



UL 83

STANDARD FOR SAFETY

Thermoplastic-Insulated Wires and Cables

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

Fifteenth Edition, Dated March 28, 2014

Summary of Topics:

This New Edition of ANSI/UL 83 is being issued to incorporate several substantive changes.

The new and revised requirements are substantially in accordance with Proposal(s) on this subject dated October 26, 2012, April 19, 2013 and January 3, 2014.

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Association of Standardization and Certification
NMX-J-010-ANCE-2014
Fifth Edition



CSA Group
CSA C22.2 No. 75-14
Tenth Edition



Underwriters Laboratories Inc.
UL 83
Fifteenth Edition

Thermoplastic-Insulated Wires and Cables

March 28, 2014



ANSI/UL 83-2014

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This ANSI/UL Standard for Safety consists of the Fifteenth Edition including revisions through March 28, 2014. The most recent designation of ANSI/UL 83 as an American National Standard (ANSI) occurred on March 26, 2014. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, Title Page (front and back), or the Preface. The National Difference Page and IEC Foreword are also excluded from the ANSI approval of IEC-based standards.

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 Fifth edition of NMX-J-010-ANCE, the Tenth edition of CAN/CSA-C22.2 No. 75, and the Fifteenth edition of UL 83. This edition of NMX-J-010-ANCE supersedes the previous edition published in 2008. This edition of CAN/CSA-C22.2 No. 75 supersedes the previous edition published in 2008. This edition of UL 83 supersedes the previous edition published in 2008.

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 Comité de Normalización de la Asociación de Normalización y Certificación, 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 approved by the American National Standards Institute (ANSI) as an American National Standard.

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 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.

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.

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Interpretations

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

ANCE Effective Date

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

CSA Group Effective Date

The effective date for CSA Group will be announced through a *CSA Informs* or *CSA Group Certification Notice*.

UL Effective Date

As of March 28, 2014 all products Listed or Recognized by UL must comply with the requirements in this standard.

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

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 (CEC), 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 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 Clause 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 rated 600 V 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

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

2.2 Reference publications

This Standard refers to the following publications and where such reference is made to ANCE, CSA, or UL Standards, it shall be to the latest edition and all amendments published thereto. Where such reference is made to other publications, it shall be to the edition listed below.

ANCE Standards

NOM-001-SEDE,
Standard for Electrical Installations

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-032-ANCE,
Wires and Cables – Concentric Lay Stranded Aluminum 1350 Cable, for Electrical Purposes – Specifications

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-129-ANCE,
Wire and Cables – Determination of Cross Sectional Area of Stranded Electrical Conductors Related to the Mass – 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

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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-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

C22.1-12,
Canadian Electrical Code, Part I

CAN/CSA C22.2 No. 2556-07,
Wire and Cable Test Methods

UL Standards

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

UL 2556
Wire and Cable Test Methods

ASTM (American Society for Testing and Materials) Standards

B3-01(2007),
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 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

B231/B231M-11,
Standard Specification for Concentric-Lay-Stranded Aluminum 1350 Conductors

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

IEC (International Electrotechnical Commission) Standards

60228 (2004-11),
Conductors of insulated cables

NFPA (National Fire Protection Association) Publication

NFPA 70,
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.

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 *CEC*, 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 mm² (14 AWG), 3.31 mm² (12 AWG), and 5.26 mm² (10 AWG) stranded copper conductor with a layer of tin shall be optional.

4.1.5 Sizes and stranding

4.1.5.1 Sizes

Conductors shall be as shown in Table 1.

Note: IEC conductor sizes are not recognized in the CEC, 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

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

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

4.1.5.2.2 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 mm² (2 AWG) and smaller, the maximum lay length shall be 17.5 times the outside diameter. The direction of lay of the outermost layer shall be left-hand, and it shall be reversed or unidirectional/unilay in successive layers.

4.1.5.2.3 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.

4.1.5.2.4 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.

4.1.5.2.5 Length and direction of lay

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

- a) The direction of lay of the strands, members, or ropes in a 13.3 – 1010 mm² (6 AWG – 2000 kcmil) conductor, other than a combination unilay or a compressed unilay or compressed unidirectional lay conductor, shall be reversed in successive layers. Rope-lay conductors with bunch-stranded or concentric-stranded members shall be either unidirectional or reversed. All unidirectional lays and the outer layer of reversed lays shall be in the left-hand direction.
- b) For a bunch-stranded member of a rope-lay-stranded conductor in which the members are formed into rope-stranded components that are then cabled into the final conductor, the length of lay of the individual members within each component shall not be more than 30 times the outside diameter of one of those members.
- c) For a concentric-stranded member of a rope-lay-stranded conductor, the length of lay of the individual strands in a member shall be 8 – 16 times the outside diameter of the member. The direction of lay of the strands in each member shall be reversed in successive layers of the member.
- d) The length of lay of the strands in both layers of a 19-wire combination round-wire unilay-stranded copper or aluminum conductor shall be 8 – 16 times the outside diameter of the completed conductor. Otherwise, the length of lay of the strands in every layer of a concentric-lay-stranded conductor consisting of fewer than 37 strands shall be 8 – 16 times the outside diameter of the conductor.
- e) The length of lay of the strands in the outer two layers of a concentric-lay-stranded conductor consisting of 37 or more strands shall be 8 – 16 times the outside diameter of the conductor.
- f) The length of lay of the members or ropes in the outer layer of a rope-lay-stranded conductor shall be 8 – 16 times the outside diameter of that layer.

4.1.6 Diameter and cross-sectional area

4.1.6.1 The nominal diameters of solid and stranded conductors are shown in Tables 4 – 9. 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-129-ANCE.

Conductor sizes in mm² (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.

The nominal cross-sectional area, if required, shall be determined in accordance with the test, Cross-sectional area, in UL 2556, CSA C22.2 No. 2556, or NMX-J-129-ANCE.

4.1.6.2 In the United States, compressed unilay or compressed unidirectional lay copper conductors that are smaller in diameter than the requirement (0.98 x nominal in Table 6) for compressed concentric lay conductors shall be marked in accordance with Clause 6.1.6.

In Canada and Mexico, this requirement does not apply.

4.1.7 Joints

4.1.7.1 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.

4.1.7.2 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.

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

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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

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.

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

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

4.2.3 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

The average and minimum thickness 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.

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

4.2.5.1.1 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

4.2.5.2.1 Compliance with Clause 4.2.5.1.1 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/in²), 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 mm² (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 shown in Tables 14 – 23 inclusive. For conductors for which the maximum resistance is not tabulated in Tables 14 – 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 A twisted conductor assembly shall not exceed the value tabulated in Tables 14 – 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

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/in²). The tensile strength of all other conductors shall be 103 – 152 MPa (15,000 – 22,000 lbf/in²). Compliance shall be determined in accordance with the test, Physical properties of conductors – Maximum tensile strength and elongation at break, in UL 2556, CSA C22.2 No. 2556, or NMX-J-556-ANCE.

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

5.3.2 High-current heat cycling

5.3.2.1 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, CSA C22.2 No. 2556, or NMX-J-556-ANCE.

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

5.5.1 Minimum acceptable value

5.5.1.1 The insulation of wet-rated single-conductor cable and of the individual single conductors of multiconductor cable shall have insulation resistance at the specified temperature in tap water not less than specified in Table 24 at any time during immersion, in accordance with the test, Insulation resistance, in UL 2556, CSA C22.2 No. 2556, or NMX-J-556-ANCE. The period of immersion shall be 12 weeks or more if the insulation resistance during the last 6 weeks of the period is higher than 3 GΩ·m (10 MΩ·1000 ft). The period of immersion shall be 24 – 36 weeks if the insulation resistance is less than 3 GΩ·m (10 MΩ·1000 ft), but equals or exceeds the value indicated in Table 24. An a-c voltage of 600 V rms shall be applied to the insulation at all times other than while reading the insulation resistance.

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

5.5.1.2 The extended immersion tests at 50°C (122°F) or 60°C (140°F) for Types TW and TWU; at 75°C (167°F) for Types THW, THWN, THW-LS, THHW-LS, THHW, TW75, TWN75, and TWU75; and at 90°C (194°F) for Types THW-2 and THWN-2 shall be considered accelerated tests.

5.5.2 Maximum acceptable rate of decrease

5.5.2.1 During the extended immersion, the maximum decrease in insulation resistance per week, as determined from a curve (derived from the best fit using the method of least squares representing the average of actual values), for every continuous period of 3 weeks during the latter half of the specified immersion time shall be not more than 4 percent if and while the insulation resistance is 3 GΩ·m (10 MΩ·1000 ft) or more, and shall be not more than 2 percent if the insulation resistance is less than 3 GΩ·m (10 MΩ·1000 ft), but more than the value indicated in Table 24.

5.5.2.2 Any coil that shows a greater percent decrease in insulation resistance than those indicated in Clause 5.5.2.1 during the extended period of time in the water tank may be tested for additional one week periods in the water tank and judged on the basis of the results for every continuous period of 3 weeks during the last 6-week period in the water tank, provided that the final insulation resistance is not less than as specified in Table 24.

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

5.6.1 Applicability

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

5.6.2 Maximum acceptable rate of decrease

5.6.2.1 The maximum acceptable rate of decrease shall be as specified in Clause 5.5.2.

5.6.2.2 Any coil that shows a greater percent decrease in insulation resistance than those indicated in Clause 5.5.2.1 during the extended period of time in the oven shall be allowed to be tested for additional one-week periods in the oven and judged on the basis of the results for every continuous period of 3 weeks during the last 12 weeks in the oven, provided that the final insulation resistance is not less than as specified in Table 24.

5.6.3 Minimum acceptable value

5.6.3.1 The 90°C rated insulation of the individual conductors without covering shall have insulation resistance in air at $97 \pm 1^\circ\text{C}$ that is not less than indicated in Table 25 at any time during an extended period in an acceptable full-draft circulating-air oven under the following conditions. The period in the oven shall be 12 weeks or more, to a maximum of 36 weeks, if the insulation resistance throughout the last 6 weeks of the period is $3 \text{ G}\Omega\cdot\text{m}$ ($10 \text{ M}\Omega\cdot 1000 \text{ ft}$) or higher. If the insulation resistance is less than $3 \text{ G}\Omega\cdot\text{m}$ ($10 \text{ M}\Omega\cdot 1000 \text{ ft}$), but equals or exceeds the values in Table 25, the period in the oven shall be 24 weeks or more to a maximum of 36 weeks. A 600 V rms voltage shall be applied at all times other than while reading the insulation resistance.

5.6.3.2 The insulation resistance shall be measured between the conductor and an electrode (either graphite powder or a snug-fitting close-weave copper braid) applied over the insulation, or other equivalent means.

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°C, 75°C, or 90°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-covered wires, the nylon shall be removed prior to testing.

5.8 Flexibility at room temperature after aging

The insulation and nylon covering (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 When tested in accordance with the test, Heat shock, in UL 2556, CSA C22.2 No. 2556, or NMX-J-190-ANCE, the insulation of single insulated conductors shall not show any cracks, on the surface or internally, after a specimen of finished wire is wound around a mandrel with a diameter specified in Column A of Table 26 after conditioning in an air-circulating oven for 1 h to a temperature of $121 \pm 1^\circ\text{C}$.

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° .

5.10 Cold bend and cold impact

5.10.1 Cold bend

5.10.1.1 After conditioning at a temperature of $-25 \pm 1^\circ\text{C}$ 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 $-40 \pm 1^\circ\text{C}$ 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° U-bend shall be performed.

5.10.1.3 When the wire or cable is marked with the optional -40°C marking in accordance with Clause 6.1.8, conditioning shall be carried out at a temperature of $-40 \pm 1^\circ\text{C}$.