UL 44

Underwriters Laboratories Inc.

Standard for Safety

Thermoset-Insulated Wires and Cables

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UL Standard for Safety for Thermoset-Insulated Wires and Cables, UL 44

Seventeenth Edition, Dated September 10, 2010

Summary of Topics

This new edition of ANSI/UL 44 includes Major Revisions Based on Publication of UL 2556, and other Revised Construction, Performance, and Marking Requirements Including but not Limited to the Following Significant Changes: Deletion of all Figures, Several Tables, Annex H, and all of the Test Methods, and Extensive Revision of the Test Requirements Section; Deletion of Requirements for Lead-Alloy Conductors; Various Revisions to Marking Requirements Including Those for Aluminum Conductors, Clarification of Country- Specific Marking Requirements, and Addition of a Marking for Cables not Intended for Outdoor Use; Revision to the Mandrel Diameter and Related Testing Requirements; Reinstatement of Previously Deleted Requirements for Thickness of Overall Jacket on Deep Well Pump Cables; Clarification to Several Tables Addressing Various Requirements for Types RW75, RW90, RWU75, and/or RWU90 cables; and Miscellaneous Editorial Wording Revisions

The new and revised requirements are substantially in accordance with Proposal(s) on this subject dated February 15, 2008 and December 4, 2009.

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The following table lists the future effective date with corresponding text references.

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Future Effective Date	References
September 10, 2011	Paragraphs 6.2 and 7.3.1.1, and Table 31

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Association of Standardization and Certification
NMX-J-451-ANCE
Fourth Edition

Canadian Standards Association
CSA C22.2 No. 38-10
Ninth Edition

Underwriters Laboratories Inc.
UL 44
Seventeenth Edition

Thermoset-Insulated Wires and Cables

September 10, 2010

ANSI/UL 44-2010

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This standard is issued jointly by the Association of Standardization and Certification (ANCE), the Canadian Standards Association (CSA), and Underwriters Laboratories Inc. (UL). Comments or proposals for revisions on any part of the standard may be submitted to ANCE, CSA, or UL at any time. Revisions to this standard will be made only after processing according to the standards development procedures of ANCE, CSA, and UL. CSA 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 and UL pages.

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This ANSI/UL Standard for Safety consists of the Seventeenth Edition.

The most recent designation of ANSI/UL 44 as an American National Standard (ANSI) occurred on September 10, 2010. 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 44 on April 5, 1985. The publication of revised pages or a new edition of this Standard will not invalidate the DoD adoption.

Comments or proposals for revisions on any part of the Standard may be submitted to UL at any time. Proposals should be submitted via a Proposal Request in UL's On-Line Collaborative Standards Development System (CSDS) at http://csds.ul.com.

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Preface

This is the harmonized ANCE, CSA, and UL standard for Thermoset-Insulated Wires and Cables. It is the Fourth edition of NMX-J-451-ANCE, the Ninth edition of CSA C22.2 No. 38, and the Seventeenth edition of UL 44. This edition of NMX-J-451-ANCE cancels the previous edition published in 2005. This edition of CSA C22.2 No. 38 supersedes the previous edition published in 1995. This edition of UL 44 supersedes the previous edition published in 2005.

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

This Standard 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 Subcommittee on C22.2 No. 38, under the jurisdiction of the CSA Technical Committee on Wiring Products and the CSA Strategic Steering Committee on Requirements for Electrical Safety, and has been formally approved by the CSA Technical Committee.

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

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

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

Level of harmonization

This standard uses the IEC format but is not based on, nor is considered equivalent to, an IEC standard.

This standard is published as an equivalent standard for ANCE, CSA, and UL.

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

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Reasons for differences from IEC

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

Interpretations

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

ANCE effective date

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

CSA effective date

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

UL effective date

As of September 10, 2010 all products Listed or Recognized by UL must comply with the requirements in this standard except for clauses, figures, and tables in the following list, which are effective September 10, 2011:

Clauses 6.2 and 7.3.1.1 and Table 31.

Between September 10, 2010 and September 10, 2011, new product submittals to UL may be evaluated under all requirements in this standard or, if requested in writing, evaluated under presently effective requirements only. The presently effective requirements are contained in the Sixteenth edition of UL 44.

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

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Thermoset-Insulated Wires and Cables

1 Scope

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

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

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

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

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

2 Definitions

2.1 The following definitions apply in this Standard:

Composite insulation system – a multiple-layer system of materials that fulfills the requirements for both electrical and mechanical integrity of the cable or wire.

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

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

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

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

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

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

Neoprene – a thermoset compound whose characteristic constituent is polychloroprene.

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

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

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

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

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

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

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

3 General

3.1 Units of measure

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

3.2 Reference publications

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

ANCE Standards

NOM-001-SEDE
Standard for Electrical Installations

NMX-E-034-SCFI
Plastics Industry – Carbon Black Contents on Polyethylene Materials – Test Method

NMX-J-008-ANCE
Tinned Soft or Annealed Copper Wire for Electrical Purposes – Specifications

NMX-J-012-ANCE
Wires and Cables – Concentric Lay Stranded Copper Conductors for Electrical Purposes – Specifications

NMX-J-013-ANCE
Wires and Cables – Rope Lay Stranded Copper Conductors Having Concentric Stranded Members for Electrical Purposes – Specifications

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

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

NMX-J-036-ANCE
Soft or Annealed Copper Wire for Electrical Purposes – Specifications

NMX-J-040-ANCE
Wires and Cables – Determination of the Moisture Absorption in Insulations of Electrical Conductors – Test Method

NMX-J-066-ANCE
Determination of Diameters of Electrical Conductors – Test Method

NMX-J-093-ANCE
Wires and Cables – Determination of the Resistance to Fire Propagation on Electrical Conductors – Test Method

NMX-J-177-ANCE
Wires and Cables – Determination of Thickness in Semiconductive Shielding, Insulations, and Jackets of Electrical Conductors – Test Method

NMX-J-178-ANCE
Wires and Cables – Ultimate Strength and Elongation of Insulation, Semiconducting Shields and Jackets of Electrical Conductors – Test Method

NMX-J-186-ANCE
Wires and Cables – Accelerated Aging in Forced Convection Oven of Semiconducting Shields, Insulations and Jackets of Electrical Conductors – Test Method

NMX-J-190-ANCE
Wires and Cables – Thermal Shock Resistance of PVC Insulations and Protective Coverings of Electrical Conductors – Test Method

NMX-J-191-ANCE
Wires and Cables – Heat Distortion of Insulations and Protective Coverings of Electrical Conductors – Test Method

NMX-J-192-ANCE
Electrical Products – Wires and Cables – Flame Test on Electrical Wires – Test Method

NMX-J-193-ANCE
Wires and Cables – Cold Bend of Insulation and Non-Metallic 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
Wires and Cables – Electrical Resistance, Resistivity and Conductivity – Test Method

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

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NMX-J-294-ANCE
Wires and Cables – Insulation Resistance – Test Method

NMX-J-312-ANCE
Wires and Cables – Tensile Strength and Elongation at Break of Electrical Conductors – Test Method

NMX-J-432-ANCE
Wires and Cables – Determination of Hot Elongation and Permanent Deformation (Hot Creep), to Ethylene Propylene Rubber and Cross-Linked Polyethylene Insulations – Test Method

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 Method

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

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 Standards

C22.1-09
Canadian Electrical Code, Part I

C22.2 No. 2556-07
Wire and Cable Test Methods

UL Standards

UL 2556
Wire and Cable Test Methods

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

ASTM (American Society for Testing and Materials)

B3-01
Soft or Annealed Copper Wire

B8-99
Concentric-Lay-Stranded Copper Conductors, Hard, Medium-Hard, or Soft

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B33-00
Tinned Soft or Annealed Copper Wire for Electrical Purposes

B172-01
Rope-Lay-Stranded Copper Conductors Having Bunch-Stranded Members, for Electrical Conductors

B173-01
Rope-Lay-Stranded Copper Conductors Having Concentric-Stranded Members, for Electrical Conductors

B231-99
Standard Specification for Concentric-Lay-Stranded Aluminum 1350 Conductors

B298-99
Standard Specification for Silver-Coated Soft or Annealed Copper Wire

B355-95
Standard Specification for Nickel-Coated Soft or Annealed Copper Wire

B835-00
Standard Specification for Compact Round Stranded Copper Conductors Using Single Input Wire Construction

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

IEC (International Electrotechnical Commission)

60228 (1978-01)
Conductors of insulated cables

60228A (1993-01)
Conductors of insulated cables – Amendment No. 1

National Research Council Canada

National Building Code of Canada, 2010

NFPA (National Fire Protection Association)

NFPA 70-2008
National Electrical Code

4 Construction

4.1 Conductors

4.1.1 General

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

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4.1.2 Aluminum conductors

In Mexico, aluminum conductors shall be AA 8000 series alloy or 1350 aluminum alloy.

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

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

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

4.1.3 Copper-clad aluminum conductors

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

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

4.1.4 Copper conductors

4.1.4.1 General

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

4.1.4.2 Coated copper conductors

4.1.4.2.1 Each tin-coated conductor shall comply with the requirements of ASTM B33 or NMX-J-008-ANCE; a nickel-coated wire shall comply with ASTM B355, and a silver-coated wire shall comply with ASTM B298. Conductors coated with other metals or alloys shall be subjected to special investigation.

Note: *In Mexico, the use of ASTM B355 is recommended for nickel-coated wire, and the use of ASTM B298 is recommended for silver-coated wire.*

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

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4.1.4.3 Uncoated copper conductors

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

4.1.5 Sizes and stranding

4.1.5.1 Sizes

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

Copper strands smaller than 0.0127 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.

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

4.1.5.2 Stranding

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

4.1.5.3 Compact

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

4.1.5.4 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.

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4.1.5.5 Assembly of strands

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

4.1.5.6 Length and direction of lay

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

a) The direction of lay of the strands, members, or ropes in a 13.3 – 1010 mm^2 (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.

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4.1.6 Diameter and cross-sectional area

4.1.6.1 The nominal diameters of solid and stranded conductors are shown in Tables 5 – 10. The minimum diameter for a stranded conductor is 98 percent of the nominal. The maximum diameter of any conductor is 101 percent of the nominal. Verification of the diameter shall be determined in accordance with the test, Conductor diameter, in UL 2556, CSA C22.2 No. 2556, or NMX-J-066-ANCE.

Conductor sizes in mm^2 (AWG/kcmil) covered by this Standard are shown in Table 5. The nominal cross-sectional area of a conductor identified in Table 5 is not a requirement.

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

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

4.1.7 Joints

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

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

A joint shall be allowed in a Class B stranded 2.08 mm^2 (14 AWG), 3.31 mm^2 (12 AWG), or 5.26 mm^2 (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, when present between the conductor and the insulation, shall be of contrasting color to the conductor color, except that clear or green shall not be used. A white colored separator over aluminum complies with this requirement. The separator and the other wire or cable components shall not have any deleterious effect on one another.

4.2 Insulation

4.2.1 General

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

The physical properties of the insulation shall comply with Table 11, when determined in accordance with the test, Physical properties (ultimate elongation and tensile strength), in UL 2556, CSA C22.2 No. 2556, or NMX-J-178-ANCE and NMX-J-186-ANCE.

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

a) XL;

b) EPCV;

c) Composite Insulation;

i) Inner – EP, EPCV, Silicone, or XL;

The inner layer of a composite insulation shall be silicone only for Types RW90, RW75, and R90.

ii) Outer – EPCV, XL, CP, or CPE;

d) EP;

e) SBR/IIR/NR;

f) Silicone; and

g) CP, CPE.

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

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4.2.2 Repairs

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

4.2.3 Thickness

The minimum average and minimum insulation thickness shall be as shown in Tables 12 – 18, when measured in accordance with the test, Thickness, as described in UL 2556, CSA C22.2 No. 2556, or NMX-J-177-ANCE.

4.2.4 Centering

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

4.2.5 Insulation strand penetration (fall-in)

The insulation shall not penetrate the stranded conductor in a manner that would hamper the free stripping of the insulation when tested in accordance with the test, Fall-in of extruded materials, in UL 2556, CSA C22.2 No. 2556, or NMX-J-556-ANCE.

4.3 Jackets or fibrous coverings over single conductors

4.3.1 A single-conductor wire and each conductor of any 2-conductor flat parallel cable, and each conductor of any multiple-conductor cable, shall have a protective covering of fibrous material or a jacket applied over the outer surface of the insulation, in accordance with Table 19. The temperature rating of the jacket shall be the same as that of the insulated conductor. Requirements for protective coverings other than jackets are covered in Annex F of this Standard. Physical property requirements for jackets shall comply with Table 20, when tested in accordance with the test, Physical properties (ultimate elongation and tensile strength), in UL 2556, CSA C22.2 No. 2556, or NMX-J-178-ANCE and NMX-J-186-ANCE. Jacket thickness requirements are shown in Tables 21 – 23.

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

a) Rubber-filled woven cotton tape;

b) Polypropylene tape under a fibrous wrap or braid;

c) Oriented polyethylene terephthalate tape under a fibrous wrap or braid;

d) Fibrous braid;

e) Fibrous wrap;

f) Neoprene jacket;

g) NBR/PVC jacket;

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h) CPE jacket;

i) CP jacket;

j) PVC jacket;

k) XL jacket.

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

4.4 Shielding (optional)

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

4.5 Multiple-conductor cables

4.5.1 Lay of cabled conductors

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

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

a) All cables in sizes larger than 13.3 mm^2 (6 AWG) twisted in accordance with Clause 4.5.1.3; and

b) All cables in sizes 13.3 mm^2 (6 AWG) and smaller twisted in accordance with Clause 4.5.1.3 or parallel.

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

a) Each area in which the lay is right- or left-hand for a minimum of five complete twists (full 360° cycles) shall have the insulated conductors cabled with a length of lay that is not greater than indicated in Table 24; and

b) The length of each lay-transition zone (oscillated section) between these areas of right- and left-hand lay shall not exceed 1.8 times the maximum length of lay indicated in Table 24.

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

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

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4.5.2 Equipment-grounding conductor

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

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

4.6 Color coding

4.6.1 Color of insulated equipment-grounding conductor

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

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

4.6.2 Identification of ungrounded circuit conductor(s)

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

a) One or more broken or unbroken straight or helical stripes. See Clause 4.6.1.2 for details on stripes;

b) An unbroken series of identical hash marks or other symbols with dimensions as specified for stripes and with regular spacing; and

c) Numerals, letters, words, or a combination thereof that comply with this Standard.

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

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

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

4.6.3 Identification of grounded circuit conductor(s)

4.6.3.1 An insulated conductor intended for use as a grounded circuit conductor shall be finished to show the color white or gray throughout the entire length and circumference of its outer surface, or shall be identified by three continuous straight or helical, unbroken white stripes on other than green insulation, along its entire length. Straight stripes shall be placed a nominal 120° apart. Where multiple grounded circuit conductors are used in a cable, no more than one shall employ white stripes. Additional conductors intended to be grounded circuit conductors shall be finished white (gray is not appropriate except in a 4-circuit-conductor cable) and shall have any one of the features described in Clause 4.6.2.1 a), b), or c) throughout the length of the wire or cable in a color or combination of colors other than, and in contrast with, white, gray, or green.

See 4.6.1.2 for details on stripes.

4.7 Fillers and protective materials

When used in a cable or assembly, fillers or any additional optional protective materials shall not have any deleterious effect on other cable components.

4.8 Jacket separators

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

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

4.9 Jackets

4.9.1 General

4.9.1.1 A multiple-conductor cable shall have a protective covering of fibrous material or a jacket applied over the cabled conductors in accordance with Table 19. Requirements for protective coverings, other than jackets, applied over cabled conductors are provided in Annex F of this Standard. Where a thermoplastic or thermoset jacket is required or applied, the jacket shall fit tightly and be applied over cabled conductors or over a jacket separator in compliance with Clause 4.8. The temperature rating of the jacket shall be 75°C. The use of a 90°C rated jacket is optional. The physical properties of the jacket shall comply with Table 20, when determined in accordance with the test, Physical properties (ultimate elongation and tensile strength), in UL 2556, CSA C22.2 No. 2556, or NMX-J-178-ANCE and NMX-J-186-ANCE. Requirements for jackets over individual conductors are described in Clause 4.3.

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

4.9.2 Jacket thickness

The minimum average and minimum thickness of a jacket shall not be less than indicated in Table 26 when determined by the method described in the test, Thickness, in UL 2556, CSA C22.2 No. 2556, or NMX-J-177-ANCE.

4.9.3 Diameter of conductor assembly under jacket

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

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

4.10.1 Materials having characteristics different from those specified in Table 11 or 20 shall be evaluated for the requested temperature rating in accordance with Clause 5.22. To be evaluated, insulations for use without jackets or additional coverings, the outer insulation layer of a composite insulation, and jackets shall have an initial absolute minimum tensile strength of not less than 6.8 MPa (1000 lbf/in^2), and an absolute minimum elongation of 100 percent before aging. Insulations for use with jackets or additional coverings, or the inner layer of composite insulation, shall have an initial absolute minimum tensile strength of not less than 3.4 MPa (500 lbf/in^2) and an absolute minimum elongation of 100 percent before aging.

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

4.11 Assemblies that include single-conductor thermoset-insulated wires

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

Completed assemblies shall comply with the requirements of Clause 4.11.2.

4.11.2 Completed assemblies shall comply with the following requirements:

a) Assemblies in which an uninsulated copper conductor is included shall be tested in accordance with Clause 5.24.

b) Each assembly in which an uninsulated conductor is not included shall be tested in accordance with Clause 5.23 or Clause 5.24, with each layer in a multiple-layer assembly spark tested separately.

c) Each 2.08 – 8.37 mm^2 (14 – 8 AWG) conductor in an assembly shall be individually tested for continuity in accordance with Clause 5.26 after the assembly is completed.

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5 Test requirements

5.1 General

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

5.2 Conductor resistance

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

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

a) Cabled in one layer: 1.02;

b) Cabled in more than one layer: 1.03; or

c) Cabled as an assembly of other pre-cabled units: 1.04

5.2.3 Compliance shall be determined in accordance with the test, DC Resistance, in UL 2556, CSA C22.2 No. 2556, or NMX-J-212-ANCE.

5.3 Tests of aluminum conductors

5.3.1 Physical properties

5.3.1.1 All aluminum conductors shall have a minimum elongation of 10 percent. Wires (strands) removed from a finished stranded conductor shall have a tensile strength of 98 – 159 MPa (14,250 – 23,100 lbf/in^2). The tensile strength of solid 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, CSA C22.2 No. 2556, or NMX-J-312-ANCE.

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

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

5.4 Long-term insulation resistance in water

5.4.1 Acceptable criteria

5.4.1.1 The insulation, without the protective covering, of wet-rated single-conductor cable and of the individual single conductors of multiple-conductor cable shall have an insulation resistance at the rated temperature in tap water not less than specified in Tables 33 – 35 at any time during immersion. 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 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) but equals or exceeds the value indicated in Tables 33 – 35. An a-c voltage equal to the voltage rating of the wire (600 V, 1000 V, or 2000 V rms) shall be applied to the insulated conductor at all times other than while measuring the insulation resistance. These tests are accelerated tests. Composite insulation systems shall be tested as a unit.

5.4.1.2 The values in Tables 33 – 35 apply only to conductor types with the corresponding insulation thicknesses specified in this Standard. For other parameters of any material, the insulation resistance values shall be calculated by means of the formula in Annex H. The maximum decrease in insulation resistance shall not be more than 4 percent if and while the insulation resistance is 3 GΩ·m (10 MΩ·1000 ft) or more; and shall not be more than 2 percent if the insulation resistance is less than 3 GΩ·m (10 MΩ·1000 ft) but more than the value indicated in Tables 33 – 35. If the results of the test do not meet either of these criteria, 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 5.4.1.1.

5.4.1.3 Any coil that shows a greater percent decrease in insulation resistance during the extended immersion period shall be allowed to be tested for additional 1-week immersion periods and judged on the basis of the results for every continuous period of 3 weeks during the last 12 weeks of immersion, provided that the final insulation resistance is not less than as specified in Tables 33 – 35.

5.4.1.4 Compliance with 5.4.1.1 – 5.4.1.3 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.

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

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

5.5.2 Minimum acceptable value

5.5.2.1 The insulation on Type XHH, RHH, and R90 wires shall have an insulation resistance in air at 97 ±1°C that is not less than indicated in Table 36 or 37, whichever is applicable, at any time during an extended period in an acceptable full-draft circulating-air oven. Compliance 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 under the following conditions. The period in the oven shall be 12 weeks or more if the insulation resistance throughout the last 6 weeks of the period is 3 GΩ·m (10 MΩ·1000 ft) or higher. The period in the oven shall be 24 – 36 weeks if the insulation resistance is less than 3 GΩ·m (10 MΩ·1000 ft) but equals or exceeds the values in Table 36 or 37, whichever is applicable. An rms potential equal to the voltage rating of the wire shall be applied at all times other than while reading the insulation resistance.

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

5.5.3 Maximum acceptable rate of decrease

5.5.3.1 The maximum acceptable rate of decrease shall be the same as specified in Clause 5.4.1.2 and 5.4.1.3, except that the final insulation resistance shall not be less than specified in Table 36 or 37.

5.6 Capacitance and relative permittivity

5.6.1 The insulation, without the protective covering, of wet-rated single-conductor cable and of the individual single conductors of multiple-conductor cable immersed in water at rated temperature, 75°C or 90°C, shall comply with each of the following:

a) The relative permittivity determined after immersion for 24 h shall not be more than 10.0 for CP, silicone, and CPE insulation and shall be 6.0 or less for all other insulations.

b) The capacitance for CP, silicone, and CPE insulations after immersion for 14 d shall be no more than 6 percent higher than the capacitance after 24 h immersion, and no more than 10 percent higher for all other insulations.

c) The capacitance determined for CP, silicone, and CPE insulations after 14 d immersion shall be no more than 2 percent higher than the capacitance determined after immersion for 7 d, and no more than 4 percent higher for all other insulations.

Composite insulation systems shall be tested as a unit. Compliance shall be determined in accordance with the test, Capacitance and relative permittivity, in UL 2556, CSA C22.2 No. 2556, or NMX-J-040-ANCE.

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5.7 Conductor corrosion

5.7.1 Bare unprotected copper conductor used without a separator under the insulation or jacket shall not show surface deterioration during visual examination. Compliance shall be determined in accordance with the test, Copper corrosion, in UL 2556, CSA C22.2 No. 2556, or NMX-J-556-ANCE.

5.8 Insulation fall-in

5.8.1 The stranded conductor shall be free of residual insulation or extruded conductor-shield material. Compliance shall be determined in accordance with the test, Fall-in of extruded materials, in UL 2556, CSA C22.2 No. 2556, or NMX-J-556-ANCE.

5.9 Heat shock of thermoplastic jacket

5.9.1 A thermoplastic jacket shall not show any cracks after a specimen of finished wire or cable has been wound or bent around a mandrel having a diameter in accordance with Table 38, and while still on the mandrel, subjected to a temperature of 121 ±1°C for a period of 1 h. For flat cable, the minor cross-sectional dimension of the cable shall be used in determining the mandrel diameter, and the cable shall be wound or bent flatwise around the mandrel. Compliance shall be determined in accordance with the test, Heat shock, in UL 2556, CSA C22.2 No. 2556, or NMX-J-190-ANCE.

5.10 Flexibility of separator under a thermoplastic jacket

5.10.1 A separator under a thermoplastic jacket, as required in Clause 4.8.1, shall not show cracks or open up after a specimen of the finished single-conductor wire or cable, or of the finished multiple-conductor cable, is wound at room temperature around a mandrel. Compliance shall be determined in accordance with the test, Flexibility of separator tape under a jacket, in UL 2556, CSA C22.2 No. 2556, or NMX-J-556-ANCE.

5.11 Cold bend and cold impact

5.11.1 Cold bend

5.11.1.1 After conditioning at a temperature of −25 ±1°C for 4 h, the insulation or jacket of a wire, cable, or assembly shall not show any cracks, nor shall any thread or threads of a fibrous covering of a wire, cable, or assembly show any breaks. Compliance shall be determined in accordance with the test, Cold bend, in UL 2556, CSA C22.2 No. 2556, or NMX-J-193-ANCE. The mandrel diameter shall be as specified in Table 39 for single conductors. Single-conductor specimens 2.08 – 33.6 mm^2 (14 – 2 AWG) shall be wound for six adjacent turns around the mandrel. Specimens 42.4 mm^2 (1 AWG) and larger shall be bent 180° around the mandrel. The mandrel diameter shall be as specified in Table 40 for 2-conductor parallel and multiple-conductor cables. When the wire or cable is marked with the optional −40C marking in accordance with Clause 6.1.8, conditioning shall be carried out at a temperature of −40 ±1°C.

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5.11.2 Cold impact (optional)

5.11.2.1 Where required, the jacket and/or insulation on at least 8 out of 10 completed cable specimens shall not crack or rupture, nor shall any thread or threads of a fibrous covering, if present, break, when tested at −40°C. Compliance shall be determined in accordance with the test, Cold impact, in UL 2556, CSA C22.2 No. 2556, or NMX-J-556-ANCE.

5.12 Deformation

5.12.1 The thickness of XL insulation shall not decrease more than 30 percent for conductor sizes 2.08 – 107.2 mm^2 (14 – 4/0 AWG) or 15 percent for conductor sizes 127 – 1010 mm^2 (250 – 2000 kcmil) when subjected for 30 min, at a temperature of 131°C ±1°C, to the load specified in Table 41. Compliance shall be determined in accordance with the test, Deformation, in UL 2556, CSA C22.2 No. 2556, or NMX-J-191-ANCE, except that the test specimens shall be unconditioned.

5.12.2 The thickness of a jacket of thermoplastic material shall not decrease more than 50 percent when subjected to a temperature of 121 ±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-191-ANCE.

5.13 Hot-creep elongation and hot-creep set

5.13.1 Hot-creep elongation and hot-creep set of EP and EPCV insulation shall not exceed 50 percent and 5 percent, respectively, after conditioning at 150 ±2°C (302.0 ±3.6°F) for 15 min in an air oven. Compliance shall be determined in accordance with the test, Hot creep elongation and hot creep set, in UL 2556, CSA C22.2 No. 2556, or NMX-J-432-ANCE.

5.14 Flame and smoke

5.14.1 FT2/FH/Horizontal Flame (XHH, XHHW, XHHW-2, RHH, RHW, RHW-2, SA, SF, and SIS, and Non XL Insulated Types R90, RW75, RW90, RWU75, and RWU90)

5.14.1.1 A finished wire or cable of any construction shall not convey flame along its length or to combustible materials in its vicinity when a specimen is subjected to the test, FT2/FH/Horizontal flame, in UL 2556, CSA C22.2 No. 2556, or NMX-J-192-ANCE. The total length of char on the specimen shall not exceed 100 mm (4 inches), and the dripping particles emitted by the specimen during or after the application of flame shall not ignite the cotton on the floor of the enclosure, on the base of the burner, or on the wedge. Flameless charring of the cotton shall be ignored.

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

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5.14.2 Burning particles (dropping) (R90, RW75, RW90, RWU75, and RWU90)

5.14.2.1 insulation shall be such that when a specimen of single-conductor wire or cable without a covering or jacket is subjected to the test, Burning particles (dropping), in UL 2556, CSA C22.2 No. 2556, or NMX-J-556-ANCE, burning particles from the specimen shall not cause the newsprint to ignite (flame). The specimen shall be tested after allowing at least 3 weeks after manufacture. Earlier testing by the manufacturer is optional.

5.14.3 FT1 (optional)

5.14.3.1 A finished conductor shall be considered to have met the requirements for this marking if:

a) It does not convey flame.

b) It does not continue to burn for more than 60 s after five 15 s applications of flame in the standard vertical flame test.

c) The extended portion of the indicator is not burned more than 25 percent.

Compliance shall be determined in accordance with the test, FT1, in UL 2556, CSA C22.2 No. 2556, or NMX-J-556-ANCE.

5.14.4 FV-2/VW-1 (optional)

5.14.4.1 For a given size of a finished wire or cable to be marked VW-1, that size and 2.08 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 5.14.1, and shall be judged capable of not conveying flame along its length or in its vicinity. Compliance shall be determined in accordance with the test, FV-2/VW-1, in UL 2556, CSA C22.2 No. 2556, or NMX-J-192-ANCE. If any specimen shows more than 25 percent of the indicator flag burned away or charred (soot that can be removed with a cloth or the fingers and brown scorching area shall be ignored) after any of the five applications of flame, the wire or cable shall be judged capable of conveying flame along its length. If any specimen emits flaming or glowing particles or flaming drops at any time that ignite the cotton on the burner, wedge, or floor of the enclosure (flameless charring of the cotton shall be ignored), the wire or cable shall be judged capable of conveying flame to combustible materials in its vicinity. If any specimen continues to flame longer than 60 s after any application of the gas flame, the wire or cable shall be judged capable of conveying flame to combustible materials in its vicinity.

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5.14.5 Vertical-tray (optional)

Finished wires or cables shall not exhibit damage that reaches the upper end of any of two sets of specimens when subjected to the test, Vertical tray flame tests (Method 1-vertical tray), in UL 2556, CSA C22.2 No. 2556, or NMX-J-498-ANCE.

5.14.6 FT4 vertical-tray (optional)

Finished wires or cables shall not exhibit charred material beyond a length exceeding 1.5 m (5 ft) from the lower edge of the burner face when subjected to the test, Vertical tray flame tests (Method 2-FT4), in UL 2556, CSA C22.2 No. 2556, or NMX-J-556-ANCE. Conductors complying with this requirement need not be subjected to the test described in Clause 5.14.5.

5.14.7 ST1 limited smoke (optional)

5.14.7.1 General

When subjected to the test, ST1 limited smoke, in UL 2556, CSA C22.2 No. 2556, or NMX-J-556-ANCE, each finished insulated single conductor shall comply with the test criteria in Clauses 5.14.5 or 5.14.6. Limits are specified for each fire test to make the following tests equally acceptable for the purpose of quantifying the smoke. The cable manufacturer shall specify, for testing each ″ST1″ (limited smoke) cable construction, the vertical flame exposure referenced in either Clause 5.14.5 or 5.14.6.

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

5.14.7.2 Vertical-tray flame exposure

Finished wires or cables shall exhibit the following properties when subjected to the test, Vertical tray flame tests (Method 1 – vertical tray), in UL 2556, CSA C22.2 No. 2556, or NMX-J-556-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. The values obtained from the third set of specimens shall be within the limits in items a), b), and c).

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5.14.7.3 FT4 vertical-tray flame exposure

Finished wires or cables shall exhibit the following properties when sets of specimen lengths are subjected to the test, Vertical tray flame tests (Method 2 – FT4), in UL 2556, CSA C22.2 No. 2556, or NMX-J-556-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 minutes 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. The values obtained from the third set of specimens shall be within the limits in items a), b), and c).

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

5.14.8.1 General

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

5.14.8.2 Smoke emission

The components of cables shall be subjected to 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 min (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. Tests shall be performed on die-cut specimens 2 mm (0.08 inch) in thickness.

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5.14.8.3 Fire propagation/RPI

Finished wires or cables shall not exhibit a length of degradation that exceeds the upper limit of the test chimney (0.80 m over the oven), when subjected to the test, Fire propagation/RPI, in UL 2556, CSA C22.2 No. 2556, or NMX-J-093-ANCE.

5.14.8.4 Halogen acid gas emission

Samples of nonmetallic components of cables shall have a maximum loss of mass in the form of acid gas emission not greater than 20 percent (by weight) of halogen acid gas (except hydrogen fluoride), produced by pyrolysis. Compliance shall be determined in accordance with the test, Halogen acid gas emission, in UL 2556, CSA C22.2 No. 2556, or NMX-J-472-ANCE.

5.15 Weather (sunlight) resistance (optional)

5.15.1 To be marked SR, unfilled XL material shall contain a minimum of 2.0 percent carbon black content, determined in accordance with the test, Carbon black content, in UL 2556, CSA C22.2 No. 2556, or NMX-E-034–SCFI, and having a particle size of 35 nm or less.

Note: *Particle size values may be obtained from the compound supplier.*

5.15.2 To be marked SR, materials other than unfilled XL shall retain 80 percent of their initial tensile strength and elongation values after being subjected to 720 h xenon or carbon arc exposure in accordance with the test, Physical properties (ultimate elongation and tensile strength) – Weather (sunlight) resistance, in UL 2556, CSA C22.2 No. 2556, or NMX-J-553-ANCE.

5.16 Oil resistance (optional)

5.16.1 Oil resistance at 60°C

To be marked PR I, the retention of tensile strength and elongation of the insulation, or jacket where used, shall not be less than 50 percent of the unconditioned value after immersion of the finished wire in IRM 902 oil for 96 h at 100°C as described in the test, Physical properties (ultimate elongation and tensile strength) – Oil resistance, in UL 2556, CSA C22.2 No. 2556, or NMX-J-194-ANCE.

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5.16.2 Oil resistance at 75°C

To be marked PR II, the retention of tensile strength and elongation of the insulation, or jacket where used, shall not be less than 65 percent of the unconditioned value after immersion of the finished wire in IRM 902 oil for 60 d at 75°C, as described in the test, Physical properties (ultimate elongation and tensile strength) – Oil resistance, in UL 2556, CSA C22.2 No. 2556, or NMX-J-194-ANCE.

5.17 Gasoline and oil resistance (optional)

5.17.1 To be marked GR I or GR II, insulation, or jackets where used, shall comply with the requirements of Clause 5.16.1 or 5.16.2, respectively, and shall retain not less than 65 percent of their original tensile strength and elongation after 30 d immersion in water saturated with equal volumes of iso-octane and toluene (ASTM Reference Fuel C) maintained at 23 ±1°C, in accordance with the test, Physical properties (ultimate elongation and tensile strength) – Gasoline resistance, in UL 2556, CSA C22.2 No. 2556, or NMX-J-556-ANCE.

5.18 Crushing resistance

5.18.1 An average of not less than 5338 N (1200 lbf) shall be necessary to crush finished solid 2.08 mm^2 (14 AWG) Type XHH, XHHW, and XHHW-2 wires, or not less than 8007 N (1800 lbf) to crush finished stranded 33.6 mm^2 (2 AWG) Type XHH, XHHW, and XHHW-2 wires, to the point that the conductor contacts the earth-grounded metal of the testing machine used in the test, Crush resistance, Method 1 (two steel plates), in UL 2556, CSA C22.2 No. 2556, or NMX-J-556-ANCE.

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

5.19 Dielectric breakdown after glancing impact

5.19.1 The average breakdown potential for six specimens of finished solid 2.08 mm^2 (14 AWG) Type XHH, XHHW, and XHHW-2 wires that have separately been subjected to a glancing impact of 2 J (18 in-lbf) shall not be less than 20 percent of the average breakdown potential of six adjacent specimens of the same wire not subjected to the impact. Compliance shall be determined in accordance with the test, Dielectric breakdown after glancing impact, in UL 2556, CSA C22.2 No. 2556, or NMX-J-556-ANCE.

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