UL 83

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Thermoplastic-Insulated Wires and Cables

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Underwriters Laboratories Inc. (UL)
333 Pfingsten Road
Northbrook, IL 60062-2096

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

Thirteenth Edition, Dated November 15, 2003

Revisions: This Standard contains revisions through and including April 24, 2006

Summary of Topics:

The effective date for Table 34 has been changed from April 7, 2006 to October 17, 2007. ANCE and CSA will issue the corresponding affected pages for their Standards during their next amendment cycles.

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

Future Effective Date	References
October 17, 2007	Table 34

The revisions dated April 24, 2006 include a reprinted title page (page1) for this Standard.

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that have been revised and that have a future effective date are located after the Standard, and are preceded by a ″SUPERSEDED REQUIREMENTS″ notice.

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

Page	Date
1-2	April 24, 2006
3-5	November 15, 2003
6-7	April 24, 2006
8-138	November 15, 2003
A1-A4	November 15, 2003
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G1-G2	November 15, 2003
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I1-I2	November 15, 2003
J1-J2	November 15, 2003
K1	January 28, 2005
K2	November 15, 2003

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Preface

This is the harmonized ANCE, CSA, and UL Standard for Thermoplastic-Insulated Wires and Cables. It is the third edition of NMX-J-010-ANCE, the eighth edition of CSA-C22.2 No. 75, and the thirteenth edition of UL 83. This edition of CSA-C22.2 No. 75 supersedes the previous edition published in 1983. This edition of UL 83 supersedes the previous edition published in 1998.

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 was reviewed by the CSA Subcommittee on C22.2 No. 75, under the jurisdiction of the CSA Technical Committee on Wiring Products and the CSA Strategic Steering Committee on Requirements for Electrical Safety, and has been formally approved by the CSA Technical Committee. This standard was reviewed and approved by the Committee de Normalizacion of ANCE (CONANCE). This standard was reviewed by UL's Standards Technical Panel (STP) for Power Cables, STP 83.

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

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

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

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

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

Level of Harmonization

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

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

Reasons for Differences to 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.

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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 effective date

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

UL effective date

As of April 24, 2006, 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 October 17, 2007:

Table 34.

Between April 24, 2006 and October 17, 2007, 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 for Table 34 are contained in the 12th Edition of UL 83.

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

The most recent designation of ANSI/UL 83 as an American National Standard (ANSI) occurred on September 10, 2003.

This ANSI/UL Standard for Safety, which consists of the Thirteenth Edition with revisions through April 24, 2006, is under continuous maintenance, whereby each revision is ANSI approved upon publication. Comments or proposals for revisions on any part of the Standard may be submitted to UL at any time. Proposals should be submitted via a Proposal Request in UL's On-Line Collaborative Standards Development System (CSDS) at http://csds.ul.com.

The Department of Defense (DoD) has adopted UL 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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Foreword (ANCE)

The present Mexican Standard was developed by the Low Voltage Wires and Cables Subcommittee from the Comite de Normalizacion de la Asociacion de Normalizacion y Certificacion, A.C., CONANCE, with the collaboration of wire and cable manufacturers and users.

ANCE is an Organization for Standardization (ONN) registered by the DGN (Dirección General de Normas) in the electrical sector and household appliances. ANCE develops Mexican Standards (NMX) and collaborates in the development of Mexican Official Standards (NOM); these are voluntary and normative standards, respectively.

Conformity assessment in accordance with ANCE Mexican Standards is the responsibility of ANCE Certification Products Division.

ANCE's Product Certification Division is accredited by the EMA (Entidad Mexicana de Acreditación) to certify a variety of products. Certification is carried out following the relevant procedures established and developed by the Technical Committee on Certification in connection with the test reports produced in test labs accredited by the EMA.

The conformity assessment activities developed by ANCE cover quality systems, test labs, and product verification.

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CSA Certification for a number of products is provided in the interest of maintaining agreed-upon standards of quality, performance, interchangeability and/or safety, as appropriate. Where applicable, certification may form the basis for acceptance by inspection authorities responsible for enforcement of regulations. Where feasible, programs will be developed for additional products for which certification is desired by producers, consumers, or other interests. In performing its functions in accordance with its objectives, CSA does not assume or undertake to discharge any responsibility of the manufacturer or any other party. The opinions and findings of the Association represent its professional judgement given with due consideration to the necessary limitations of practical operation and state of the art at the time the Standard is processed.

Products in substantial accord with this Standard but which exhibit a minor difference or a new feature may be deemed to meet the Standard providing the feature or difference is found acceptable utilizing appropriate CSA International Operating Procedures. Products that comply with this Standard shall not be certified if they are found to have additional features which are inconsistent with the intent of this Standard. Products shall not be certifiable if they are discovered to contravene applicable laws or regulations.

Testing techniques, test procedures, and instrumentation frequently must be prescribed by CSA International in addition to the technical requirements contained in Standards of CSA. In addition to markings specified in the Standard, CSA International may require special cautions, markings, and instructions that are not specified by the Standard.

Some tests required by CSA Standards may be inherently hazardous. The Association neither assumes nor accepts any responsibility for any injury or damage that may occur during or as the result of tests, wherever performed, whether performed in whole or in part by the manufacturer or the Association, and whether or not any equipment, facility, or personnel for or in connection with the test is furnished by the manufacturer or the Association.

Manufacturers should note that, in the event of the failure of CSA International to resolve an issue arising from the interpretation of requirements, there is an appeal procedure: the complainant should submit the matter, in writing, to the Secretary of the Canadian Standards Association.

If this Standard is to be used in obtaining CSA Certification please remember, when making application for certification, to request all current Amendments, Bulletins, Notices, and Technical Information Letters that may be applicable and for which there may be a nominal charge. For such information or for further information concerning CSA Certification, please address your inquiry to Applications and Customer Service, CSA International, 178 Rexdale Boulevard, Toronto, Ontario, Canada M9W 1R3.

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Foreword (UL)

A. This Standard contains basic requirements for products covered by Underwriters Laboratories Inc. (UL) under its Follow-Up Service for this category within the limitations given below and in the Scope section of this Standard. These requirements are based upon sound engineering principles, research, records of tests and field experience, and an appreciation of the problems of manufacture, installation, and use derived from consultation with and information obtained from manufacturers, users, inspection authorities, and others having specialized experience. They are subject to revision as further experience and investigation may show is necessary or desirable.

B. The observance of the requirements of this Standard by a manufacturer is one of the conditions of the continued coverage of the manufacturer's product.

C. A product which complies with the text of this Standard will not necessarily be judged to comply with the Standard if, when examined and tested, it is found to have other features which impair the level of safety contemplated by these requirements.

D. A product employing materials or having forms of construction which conflict with specific requirements of the Standard cannot be judged to comply with the Standard. A product employing materials or having forms of construction not addressed by this Standard may be examined and tested according to the intent of the requirements and, if found to meet the intent of this Standard, may be judged to comply with the Standard.

E. UL, in performing its functions in accordance with its objectives, does not assume or undertake to discharge any responsibility of the manufacturer or any other party. The opinions and findings of UL represent its professional judgment given with due consideration to the necessary limitations of practical operation and state of the art at the time the Standard is processed. UL shall not be responsible to anyone for the use of or reliance upon this Standard by anyone. UL shall not incur any obligation or liability for damages, including consequential damages, arising out of or in connection with the use, interpretation of, or reliance upon this Standard.

F. Many tests required by the Standards of UL are inherently hazardous and adequate safeguards for personnel and property shall be employed in conducting such tests.

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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 NFPA Standard 70, *National Electrical Code (NEC)*.

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 may have applications not described in the electrical codes listed in Clause 1.1.

2 Definitions

2.1 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.

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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

This Standard refers to the following publications; where such reference is made to ANCE, CSA, or UL Standards, it shall be considered to refer 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-040-ANCE,
Determination of Moisture Absorption in Insulations and Jackets of Electrical Conductors – Test Method;

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

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

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

NMX-J-178-ANCE,
Ultimate Strength and Elongation of Insulation, Semiconductive Shielding and Jackets of Electrical Conductors – Test Method;

NMX-J-186-ANCE,
Accelerated Aging in Forced-Convection Ovens of Semiconductive Shielding, Insulations and Jackets of Electrical Conductors - Test Method;

NMX-J-190-ANCE,
Thermal 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;

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NMX-J-193-ANCE,
Cold Bend of Thermoplastic Insulation and Protective Jackets, Used on Insulated Wire and Cable – Test Method;

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

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

NMX-J-312-ANCE,
Rupture Strength and Elongation by Strain of Wires for Electrical Conductors – Test Method;

NMX-J-417-ANCE,
Wires and Cables – Convection Laboratory Ovens for Evaluation of Electrical Insulation – Specifications and Test Methods;

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

CSA Standards

C22.1-02,
Canadian Electrical Code, Part I;

C22.2 No. 0.3-96 (R2000),
Test Methods for Electrical Wires and Cables;

C22.2 No. 42-99,
General Use Receptacles, Attachment Plugs, and Similar Wiring Devices;

CAN/CSA-C22.2 No. 48-M90 (R2000),
Nonmetallic Sheathed Cables;

CAN/CSA-C22.2 No. 131-M89 (R1999),
Type TECK 90 Cable;

C22.2 No. 230-M1988 (R1999),
Tray Cables;

C22.2 No. 239-97,
Control and Instrumentation Cables.

UL Standards

UL 498,
Attachment Plugs and Receptacles;

UL 1567,
Receptacles and Switches Intended for Use with Aluminum Conductors;

UL 1581,
Reference Standard for Electrical Wires, Cables, and Flexible Cords;

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

ASTM* Standards

A 29/A 29M-99e1,
Standard Specification for Steel Bars, Carbon and Alloy, Hot-Wrought and Cold Finished, General Requirements for;

B 3-95,
Standard Specification for Soft or Annealed Copper Wire;

B 33-00,
Standard Specification for Tinned Soft or Annealed Copper Wire for Electrical Purposes;

B 189-95,
Standard Specification for Lead-Coated and Lead-Alloy-Coated Soft Copper Wire for Electrical Purposes.

IEC† Standards

60228 (1978-01),
Conductors of insulated cables;

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

IEEE‡ Standards

1202-1991 (R1996),
IEEE Standard for Flame Testing of Cables for Use in Cable Tray in Industrial and Commercial Occupancies.

NFPA§ Publication

NFPA 70-2002,
National Electrical Code.

**American Society for Testing and Materials.*

†International Electrotechnical Commission.

‡Institute of Electrical and Electronics Engineers.

§National Fire Protection Association.

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3.3 Summary of requirements

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

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, the following applies: all 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, the following applies: 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 following applies: 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.

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4.1.4.2 **Bare copper conductors**

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

4.1.4.3 **Coated copper conductors**

Each wire in a tin-coated conductor shall comply with the requirements of ASTM B 33 or NMX-J-008-ANCE. Each wire in a lead-alloy-coated copper conductor shall comply with the requirements of ASTM B 189. Overcoating of 2.08 mm^2 (14 AWG), 3.31 mm^2 (12 AWG), and 5.26 mm^2 (10 AWG) stranded copper conductor with a layer of tin or lead alloy shall be optional.

In Mexico, the use of ASTM B 189 is recommended for lead-alloy-coated copper conductors.

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

4.1.5.2.2 **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 each compacted layer including the outermost layer shall be essentially smooth. A compact-stranded conductor is rolled, drawn, or otherwise compressively formed to change the originally round or partially pre-shaped strands to various close-fitting shapes that achieve almost complete filling of the spaces originally present between the strands. The lay length of every layer shall be not less than 8 times nor more than 16 times the outside diameter of the completed conductor, except that for sizes 33.6 mm^2 (2 AWG) and smaller, the maximum lay length shall be 17.5 times the outside diameter. The direction of lay of the outermost layer shall be left-hand, and the direction of lay for other layers shall be left-hand unidirectional or unilay or reversed.

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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 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 4, 5, 6, 7, 8, and 9. The minimum diameter for stranded conductors shall not be less than 98 percent of the nominal. The maximum diameter shall be not more than 101 percent of the nominal. Verification of the diameter shall be determined in accordance with UL 1581, Section 220; CSA C22.2 No. 0.3, Clause 4.1.1; or NMX-J-066-ANCE.

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

4.1.6.2 In the United States, the following applies: 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**

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.

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.

4.1.8 **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.

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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 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).

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4.2.4 **Thickness and centering**

The average and minimum thickness of the insulation shall be as shown in Table 10 when measured in accordance with UL 1581, Section 240; CSA C22.2 No. 0.3, Clause 4.2.1; or NMX-J-177-ANCE.

The insulation shall have a circular cross-section and shall be applied concentrically about the conductor (so that the conductor is well centered in the insulation), and shall fit tightly thereto.

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 shall be determined using the apparatus and method in CSA C22.2 No. 0.3, Clause 4.3.1; UL 1581, Section 400; or NMX-J-178-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 for use in the United States and Mexico shall be evaluated in accordance with Clauses 4.2.5.3.2 – 4.2.5.3.4.

Requirements for evaluation of new insulation materials for use in Canada are under development.

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

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

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

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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 1581, Section 240; CSA C22.2 No. 0.3, Clause 4.2.1; 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, a lead-base alloy, or other metal shall be optional. A bare, coated copper conductor shall not be covered. The completed assembly shall meet the following requirements:

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

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

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

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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

The direct-current resistance of the conductor shall not be greater than shown in Tables 14 – 22 inclusive, except that a tolerance of plus 2 percent shall be optional in the case of a conductor in a twisted conductor assembly. Compliance shall be determined in accordance with Clause 8.2.

5.3 Tests on aluminum conductors

5.3.1 Physical properties

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 – 59 MPa (14,250 – 23,100 lbf/in^2). The tensile strength of all other conductors shall be 103 – 152 MPa (15,000 – 22,000 lbf/in^2) (see Clause 8.3.1).

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

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

5.4 Short-term insulation resistance at elevated temperature in water

The resistance values shall not be less than those shown in Table 23 when tested in accordance with Clause 8.4, after immersion in water for at least 6 h at the same temperature as the temperature rating of the insulation.

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5.5 Long-term insulation resistance in water

5.5.1 Minimum acceptable value

5.5.1.1 The insulation, without covering, 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 23 at any time during immersion, in accordance with 8.5. 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 23. An a-c voltage of 600 V rms shall be applied to the insulation at all times other than while reading the insulation resistance.

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.

5.5.1.3 The values in Table 23 shall apply only to conductors with the insulation thicknesses indicated in Table 10. For other thicknesses of the same materials, the insulation resistance values shall be calculated by means of whichever of the formulas in Annex H and J are applicable.

5.5.2 Maximum acceptable rate of decrease

During the extended immersion, the maximum decrease in insulation resistance per week, as determined from a curve (drawn to represent the average of actual values), for every continuous period of 3 weeks during the later half of the specified immersion time shall 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 23.

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.

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5.6.2 **Minimum acceptable value**

The 90°C rated insulation of the individual conductors without covering shall have insulation resistance in air at 97 ± 1°C that is not less than indicated in Table 24 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 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 24. A 600 V rms voltage shall be applied at all times other than while reading the insulation resistance.

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.

5.6.3 **Maximum acceptable rate of decrease**

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

5.7 Capacitance and relative permittivity of wet rated wires (types including ″W″)

Specimens of finished wire immersed in water at rated temperature, 60°C, 75°C, and 90°C, shall comply with each of the following, when tested in accordance with Clause 8.7:

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 be 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.

5.8 Flexibility at room temperature after aging

When tested in accordance with Clause 8.8, the insulation and nylon covering (if present) shall not show any cracks, either on the surface or internally, when wound around a mandrel at room temperature.

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5.9 Heat shock

When tested in accordance with Clause 8.9, 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 25 after conditioning in an air oven.

5.10 Cold bend and cold impact

5.10.1 Cold bend

After conditioning at a temperature of −25 ± 1°C for 4 h, the insulation and nylon covering (if present) shall not show any cracks when tested in accordance with Clause 8.10.1. The mandrel diameter shall be as specified in Column B of Table 25. Conditioning at a temperature of −40 ± 1°C shall be optional.

5.10.2 Cold impact (optional)

The insulation and jacket, where present, on at least 8 out of 10 complete cable specimens shall not crack or rupture when tested at −40°C in accordance with Clause 8.10.2.

5.11 Deformation

The thickness of 60°C, 75°C, and 90°C rated insulations shall not decrease by more than 50, 30, and 30 perecent, respectively, when subjected to the load specified in Table 26 and tested in accordance with Clause 8.11.

5.12 Flame and smoke

5.12.1 Vertical flame

When tested in accordance with Clause 8.12.1, a specimen of a wire or cable shall not flame longer than 60 s following five 15 s applications of the test flame, the period between applications being 15 s. If any specimen shows more than 25 percent of the indicator flag burned away or charred (soot that can be removed with a cloth or the fingers and brown scorching area shall be ignored) after any of the five applications of flame, the wire or cable shall be judged capable of conveying flame along its length. If any specimen emits flaming or glowing particles or flaming drops at any time that ignite the cotton on the burner, wedge, or floor of the enclosure (flameless charring of the cotton shall be ignored), the wire or cable shall be judged capable of conveying flame to combustible materials in its vicinity.

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5.12.2 **FT1**

In Canada, when tested in accordance with Clause 8.12.2, a finished conductor shall not convey flame or continue to burn for more than 60 s after five 15 s applications of the test flame. If more than 25 percent of the extended portion of the indicator is burned, the conductor shall be considered to have conveyed flame.

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

5.12.3 **VW-1 (optional)**

5.12.3.1 **Vertical specimen**

For a given size of a finished wire or cable to be marked VW-1, that size and 2.08 mm^2 (14 AWG) copper or 3.31 mm^2 (12 AWG) aluminum shall comply with the requirements of the horizontal flame test described in Clause 5.12.3.2, and shall be judged not capable of conveying flame along its length or in its vicinity when tested in accordance with Clause 8.12.3.1. If any specimen shows more than 25 percent of the indicator flag burned away or charred (soot that can be removed with a cloth or the fingers and brown scorching area shall be ignored) after any of the five applications of flame, the wire or cable shall be judged capable of conveying flame along its length. If any specimen emits flaming or glowing particles or flaming drops at any time that ignite the cotton on the burner, wedge, or floor of the enclosure (flameless charring of the cotton shall be ignored), the wire or cable shall be judged capable of conveying flame to combustible materials in its vicinity. If any specimen continues to flame longer than 60 s after any application of the gas flame, the wire or cable shall be judged capable of conveying flame to combustible materials in its vicinity.

5.12.3.2 **Horizontal specimen**

Each size of a given construction of a finished wire that is marked VW-1, in addition to complying with Clause 5.12.3.1, shall be capable of not conveying flame along its length or in its vicinity when a specimen is subjected to the flame test described in Clause 8.12.3.2. The total length of the char in the specimen shall not exceed 100 mm (4 inches), and the dripping particles emitted by the specimen during or after the application of the flame shall not ignite the cotton on the floor of the enclosure, on the base of the burner, or on the wedge.

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5.12.4 **Vertical tray (optional)**

Finished single conductors shall not exhibit damage that reaches the upper end of any of two sets of specimen, when subjected for the specified period to the flame test in Clause 8.12.4.

5.12.5 **FT4 vertical tray (optional)**

Finished single conductors shall not exhibit charred material beyond a length exceeding 1.5 m from the flame impingement, when tested for the specified period in accordance with Clause 8.12.5.

5.12.6 **ST1 limited-smoke (optional)**

5.12.6.1 **General**

When tested in accordance with Clause 8.12.6, each finished insulated single conductor shall meet the test criteria in Clauses 5.12.4 or 5.12.5. Limits are specified for each fire test to make the following tests equally acceptable for the purpose of quantifying the smoke. The cable manufacturer shall specify, for testing each ST1 (limited-smoke) cable construction, either the vertical flame exposure described in Clause 8.12.6.1 or the vertical flame exposure described in Clause 8.12.6.2.

Typically, for a range of sizes to be marked ST1, the smallest conductor in the range, the smallest conductor employing the same insulation thickness as the largest conductor in the range, and an intermediate conductor shall be selected for testing. Testing of individual conductor sizes shall be optional.

5.12.6.2 **Vertical-tray flame exposure**

Finished insulated single conductors shall exhibit the following properties when tested in accordance with Clause 8.12.6.1:

a) The cable damage height for each set of specimens shall be less than 2.44 m (8 ft) when measured from the bottom of the cable tray.

b) The total smoke released in 20 min for each set of specimens shall not exceed 95 m^2.

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

d) The values of cable damage height, total smoke released, and peak smoke release rate obtained from one set of specimens shall not differ by more than 15 percent from the values obtained from the second set of specimens. If any of the values differ by more than 15 percent between the two sets of specimens, a third set of specimens shall be tested as described in Clause 8.12.6.1. The values obtained from the third set of specimens shall be within the limits specified in a), b), and c).

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5.12.6.3 **FT4 vertical-tray flame exposure**

Finished insulated single conductors shall exhibit the following properties when sets of specimen lengths are tested in accordance with Clause 8.12.6.2:

a) The cable damage height for each set of specimens shall be less than 1.50 m when measured from the bottom of the cable tray.

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

c) The peak smoke release rate for each set of specimens shall not exceed 0.40 m^2/s.

d) The values of cable damage height, total smoke released, and peak smoke release rate obtained from one set of specimens shall not differ by more than 15 percent from the values obtained from the second set of specimens. If any of the values differ by more than 15 percent between the two sets of specimens, a third set of specimens shall be tested as described in Clause 8.12.6.2. The values obtained from the third set of specimens shall be within the limits specified in a), b), and c).

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

5.12.7.1 **General**

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

5.12.7.2 **Smoke emission**

The components of cables shall be tested in accordance with the method described in Clause 8.12.7.1 to obtain the smoke-emission performance. For cables up to 10 mm (0.40 inch) external diameter, the maximum specific optical density (DM) shall not be more than 500, and the value of smoke obscuration in the first four minutes (VOF_4) shall not be more than 400. For cables with an external diameter larger than 10 mm (0.40 inch), the maximum specific optical density (DM) shall not be more than 500, and the value of smoke obscuration in the first four minutes (VOF_4) shall not be more than 800. Tests shall be performed on die-cut specimens 2 mm (0.08 inch) in thickness.

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5.12.7.3 **Fire propagation (RPI)**

Finished cable samples shall be subjected to the test method described in Clause 8.12.7.2 for testing fire-propagation resistance of single or multiple conductors. The cables shall be considered in compliance if the damage produced by the test does not exceed the upper limit of the chimney of the testing equipment (0.80 m over the oven).

5.12.7.4 **Halogen acid gas emission**

Samples of nonmetallic materials of cables when tested in accordance with the method described in Clause 8.12.7.3 shall have a maximum loss of mass, in the form of acid-gas emission produced by pyrolysis, not greater than 20 percent. Acid gas shall be expressed as percentage of the hydrogen chloride evolved during the test.

5.13 Weather resistance (optional)

To be marked SR, the insulation of a single wet-rated conductor having no outer jacket or covering, the outer jacket of a multiconductor cable, and the insulation and nylon covering of nylon-covered conductors of a completed single wire or a multiconductor cable shall retain at least 80 percent of their unconditioned tensile strength and elongation values, after conditioning in xenon or carbon arc in accordance with Clause 8.13.

In the United States and Mexico, the conditioning shall be 720 h.

In Canada, the conditioning shall be 1000 h.

5.14 Oil resistance (optional)

5.14.1 **Oil resistance at 60°C**

To be marked PR I, the retention of tensile strength and elongation of the insulation shall not be less than 50 percent of the unconditioned value after immersion of the finished wire in IRM 902 oil for 96 h at 100°C, as described in Clause 8.14.1.

5.14.2 **Oil resistance at 75°C**

To be marked PR II, the retention of tensile strength and elongation of the insulation shall be not less than 65 percent of the unconditioned value after immersion of the finished wire in IRM 902 oil for 60 d at 75°C, as described in Clause 8.14.2.

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5.15 Gasoline and oil resistance (optional)

To be marked GR I or GR II, the retention of tensile strength and elongation of insulated conductors found to be in compliance with the requirements of Clause 5.14.1 or 5.14.2, respectively, shall not be less than 65 percent after 30 d immersion in water saturated with equal volumes of iso-octane and toluene (ASTM Reference Fuel C) maintained at 23 ± 1°C, in accordance with Clause 8.15.

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

The insulation and nylon jacket (if present) on solid 2.08 mm^2 (14 AWG) conductors shall not wear through to expose the conductor on any of 6 specimens subjected to 800 cycles of the abrasion procedure in Clause 8.16.

5.17 Crushing resistance (nylon-covered types or insulations other than PVC)

An average of not less than 1000 N (225 lbf) shall be necessary to crush solid 2.08 mm^2 (14 AWG) insulated conductors until contact is established between the earth-grounded flat steel plate or steel rod when 10 specimens of the finished wire are subjected to the crushing procedure described in Clause 8.17.

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

A free-falling steel weight that impacts with an energy of 2.7 J (2 ft-lbs) upon the insulation and nylon jacket (if present) of a solid 2.08 mm^2 (14 AWG) specimen shall not expose the conductor to view or cause the lamp of the test apparatus to light, when tested in accordance with Clause 8.18.

5.19 Durability of ink printing

The printing on the finished wire shall remain legible after being subjected to the test specified in Clause 8.19.

5.20 Color coating

If color coding of the thermoplastic-insulated wire is accomplished by means of a surface coating, the coating shall comply with each of the following requirements:

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

b) The coating shall not flake off of the surface of the insulation when samples of the wire are flexed at room temperature in the manner described in Clause 8.20 both before and after the air-oven aging applicable to the insulation.

c) The surface coating shall not migrate when tested in accordance with Clause 8.20.

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5.21 Long-term aging of insulation

The absolute elongation of insulation material referenced in Clause 4.2.5.3 shall be not less than 50 percent after being subjected to long-term aging in an air oven in accordance with Clause 8.21.

5.22 A-C spark test

Substitution of the requirements of this clause for those for dielectric voltage-withstand, Clause 5.23, and for insulation resistance, Clause 5.24, on every finished production length shall be optional. The test shall be performed in accordance with Clause 8.22. The test potential shall be as follows:

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

5.23 Dielectric voltage-withstand in water

The insulation of single conductors shall be capable of withstanding for 60 s without breakdown the application of the essentially rms test potential shown below and under the following conditions. The wire shall be immersed in water at room temperature for not less than 6 h, following which it shall be subjected to the voltage test while still immersed. The dielectric voltage-withstand test shall be conducted before the insulation resistance test. The test shall be performed in accordance with Clause 8.23. Unless the insulated conductors are subjected to the requirements specified in Clause 5.22, each length of finished cable shall be subjected to this test.

Conductor size, mm^2 (AWG or kcmil)	RMS dielectric test potential (kV)
2.08 – 33.6 (14 – 2)	2.0
42.4 – 107 (1 – 4/0)	2.5
127 – 253 (250 – 500)	3.0
279 – 507 (550 – 1000)	3.5
557 – 1010 (1100 – 2000)	4.0

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5.24 Insulation resistance in water at 15°C

The insulation of single conductors shall have an insulation resistance not less than the values specified in Table 27 when tested at the prevailing water temperature and corrected to 15°C. The apparatus and test method shall be in accordance with Clause 8.24. When the water temperature is other than 15°C, the correction factor determined by the method described in Clause 8.24 shall be used. Unless the spark test specified in Clause 5.22 is carried out, each length of finished cable shall be subjected to this test.

5.25 Electrical continuity

Each conductor shall be continuous when tested in accordance with Clause 8.25.

6 Marking

6.1 Marking on product

6.1.1 General

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

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

For products intended for specific national applications, the use of alternative markings to those required in this section, as provided in Annex K, shall be optional.

Clauses 6.1.2 – 6.1.7 describe required markings. Clauses 6.1.8 – 6.1.12 describe additional markings.

Marking on a product shall be optional when the product is intended for further processing.

6.1.2 Manufacturer's identification

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

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6.1.3 **Type designation**

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

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

6.1.4 **Conductor size**

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

a) mm^2 (AWG);

b) AWG (mm^2);

c) mm^2 (kcmil);

d) kcmil (mm^2);

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

6.1.5 **Aluminum conductors**

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

6.1.6 **Compact copper conductors**

In the United States, the following applies: compact-stranded copper conductors shall be marked ″Compact Copper″, or ″Compact Cu″, or ″Cmpct Cu″ after the conductor size.

In Canada and Mexico, this requirement does not apply.

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6.1.7 **Voltage marking**

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

6.1.8 **Low-temperature marking (optional)**

Wires meeting the requirements for −40°C cold bend and cold impact specified in Clause 5.10 shall be allowed to be marked ″(−40°)″.

6.1.9 **Flame test marking (optional)**

6.1.9.1 **General**

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

a) ″FT1″: Clause 5.12.2;

b) ″VW-1″: Clause 5.12.3;

c) ″CT″: Clause 5.12.4 or 5.12.5 (see 6.1.9.2 for applicability);

d) ″FT4″: Clause 5.12.5 or 5.12.6 using flame exposure in accordance with Clause 8.12.6.2;

e) ″ST1″: Clause 5.12.6;

f) ″LS″: Clause 5.12.7;

g) ″RPI″: Clause 5.12.7.3.

6.1.9.2 **Cable-tray use marking (optional)**

6.1.9.2.1 Insulated conductors meeting the requirements of either Clause 5.12.4 or Clause 5.12.5 shall be allowed to be marked ″CT″.

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

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

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

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6.1.10 **Weather resistance (optional)**

Wires or cables meeting the requirements of Clause 5.13 shall be allowed to be marked ″SR″.

6.1.11 **Oil resistance (optional)**

Wires or cables meeting the requirements of Clause 5.14.1 shall be allowed to be marked ″PR I″. Wires or cables meeting the requirements of Clause 5.14.2 shall be allowed to be marked ″PR II″.

6.1.12 **Gasoline and oil resistance (optional)**

Wires or cables meeting the requirements of Clauses 5.14.1 and 5.15 shall be allowed to be marked ″GR I″. Wires or cables meeting the requirements of Clauses 5.14.2 and 5.15 shall be allowed to be marked ″GR II″.

6.2 Marking on package

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

a) Manufacturer's identification;

b) Type designation;

c) Conductor size, in accordance with Clause 6.1.4;

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

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

f) In the United States, if stranded copper conductors are compacted, the words ″Compact Copper″ or ″Compact Cu″ or ″Cmpct Cu″ shall be included adjacent to the conductor size (item c). The following statement shall also appear on the package: ″Terminate with connectors identified for use with compact-stranded copper conductors″;

In Canada and Mexico, this requirement does not apply.

g) voltage rating;

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

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6.3 Month and year of manufacture

The month and year of manufacture shall be included among the package markings described in Clause 6.2 or shall be included among the product markings described in Clause 6.1. The marking shall be legible on or through the outer surface of the wire or cable. The use of a code shall be allowed.

7 Deep-well submersible water pump cable

7.1 General

The construction of deep-well submersible water pump cable shall consist of assemblies comprising two or more insulated circuit conductors having a wet rating, and an optional insulated equipment grounding conductor, with or without an overall jacket. These cables shall be of the twisted or parallel configuration with the option of having a low temperature rating of −40°C.

7.2 Construction

7.2.1 Conductors

Circuit conductors shall consist of solid or stranded 2.08 – 33.6 mm^2 (14 – 2 AWG) copper, solid or stranded 3.31 – 33.6 mm^2 (12 – 2 AWG) aluminum ACM, or stranded 42.4 – 253 mm^2 (1 AWG – 500 kcmil) copper or aluminum ACM. The optional insulated equipment-grounding conductor shall be of the same construction as the circuit conductor, and of a size that is not smaller than indicated in Table 28, except that a copper equipment-grounding conductor shall be allowed with aluminum circuit conductors, as described in Table 28. An aluminum equipment-grounding conductor shall be allowed with copper circuit conductors, as described in Table 29. All of the conductors shall comply with Clause 4.1.

7.2.2 Insulation

Insulated conductors of the types listed in Groups I, II, and III of Table 30, assemblies a), b), and d) of Clause 7.2.3, shall comply with the requirements of Clauses 1 – 6 of this Standard. Insulated conductors of the types listed in Groups I and III, assembly c), shall have an integral insulation-jacket consisting of the sum of the thickness of insulation of Table 10 corresponding to the types listed, plus the thickness of integral jacket from Table 31.

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

Polyethylene-insulated conductors of Group IV, assembly d) of Clause 7.2.3 shall be insulated with unfilled polyethylene and shall comply with Tables 32 and 33 and the applicable test methods of this Standard.

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7.2.3 **Assembly**

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

a) CABLED WITH OVERALL JACKET: this cable assembly has two or more insulated circuit conductors from Group I, II, III, or IV of Table 30 and shall be cabled together with an optional insulated equipment-grounding conductor in either a right- or left-hand lay of unspecified length, with an overall jacket. The jacket shall comply with the thickness requirements of Table 34 and the physical properties specified in Table 35.

b) CABLED WITHOUT OVERALL JACKET: this cable assembly has from two to six insulated circuit conductors from Group I of Table 30 with an individual jacket in accordance with Table 31, or from Group III of Table 30, and shall be cabled together helically with an optional insulated equipment-grounding conductor in either a right- or left-hand lay of unspecified length, without an overall jacket.

c) PARALLEL WITH INTEGRAL WEB WITHOUT OVERALL JACKET: this cable assembly has two, three, or four circuit conductors from Group I of Table 30 with an integral jacket from Table 31, or from Group III of Table 30, together with any optional equipment- grounding conductor laid parallel on the same axis. The conductors are joined to one another with an interconnecting web. The conductor insulation, or integral insulation, and jacket shall be extruded simultaneously with the interconnecting web and shall be of the same compound. The minimum thickness of insulation at any point on any conductor, after separation, shall not be less than required for the specified wire type.

d) PARALLEL WITH OVERALL JACKET WITH INTEGRAL FILLERS OR WEBS: this cable assembly has two, three, or four insulated circuit conductors from Group I, II, III, or IV of Table 30 laid parallel on the same axis, together with an optional insulated equipment-grounding conductor and an overall jacket that complies with the thickness requirements of Table 34, and the requirements for physical properties specified in Table 35.

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

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7.2.4 **Polarity identification of circuit conductors**

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

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

7.3 Marking

7.3.1 **Marking on product**

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

a) The manufacturer's identification;

b) The number of circuit conductors (in the case of jacketed constructions);

c) The conductor size in accordance with Clause 6.1.4;

d) The word ″AL″ or ″ALUM″, if aluminum conductors are used. The additional marking ″ACM″ shall be optional;

e) The designation ″SUBMERSIBLE PUMP CABLE″;

f) The nominal voltage rating, in accordance with Clause 6.1.7;

g) The low-temperature rating, marked in accordance with Clause 6.1.8, for cables complying with Clause 7.4.4;

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

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

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

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7.3.2 **Marking on package**

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

a) Manufacturer's name;

b) Month and year of manufacture;

c) Product designation ″SUBMERSIBLE PUMP CABLE″;

d) Conductor size in accordance with Clause 6.1.4;

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

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

g) Low-temperature rating marking, in accordance with Clause 6.1.8, for cables in compliance with Clause 7.4.4;

h) In the United States and Canada, the notation ″For Wiring Only Between Equipment Located at Water Well Heads and Motors of Installed Deep-Well Submersible Water Pumps″.

In Mexico, this requirement shall be optional;

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

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

7.4 Tests

7.4.1 **General**

In addition to the tests performed on each insulated conductor according to its type as specified in Clause 5, or in the case of polyethylene-insulated conductors as specified in Table 33, and the spark test specified in the Table 32, the completed cable shall be subjected to the tests set out in Clauses 7.4.2 – 7.4.5.

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7.4.2 **Dielectric withstand**

The finished assembly or cable shall withstand the a-c voltage specified in Clause 5.23, or in the case of polyethylene cables, Table 32. For a flat or twisted assembly, the test voltage shall be applied between each conductor and tap water in which the assembly has been immersed for 6 h.

For a jacketed cable, the test voltage shall be applied to each conductor while the remaining conductors are connected together and connected to ground.

7.4.3 **Insulation resistance**

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

7.4.4 **Low-temperature impact**

In Canada, the thermoplastic jacket or insulation on at least 8 out of 10 specimens of completed cable marked ″−40°C″ shall not crack or rupture when subjected to the tests described in Clause 8.10.

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

7.4.5 **Electrical continuity**

Each conductor shall be continuous when tested in accordance with Clause 8.25.

8 Test methods

8.1 General

The test methods are presented in Clauses 8.2 – 8.25.

8.2 Conductor resistance

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

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8.3 Test methods for aluminum conductors

8.3.1 Physical properties

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

8.3.2 High-current heat cycling

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

a) One terminal baseplate, as shown in Figure 3, shall be made out of 0.76 ± 0.03 mm 70/30 ASTM sheet brass, Rockwell B 82-86 hardness.

b) Screws shall be made of AISI* 1010 carbon steel meeting the requirements of ASTM Standard A 29 and located at 21.4 mm centers. See Figure 4 for screw description.

c) The other terminal baseplate (neutral side) shall be the same as described in Item a) but, in addition, shall have immersion tin plating of less than 0.003 mm thickness.

d) The two binding-head screws, size No. 8-32, used on the white terminal baseplate shall be zinc-plated a minimum of 0.003 mm thick and have a chromate conversion coating.

e) The other two binding head screws, size No. 8-32, in the yellow side (line) of the jig shall be zinc-plated a minimum of 0.003 mm thick and brass-finished.

f) Screws shall be free-running when finger torque is applied until the screwhead engages with the wire.

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

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

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8.3.2.3 Where a temperature exceeds 175°C (1 thermocouple measurement) within the first 50 cycles of test, the result shall not be counted in the overall performance rating. The device shall be removed and replaced by two new test jigs. These shall be inserted into the circuit in such a manner as not to disturb the wire connections or the other test jigs. The results shall be considered acceptable if temperatures measured by the 26 thermocouples are less than 175°C, with each thermocouple profile exhibiting thermal stability as described in Clause 5.3.2.

8.4 Short-term insulation resistance at elevated temperature in water

Compliance shall be determined in accordance with Clause 8.5, except that the water temperature shall be the same as the temperature rating of the insulation.

8.5 Long-term insulation resistance in water

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

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

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

Any coil that shows a greater percent decrease in insulation resistance 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.

8.7 Capacitance and relative permittivity

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

8.8 Flexibility at room temperature after aging

After aging in an air oven as specified in Table 11 or Table 12 for the insulated conductor type, the specimen shall be wound around a mandrel as specified in Table 25, Column B, within 16 to 96 h, at room temperature. The winding shall be done at a uniform rate of approximately 4 s per turn. In the case of 85.0 mm^2 (3/0 AWG) or smaller conductors, 4 adjacent turns shall be tightly wound around the mandrel. For sizes 107 mm^2 (4/0 AWG) and larger, a 180° U-bend shall be performed.

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8.9 Heat shock

Compliance shall be determined as follows in accordance with UL 1581, Section 540; CSA C22.2 No. 0.3, Clause 4.23.1; or NMX-J-190-ANCE:

a) For 42.4 mm^2 (1 AWG) and smaller, four adjacent turns shall be tightly wound around a mandrel and both ends of the specimen shall be securely held in place.

b) 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°.

After heating for 1 h to a temperature of 121 ± 1°C in a circulating-air oven, the conductor insulation surface shall be observed for cracks.

8.10 Cold bend and cold impact

8.10.1 Cold bend

Compliance shall be determined with the apparatus and method specified in UL 1581, Section 580; CSA C22.2 No. 0.3, Clause 4.12.1; or NMX-J-193-ANCE. In the case of 85.0 mm^2 (3/0 AWG) or smaller conductors, 4 adjacent turns shall be tightly wound 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.

8.10.2 Cold impact

8.10.2.1 Specimens shall be impacted on anvils consisting of 200 mm (or 8 inches) minimum lengths of 2 x 4 spruce lumber having no surface imperfections or knots. The wood anvil shall be inspected after each specimen is impacted and replaced if it shows any indentations.

Note: *"2 x 4 spruce lumber" is a typical construction grade lumber with approximate dimensions of* 40 mm x 90 mm *(1-1/2 inches x 3-1/2 inches).*

8.10.2.2 The impact energy shall be provided by a weight of 1.36 kg (3 lb) in the form of a right-circular steel cylinder having a diameter of 25 mm (1 inch) and a flat impact face that is perpendicular to the longitudinal axis of the weight and has rounded edges.

8.10.2.3 The impact specimens shall consist of 10 separate 125 mm (5 inch) sections cut from a straight sample length of the finished wire or cable.

8.10.2.4 The specimens and wood anvils shall be cooled for at least 4 h in a cold chamber maintained at a temperature of −40.0 ± 1.0°C. The impact weight and the remainder of the test apparatus shall be in thermal equilibrium with the surrounding air in the test room at a temperature of 24.0 ± 8.0°C (75.2 ± 14.4°F).

8.10.2.5 At the conclusion of at least 4 h of cooling, one of the wood anvils shall be removed from the cold chamber and shall be secured to a concrete floor, the building framework, or another solid support that does not absorb the impact. The impact weight shall be supported with its lower face horizontal. A vertical line through the centers of gravity of the impact weight and the stationary anvil shall be coincident with a vertical line through the dimensional center of the lower face of the impact weight and the dimensional center of the upper face of the stationary anvil. A set of rails or other vertical guide(s) shall constrain the impact weight and keep its lower face horizontal while the weight is falling and after it has struck the wire or cable. The rails or other guide(s) shall not interfere with the free fall of the impact weight.

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A means shall be provided at the top of the guide(s) for releasing the impact weight to fall freely from any chosen height and strike the wire or cable. A means shall also be provided to keep the weight from striking the wire or cable more than once during each drop.

8.10.2.6 One of the test specimens of the wire or cable shall be removed from the cold chamber and shall be tested as follows without delay and within 15 s of being removed from the chamber. Insulating gloves shall be worn by the person conducting the test. The time in seconds between removal of the specimen from the chamber and the impact shall be noted and recorded. The impact weight shall be secured several specimen diameters (several times the length of the minor axis in the case of a flat cable) above the anvil, and the specimen shall be placed and held on the cold anvil with the longitudinal axis of the specimen horizontal, perpendicular to the longitudinal axis of the anvil, and in the vertical plane containing the coincident vertical lines described in Clause 8.10.2.5. In the case of a flat cable, the specimen shall be flatwise on the anvil. The position of the impact weight shall be adjusted to place the lower face of the weight 900 mm (36 inches) above the upper surface of the specimen. The impact weight shall be released from this height, shall fall freely in the guides, shall strike the specimen once, and shall then be immediately raised up to and secured at the 900 mm (36 inches) height. After warming in still air at a temperature of 24.0 ± 8.0°C (75.2 ± 14.4°F) for 24 h, the specimen shall be examined for cracks, ruptures, and like damage in each of its nonmetallic components, insulation, jacket, other covering, etc. The examinations shall be made without any aid other than the examiner's normal corrective lenses, if any.

Note: *Where the cold chamber is equipped with a rigid post having a solid base, the specimens may be impacted inside the chamber.*

8.10.2.7 Each of the remaining nine specimens shall be tested in succession as described above for a total of ten strikes. The wire or cable shall not be acceptable if more than two out of ten specimens show any cracking, rupturing, or like damage.

8.11 Deformation

8.11.1 Compliance shall be determined with the apparatus and method specified in UL 1581, Section 560; CSA C22.2 No. 0.3, Clause 4.3.6.1; or NMX-J-191-ANCE.

8.11.2 Nylon-jacketed conductors shall be maintained at 136 ± 1°C during the test, with the nylon in place. Measurements shall be made over the nylon. Except as shown in Clause 8.11.3, all other conductors shall be maintained at 121 ± 1°C during the test.

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

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