·1000 ft).*

Table 31
Smallest acceptable size of optional equipment grounding conductors in deep-well submersible water pump cables with copper circuit conductors

(See Clause 7.2.1.)

Size of copper circuit conductors		Smallest acceptable size of equipment grounding conductor, AWG or kcmil					
		Conductor temperature rating, °C					
		90		75		60	
mm^2	AWG or kcmil	Copper	Aluminum	Copper	Aluminum	Copper	Aluminum
2.08	14	14	12	14	12	14	12
3.31	12	12	10	12	10	12	10
5.26	10	10	8	10	8	10	8
8.37	8	10	8	10	8	10	8
13.3	6	8	6	8	6	10	8
21.2	4	8	6	8	6	8	6
26.7	3	6	4	8	6	8	6
33.6	2	6	4	6	4	8	6
42.4	1	6	4	6	4	6	4
53.5	1/0	6	4	6	4	6	4
67.4	2/0	6	4	6	4	6	4
85.0	3/0	4	2	6	4	6	4
107	4/0	4	2	4	2	6	4
127	250	4	2	4	2	4	2
152	300	3	1	4	2	4	2
177	350	3	1	3	1	4	2
203	400	3	1	3	1	4	2
253	500	2	1/0	3	1	3	1

Table 32
Smallest acceptable size of optional equipment grounding conductors in deep-well submersible water pump cables with aluminum circuit conductors

(See Clause 7.2.1.)

Size of aluminum circuit conductors		Smallest acceptable size of equipment grounding conductor, AWG or kcmil					
		Conductor temperature rating, °C					
		90		75		60	
mm^2	AWG or kcmil	Aluminum	Copper	Aluminum	Copper	Aluminum	Copper
3.31	12	12	14	12	14	12	14
5.26	10	10	12	10	12	10	12
8.37	8	8	10	8	10	8	10
13.3	6	8	10	8	10	8	10
21.2	4	6	8	6	8	8	10
26.7	3	6	8	6	8	6	8
33.6	2	6	8	6	8	6	8
42.4	1	4	6	6	8	6	8

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Table 32 Continued

Size of aluminum circuit conductors		Smallest acceptable size of equipment grounding conductor, AWG or kcmil					
		Conductor temperature rating, °C					
		90		75		60	
mm²	AWG or kcmil	Aluminum	Copper	Aluminum	Copper	Aluminum	Copper
53.5	1/0	4	6	4	6	6	8
67.4	2/0	4	6	4	6	4	6
85.0	3/0	4	6	4	6	4	6
107	4/0	2	4	4	6	4	6
127	250	2	4	2	4	4	6
152	300	2	4	2	4	4	6
177	350	2	4	2	4	2	4
203	400	1	3	2	4	2	4
253	500	1	3	1	3	2	4

Table 33
Insulated conductors used in deep-well submersible water pump cable

(See Clauses 7.2.2 and 7.2.3.)

Group I	TW, THW, THW-2, THHW
Group II	THWN, THWN-2
Group III	TWU, TWU75
Group IV	Polyethylene insulated
Note: *In Canada, Group III conductors are required by Section 26 of the CE Code, Part I.*	

Table 34
Integral jacket thickness for Group I deep-well submersible water pump cables

(See Clauses 7.2.2 and 7.2.3.)

Conductor size		Jacket thickness			
		Minimum average		Minimum at any point	
mm²	AWG	mm	mils	mm	mils
2.08 – 8.37	14 – 8	0.38	15	0.31	12
13.3 and larger	6 and larger	Jacket optional – Thickness of jacket, if present, is not specified			

Table 35
Polyethylene insulation thickness and dielectric withstand voltage for deep-well submersible water pump cable

(See Clauses 7.2.2.3, 7.4.1, and 7.4.2.1.)

Conductor size		Insulation thickness		Dielectric test voltage,	Spark test,
		Minimum average,	Minimum at any point,		
mm^2	AWG or kcmil	mm (mils)	mm (mils)	KVAC	KVAC
2.08 – 5.26	14 – 10	1.14 (45)	1.02 (40)	5.5	10.0
8.37 – 33.6	8 – 2	1.40 (55)	1.26 (50)	7.0	12.0
53.5 – 107	1/0 – 4/0	1.65 (65)	1.50 (59)	8.0	15.0
127 253	250 – 500	2.03 (80)	1.83 (72)	9.5	20.0

Table 36
Properties of polyethylene insulation used in deep-well submersible water pump cables

(See Clauses 7.2.2.3 and 7.4.1.)

Properties	Value
Before aging	
Tensile strength, MPa	Min. 9.6
Elongation, percent	Min. 350
After air oven	
Time/temperature	48 h/100°C
Retention of elongation, percent	Min. 75
Retention of tensile strength, percent	Min. 75
Capacitance and relative permittivity	
Test temperature, °C	75
Dielectric constant 24 h	Max. 6
1 d to 14 d	Max. 10 percent
7 d to 14 d	Max. 4 percent

Table 37
Thickness of overall jacket other than polyethylene, for deep-well submersible water pump cables

(See Clause 7.2.3.)

Size of conductor	Jacket thickness			
	Minimum average		Minimum at any point	
AWG/kcmil	mm	mils	mm	mils
14 – 9 AWG	0.38	15	0.30	12
8 – 2 AWG	0.76	30	0.61	24
1 – 4/0 AWG	1.14	45	0.91	36
213 – 500 kcmil	1.65	65	1.32	52

Table 38
Thickness of overall polyethylene jacket for deep-well submersible water pump cables

(See Clause 7.2.3.)

Diameter of cable under jacket of round configuration or major dimension of flat configuration	Jacket thickness			
	Minimum average		Minimum at any point	
mm (inches)	mm	mils	mm	mils
Up to 17.8 (0.700)	1.52	60	1.21	48
17.9 – 26.7 (0.701 – 1.051)	2.03	80	1.62	64
26.8 – 38.1 (1.052 – 1.500)	2.03	80	1.62	64
38.2 – 50.1 (1.51 – 1.972)	2.79	110	2.23	88

Table 39
Physical properties of PVC jackets for deep-well submersible water pump cables

(See Clause 7.2.3.)

Condition before aging	Test	Requirements
Elongation	Minimum increase in distance between gauge marks	100 percent
Tensile strength	Minimum tensile strength	10.3 MPa (1500 lbf/in^2)
Condition after aging	**Test**	**Requirements**
After air oven test	Temperature	100°C ± 1°C
	Time	168 h
	Minimum percent of values obtained on unaged specimens	Elongation 45 percent Tensile strength 65 percent
After oil immersion	Temperature	70°C ± 1°C
	Time	4 h
	Minimum percent of values obtained on unaged specimens	Elongation 60 percent Tensile strength 80 percent

Table 40
A-C spark test potential

(See Clause 5.22.1.)

Conductor size, mm^2 (AWG or kcmil)	A-C test potential (kV)
2.08 – 5.26 (14 – 10)	7.5
8.37 – 33.6 (8 – 2)	10.0
42.4 – 107 (1 – 4/0)	12.5
127 – 253 (250 – 500)	15.0
279 – 507 (550 – 1000)	17.5
557 – 1010 (1100 – 2000)	20.0