# UL 83

# Thermoplastic-Insulated Wires and Cables

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

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

Fourteenth Edition, Dated February 15, 2008

***Summary of Topics:***

***This New Edition of ANSI/UL 83 Covers Revisions to Test Methods Based on Publication of UL 2556 and Other General, Construction, Performance, and Marking Requirements Revisions***

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

| Future Effective Date | References |
|---|---|
| February 15, 2009 | Paragraphs 4.1.4.3, 4.4, and 7.2.4 |

The new requirements are substantially in accordance with UL's Proposal(s) on this subject dated April 6, 2007 and November 16, 2007.

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

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

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

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



Revisions of UL Standards for Safety are issued from time to time. A UL Standard for Safety is current only if it incorporates the most recently adopted revisions.

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that have been revised and that have a future effective date are located after the Standard, and are preceded by a ″SUPERSEDED REQUIREMENTS″ notice.

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

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

| Page | Date |
| --- | --- |
| 1-132 | February 15, 2008 |
| SR1-SR2 | February 15, 2008 |

No Text on This Page

Association of Standardization and Certification
NMX-J-010-ANCE-2008
Fourth Edition

Canadian Standards Association
CSA C22.2 No. 75-08
Ninth Edition

Underwriters Laboratories Inc.
UL 83
Fourteenth Edition

# Thermoplastic-Insulated Wires and Cables

February 15, 2008

Approved American National Standard

ANSI/UL 83-2008

**Commitment for Amendments**

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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Revisions of this Standard will be made by issuing revised or additional pages bearing their date of issue. 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. 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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The most recent designation of ANSI/UL 83 as an American National Standard (ANSI) occurred on February 7, 2008.

This ANSI/UL Standard for Safety, which consists of the Fourteenth edition, is under continuous maintenance, whereby each revision is ANSI approved upon publication.

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

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# Preface

This is the harmonized ANCE, CSA, and UL Standard for Thermoplastic-Insulated Wires and Cables. It is the fourth edition of NMX-J-010-ANCE, the ninth edition of CSA-C22.2 No. 75, and the fourteenth edition of UL 83. This edition of CSA-C22.2 No. 75 supersedes the previous edition published in 2003. This edition of UL 83 supersedes the previous edition published in 2003.

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.

This standard was reviewed by the CSA Subcommittee on Fixed Installation Wires and Cables, 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 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.

## 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 February 15, 2008, 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 February 15, 2009:

Clauses 4.1.4.3, 4.4, and 7.2.4.

Between February 15, 2008 and February 15, 2009, 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.

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

# Thermoplastic-Insulated Wires and Cables

## 1 Scope

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

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

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

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

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

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

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

In Canada and the United States, requirements for multiple-conductor thermoplastic-insulated and -jacketed cables rated 600 V are covered in other standards.

1.4 Products for which this Standard provides requirements 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.

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

**ANCE Standards**

NOM-001-SEDE,
*Standard for Electrical Installations*

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

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

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

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

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

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

NMX-J-040-ANCE,
*Determination of Moisture Absorption in Insulations and Jackets of Electrical Conductors – Test Method*

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

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

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

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

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

NMX-J-190-ANCE,
*Heat Shock Resistance of PVC Insulations and Protective Coverings of Electrical Conductors – Test Method*

NMX-J-191-ANCE,
*Heat Distortion of Semiconductive Shielding, Insulations and Protective Coverings of Electrical Conductors – Test Method*

NMX-J-192-ANCE,
*Flame Test on Electrical Wires – Test Method*

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

NMX-J-194-ANCE,
*Wires and Cables – Oil Immersion Aging for Insulations and Jackets of Electrical Conductors – Test Method*

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

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

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

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

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

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

**CSA Standards**

C22.1-06,
*Canadian Electrical Code, Part I*

C22.2 No. 0.3-96(R2005),
*Test Methods for Electrical Wires and Cables*

CAN/CSA-C22.2 No. 131-M89(R2004),
*Type TECK 90 Cable*

C22.2 No. 230-M1988(R2004),
*Tray Cables*

C22.2 No. 239-97(R2001),
*Control and Instrumentation Cables*

C22.2 No. 2556-05,
*Wire and Cable Test Methods*

**UL Standards**

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

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

UL 2556
*Wire and Cable Test Methods*

**ASTM* Standards**

A 29/A 29M-05,
*Standard Specification for Steel Bars, Carbon and Alloy, Hot-Wrought and Cold Finished, General Requirements for*

B 3-01,
*Standard Specification for Soft or Annealed Copper Wire*

B 33-04,
*Standard Specification for Tinned Soft or Annealed Copper Wire for Electrical Purposes*

B172-01a(2007)e1,
*Standard Specification for Rope-Lay-Stranded Copper Conductors Having Bunch-Stranded Members, for Electrical Conductors*

B173-01a(2007)e1,
*Standard Specification for Rope-Lay-Stranded Copper Conductors Having Concentric-Stranded Members, for Electrical Conductors*

B231/B231M-04,
*Standard Specification for Concentric-Lay-Stranded Aluminum 1350 Conductors*

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

B836-00(2005),
*Standard Specification for Compact Round Stranded Aluminum Conductors Using Single Input Wire Construction*

**IEC† Standards**

60228 (2004-11),
*Conductors of insulated cables*

**IEEE‡ Standards**

1202-2006,
*IEEE Standard for Flame-Propagation Testing of Wire and Cable*

**NFPA§ Publication**

NFPA 70-2005,
*National Electrical Code*

**American Society for Testing and Materials.*

*†International Electrotechnical Commission.*

*‡Institute of Electrical and Electronics Engineers.*

*§National Fire Protection Association.*

## 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.

##### 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 **Tin-coated copper conductors**

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

4.1.5 **Sizes and stranding**

4.1.5.1 **Sizes**

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 formed into a smooth outermost layer by rolling, drawing, or other means. The lay length of every layer shall be not less than 8 times nor more than 16 times the outside diameter of the completed conductor, except that for sizes 33.6 $mm^2$ (2 AWG) and smaller, the maximum lay length shall be 17.5 times the outside diameter. The direction of lay of the outermost layer shall be left-hand, and it shall be reversed or unidirectional/unilay in successive layers.

4.1.5.2.3 **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.

4.1.6 **Diameter and cross-sectional area**

4.1.6.1 The nominal diameters of solid and stranded conductors are shown in Tables 4 – 9. The minimum diameter for stranded conductors is 98 percent of the nominal. The maximum diameter is 101 percent of the nominal. The diameter shall be determined in accordance with the test, Conductor diameter, in UL 2556, CSA C22.2 No. 2556, or NMX-J-129-ANCE.

Conductor sizes in $mm^2$ (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.

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

4.1.6.2 In the United States, 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**

4.1.7.1 A joint in a solid conductor or in one of the individual wires of a stranded conductor shall neither increase the diameter nor materially decrease the strength of the conductor or the individual wire. Not more than one of the wires in a stranded conductor of 19 wires or less, nor more than one of the wires in any given layer in a stranded conductor of more than 19 wires, shall be joined in any 0.3 m (1 ft) of conductor.

4.1.7.2 In a rope-lay-stranded conductor, which consists of a central core surrounded by one or more layers of stranded members (primary groups), each member shall be considered equivalent to a solid wire, and as such, shall be spliced as a unit. These joints shall not be any closer together than 2 lay lengths.

4.1.7.3 A joint shall be allowed in a Class B stranded 2.08 $mm^2$ (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.

#### 4.1.8 **Separator**

A separator of suitable material between the conductor and the insulation shall be optional. The separator shall be of contrasting color to the conductor color, except that clear or green shall not be used. White-colored separator over aluminum conductors shall be optional. The separator and the other wire or cable components shall not have any deleterious effect on each other.

### 4.2 Insulation

#### 4.2.1 **General**

Conductors shall be insulated for their entire length with PVC or other thermoplastic material meeting all the requirements of this Standard. The insulation shall be applied directly over the conductor, or over the separator if provided, and shall fit tightly thereto. The insulation shall be free from pores, splinters, and other inhomogeneities visible without magnification to normal or corrected-to-normal vision.

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

#### 4.2.2 **Repairs**

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

#### 4.2.3 **Colored insulation**

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

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

4.2.3.3 Stripes as specified in 4.2.3.2 shall be of even or varying width and shall occupy a total of 5 – 70 percent of the calculated circumference of the outer surface of the finished insulated conductor with no individual width less than 5 percent of that same circumference. The width shall be measured perpendicular to each stripe. Where broken stripes are appropriate, they shall consist of a series of identical marks and spaces, the length of each mark shall be at least 3 mm (1/8 inch), and the linear spacing between marks shall not be greater than 19 mm (3/4 inch).

4.2.4 **Thickness and centering**

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

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

4.2.5 **Physical properties of insulation**

4.2.5.1 **General**

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

4.2.5.2 **Test requirement**

4.2.5.2.1 Compliance with Clause 4.2.5.1.1 shall be determined in accordance with the test, Physical properties (ultimate elongation and tensile strength), in UL 2556, CSA C22.2 No. 2556, or NMX-J-556-ANCE.

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

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

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

### 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.

## 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 conductors twisted together in a multi-conductor assembly. Compliance shall be determined in accordance with the test, DC resistance, in UL 2556, CSA C22.2 No. 2556, or NMX-J-212-ANCE.

## 5.3 Tests on aluminum conductors

### 5.3.1 **Physical properties**

All aluminum conductors shall have a minimum elongation at break of 10 percent. Wires (strands) removed from a finished stranded conductor shall have a tensile strength of 98 – 159 MPa (14,250 – 23,100 lbf/in$^2$). The tensile strength of all other conductors shall be 103 – 152 MPa (15,000 – 22,000 lbf/in$^2$). Compliance shall be determined in accordance with the test, Physical properties of conductors – Maximum tensile strength and elongation at break, in UL 2556, CSA C22.2 No. 2556, or NMX-J-556-ANCE.

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

### 5.3.2 **High-current heat cycling**

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

5.3.2.2 Compliance shall be determined in accordance with the test, High-current heat cycling for aluminum conductors, in UL 2556, CSA C22.2 No. 2556, or NMX-J-556-ANCE.

## 5.4 Short-term insulation resistance at elevated temperature in water

The resistance values shall not be less than those shown in Table 23 when tested in accordance with the test, Insulation resistance, in UL 2556, CSA C22.2 No. 2556, or NMX-J-556-ANCE, after immersion in water for at least 6 h at the same temperature as the temperature rating of the insulation.

## 5.5 Long-term insulation resistance in water

### 5.5.1 **Minimum acceptable value**

5.5.1.1 The insulation of wet-rated single-conductor cable and of the individual single conductors of multiconductor cable shall have insulation resistance at the specified temperature in tap water not less than specified in Table 23 at any time during immersion, in accordance with the test, Insulation resistance, in UL 2556, CSA C22.2 No. 2556, or NMX-J-556-ANCE. The period of immersion shall be 12 weeks or more if the insulation resistance during the last 6 weeks of the period is higher than 3 GΩ·m (10 MΩ·1000 ft). The period of immersion shall be 24 – 36 weeks if the insulation resistance is less than 3 GΩ·m (10 MΩ·1000 ft), but equals or exceeds the value indicated in Table 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.

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

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

### 5.5.2 **Maximum acceptable rate of decrease**

5.5.2.1 During the extended immersion, the maximum decrease in insulation resistance per week, as determined from a curve (drawn to represent the average of actual values), for every continuous period of 3 weeks during the latter half of the specified immersion time shall be not more than 4 percent if and while the insulation resistance is 3 GΩ·m (10 MΩ·1000 ft) or more, and shall be not more than 2 percent if the insulation resistance is less than 3 GΩ·m (10 MΩ·1000 ft), but more than the value indicated in Table 23.

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

5.6.2 **Maximum acceptable rate of decrease**

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

5.6.2.2 Any coil that shows a greater percent decrease in insulation resistance than those indicated in Clause 5.5.2.1 during the extended period of time in the oven shall be allowed to be tested for additional one-week periods in the oven and judged on the basis of the results for every continuous period of 3 weeks during the last 12 weeks in the oven, provided that the final insulation resistance is not less than as specified in Table 23.

5.6.3 **Minimum acceptable value**

5.6.3.1 The 90°C rated insulation of the individual conductors without covering shall have insulation resistance in air at 97 ±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, to a maximum of 36 weeks, if the insulation resistance throughout the last 6 weeks of the period is 3 GΩ·m (10 MΩ·1000 ft) or higher. If the insulation resistance is less than 3 GΩ·m (10 MΩ·1000 ft), but equals or exceeds the values in Table 24, the period in the oven shall be 24 weeks or more to a maximum of 36 weeks. A 600 V rms voltage shall be applied at all times other than while reading the insulation resistance.

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

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

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

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

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

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

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

## 5.8 Flexibility at room temperature after aging

The insulation and nylon covering (if present) shall not show any cracks, either on the surface or internally, when wound around a mandrel of the diameter specified in Table 25, Column B, at room temperature, in accordance with the test, Flexibility at room temperature after aging, in UL 2556, CSA C22.2 No. 2556, or NMX-J-189-ANCE, after aging in an air oven as specified in Table 11.

## 5.9 Heat shock

5.9.1 When tested in accordance with the test, Heat shock, in UL 2556, CSA C22.2 No. 2556, or NMX-J-190-ANCE, the insulation of single insulated conductors shall not show any cracks, on the surface or internally, after a specimen of finished wire is wound around a mandrel with a diameter specified in Column A of Table 25 after conditioning in an air-circulating oven for 1 h to a temperature of 121 ±1°C.

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

## 5.10 Cold bend and cold impact

### 5.10.1 **Cold bend**

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

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

5.10.1.3 When the wire or cable is marked with the optional –40C marking in accordance with Clause 6.1.8, conditioning shall be carried out at a temperature of –40 ±1°C.

5.10.2 **Cold impact (optional)**

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

**5.11 Deformation**

5.11.1 The thickness of 60°C, 75°C, and 90°C rated insulations shall not decrease by more than 50, 30, and 30 percent, respectively, when subjected to the load specified in Table 26 and tested in accordance with the test, Deformation, in UL 2556, CSA C22.2 No. 2556, or NMX-J-191-ANCE.

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

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

**5.12 Flame and smoke**

5.12.1 **Vertical flame**

When tested in accordance with Clause 8.2.1, 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.

5.12.2 **FT1**

In Canada, when tested in accordance with Clause 8.2.2, 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 8.2.3.1. 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 8.2.3.2. 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.

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 8.2.4.

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 8.2.5.

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

5.12.6.1 **General**

When tested in accordance with Clause 8.2.6, 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 8.2.6.1 or the vertical flame exposure described in Clause 8.2.6.2.

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 8.2.6.1:

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 8.2.6.1. The values obtained from the third set of specimens shall be within the limits specified in a), b), and c).

5.12.6.3 **FT4 vertical-tray flame exposure**

Finished insulated single conductors shall exhibit the following properties when sets of specimen lengths are tested in accordance with Clause 8.2.6.2:

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 8.2.6.2. 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 8.2.7.1 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.

5.12.7.3 **Fire propagation (RPI)**

Finished cable samples shall be subjected to the test method described in Clause 8.2.7.2 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 8.2.7.3 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 by exposure to xenon- or carbon-arc.

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

In Canada, the conditioning shall be 1000 h.

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

## 5.14 Oil resistance (optional)

### 5.14.1 **Oil resistance at 60°C**

5.14.1.1 To be marked PR I, 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. Compliance shall be determined in accordance with the applicable clauses of the test, Oil resistance, in UL 2556, CSA C22.2 No. 2556, or NMX-J-194-ANCE.

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

### 5.14.2 **Oil resistance at 75°C**

5.14.2.1 To be marked PR II, 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. Compliance shall be determined in accordance with the applicable clauses of the test, Oil resistance, in UL 2556, CSA C22.2 No. 2556, or NMX-J-556-ANCE.

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

## 5.15 Gasoline and oil resistance (optional)

5.15.1 To be marked GR I or GR II, the retention of tensile strength and elongation of insulated conductors found to be in compliance with the requirements of Clause 5.14.1 or 5.14.2, respectively, shall not be less than 65 percent after 30 d immersion in water saturated with equal volumes of iso-octane and toluene (ASTM Reference Fuel C) maintained at 23 ±1°C. Compliance shall be determined in accordance with the applicable clauses of the test, Gasoline resistance, in UL 2556, CSA C22.2 No. 2556, or NMX-J-556-ANCE.

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

### 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 abrasion by means of a weight that exerts a force of 3.3 ±0.1 N or 340 ±13 gf (12.0 ±0.5 ozf), in accordance with the procedure described in the test, Abrasion resistance, in UL 2556, CSA C22.2 No. 2556, or NMX-J-556-ANCE.

In Mexico, the abrasion resistance test is not required.

### 5.17 Crush 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 the test, Crush resistance – Method 2, in UL 2556, CSA C22.2 No. 2556, or NMX-J-556-ANCE.

### 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 or cause triggering of the indicator when tested in accordance with the test, Impact resistance, in UL 2556, CSA C22.2 No. 2556, or NMX-J-556-ANCE.

### 5.19 Durability of ink printing

5.19.1 The printing on the finished wire shall remain legible after being subjected to the test, Durability of ink printing, in UL 2556, CSA C22.2 No. 2556, or NMX-J-556-ANCE.

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

### 5.20 Color coating

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

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

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

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

**5.21 Long-term aging of insulation**

5.21.1 The absolute elongation of insulation material referenced in Clause 4.2.5.3 shall be not less than 50 percent after being subjected to long-term aging in an air oven in accordance with the test, Dry temperature rating of new materials (long-term aging test), in UL 2556, CSA C22.2 No. 2556, or NMX-J-186-ANCE.

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

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

**5.22 A-C spark test**

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

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

In Mexico, the a-c spark test is not required.

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

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

**5.23 Dielectric voltage-withstand in water**

5.23.1 The insulation of single conductors, when tested in accordance with the test, Dielectric voltage-withstand, in UL 2556, CSA C22.2 No. 2556, or NMX-J-293-ANCE shall withstand, without breakdown, the application of the appropriate test voltage after immersion in water for not less than 6 h before the test potential is applied, as follows:

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

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

In Mexico, the dc test is not required.

### 5.24 Insulation resistance in water at 15°C

Following compliance with Clause 5.23, while still immersed, the insulation of single conductors shall have an insulation resistance, corrected to 15°C, if necessary, of not less than the values specified in Table 27 when tested at the prevailing water temperature. The apparatus and test method shall be in accordance with the test, Insulation resistance, in UL 2556, CSA C22.2 No. 2556, or NMX-J-294-ANCE. Unless the spark test specified in Clause 5.22 is carried out, each length of finished cable shall be subjected to this test.

### 5.25 Electrical continuity

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

## 6 Marking

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

### 6.1 Marking on product

#### 6.1.1 **General**

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).

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

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

6.1.2 **Manufacturer's identification**

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

6.1.3 **Type designation**

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

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

6.1.4 **Conductor size**

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

a) $mm^2$ (AWG);

b) AWG ($mm^2$);

c) $mm^2$ (kcmil);

d) kcmil ($mm^2$);

e) AWG;

f) kcmil.

In Mexico, items a) and c) apply.

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

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

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

6.1.5 **Aluminum conductors**

Aluminum conductors shall be marked ″AL″. 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.

6.1.7 **Voltage marking**

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

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

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

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 8.2.6.2;

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 marked ″CT″ shall meet the requirements of either Clause 5.12.4 or Clause 5.12.5.

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*.

6.1.10 **Weather resistance (optional)**

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

6.1.11 **Oil resistance (optional)**

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

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

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

### 6.2 Marking on package

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

a) Manufacturer's identification;

b) Type designation;

c) Conductor size, in accordance with Clause 6.1.4;

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

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

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

In Canada and Mexico, this requirement does not apply.

g) Voltage rating;

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

### 6.3 Month and year of manufacture

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

## 7 Deep-well submersible water pump cable

### 7.1 General

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

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 36.

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 36.

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

### 7.2.4 **Polarity identification of circuit conductors**

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

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

## 7.3 Marking

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

### 7.3.1 **Marking on product**

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

a) The manufacturer’s identification;

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

c) The conductor size in accordance with Clause 6.1.4;

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

e) The designation ″SUBMERSIBLE PUMP CABLE″ as applicable (required on jacketed constructions, optional on conductors of non-jacketed constructions);

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

g) The low-temperature rating, 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;

i) Optional markings specified in Clause 6.1 as applicable.

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

7.3.2 **Marking on package**

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

a) Manufacturer's name;

b) Month and year of manufacture;

c) Product designation ″SUBMERSIBLE PUMP CABLE″;

d) Conductor size in accordance with Clause 6.1.4;

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

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

g) 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 marking does not apply;

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

## 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.

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, Cold bend and Cold impact, in UL 2556, CSA C22.2 No. 2556, or NMX-J-177-ANCE.

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 the test, Continuity, in UL 2556, CSA C22.2 No. 2556, or NMX-J-556-ANCE.

## 8 Test methods

### 8.1 General

The test methods are presented in Clause 8.2.

## 8.2 Flame

8.2.1 **Vertical flame**

8.2.1.1 The standard test flame shall be nominally 125 mm high and shall produce heat at the nominal rate of 500 W (1700 Btu/h). The period between applications shall be 15 s regardless of whether flaming of the specimen ceases of its own accord within 15 s of the previous application. This test shall be conducted as described in UL 1581, Section 1060; CSA C22.2 No. 0.3, Clause 4.11.7; or NMX-J-192-ANCE, except as described in Clause 8.2.1.2. The results of this test shall be judged as indicated in Clause 8.2.1.3.

8.2.1.2 The burner shall be tilted forward into position to apply the gas flame to the specimen, kept there for 15 s, quickly tilted back to the stop to remove the flame from the specimen for 15 s, and so forth, for a total of five 15 s applications of the gas flame to the specimen, with 15 s between applications. The gas flame shall be reapplied to the specimen 15 s after the previous application, regardless of whether flaming of the specimen ceases of its own accord within 15 s of the previous application.

8.2.1.3 Where 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 shall be ignored) after any of the five applications of flame, the insulated conductor shall be judged capable of conveying flame along its length.

Where 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 insulated conductor shall be judged capable of conveying flame to combustible materials in its vicinity. Where any specimen continues to flame longer than 60 s after the five applications of the gas flame, the insulated conductor shall be judged capable of conveying flame to combustible materials in its vicinity.

8.2.2 **FT1**

Compliance shall be determined in accordance with UL 1581, Section 1060; CSA C22.2 No. 0.3, Clause 4.11.1; or NMX-J-192-ANCE.

8.2.3 **VW-1**

8.2.3.1 **Vertical specimen**

Compliance shall be determined in accordance with UL 1581, Section 1080; CSA C22.2 No. 0.3, Clause 4.11.7; or NMX-J-192-ANCE.

8.2.3.2 **Horizontal specimen**

Compliance shall be determined in accordance with UL 1581, Section 1100; CSA C22.2 No. 0.3, Clause 4.11.2; or NMX-J-192-ANCE.

8.2.4 **Vertical tray**

Compliance shall be determined with the apparatus and method specified in Clause 8.2.6.1. Smoke measurements shall not be applicable.

8.2.5 **FT4 vertical tray**

Compliance shall be determined in accordance with UL 1685, Sections 12 – 19; CSA C22.2 No. 0.3, Clause 4.11.4; or NMX-J-498-ANCE. Smoke measurements shall not be applicable.

8.2.6 **ST1 limited smoke**

8.2.6.1 **Vertical-tray fire propagation and smoke release**

8.2.6.1.1 **Apparatus**

The test apparatus shall include the following main components:

a) Ignition source;

b) Collection hood and exhaust duct;

c) Velocity-measuring instrumentation;

d) Smoke-measuring instruments;

e) Data-acquisition system.

8.2.6.1.2 **Cable test enclosure and exhaust duct**

The enclosure in which the cables are tested shall be as shown in Figure 1. Other enclosures shall be optional if they are shown to provide equivalent results, and are of a size [such as 2.4 $m^3$ (8 $ft^3$) or 3 $m^3$ (10 $ft^3$)] such that the internal volume of the enclosure, exclusive of the pyramidal hood, is not less than 14.5 $m^3$ (512 $ft^3$) or greater than 36 $m^3$ (1272 $ft^3$), the floor area is not smaller than 6 $m^2$ (64 $ft^2$) or larger than 9 $m^2$ (97 $ft^2$), and the maximum air movement within the enclosure complies with Clause 8.2.6.1.3.

The walls of the structure shall be of concrete masonry having a density of 1698 kg/$m^3$ (106 lb/$ft^3$) and a thermal conductivity k at 21.1°C (70.0°F) of 0.055 W/(m·K) [0.38 Btu (thermochemical)·in/(hr·$ft^2$·°F)], with the interior surface painted flat black. The walls shall contain window(s) as shown in Figure 1 for observation of the fire test. Alternative construction materials shall be acceptable for the structure walls if both of the following conditions are met:

a) The overall thermal conductivity, based on an inside wall temperature of 37.8°C (100.0°F) and an outside air temperature of 23.9°C (75.0°F), is 0.072 ± 0.043 W/(m·K) [0.50 ± 0.30 Btu (thermochemical)·in/(hr·$ft^2$·°F)].

b) The construction materials withstand the high temperatures and open flame in the test enclosure.

The enclosure shall contain a steel access door. The door shall be provided with a wired-glass window and shall be located as shown in Figure 1. The door and hood shall have an overall thermal conductivity equal to that of the walls. Alternative construction materials shall be acceptable if equivalent thermal conductivity is obtained.

A truncated-pyramid steel hood and a collection box, each formed as shown in Figure 1, shall be located on top of the enclosure walls. Compressible inorganic batting shall be used as a gasket between the hood and the walls.

The exhaust duct connected to the plenum on the hood shall consist of a steel pipe 406 mm (16 inches) in inside diameter installed horizontally as shown in Figure 1.

The baffle shown in Figure 1 shall be constructed of a 3.2 mm (1/8 inch) thick steel plate suspended horizontally over the center of the tray by chains attached to each corner of the baffle and connected to the collection hood. The baffle shall be suspended 2.95 m (116 inches) above the floor.

8.2.6.1.3 **Velocity-measuring instruments**

The velocity in the exhaust duct shall be determined by measuring the differential pressure in the flow path with the bi-directional probe shown in Figure 2. The probe shall be connected to an electronic pressure gauge or to an equivalent measuring system. The probe shall be 44 mm (1.75 inches) long and shall have an outside diameter of 22 mm (0.875 inch). The pressure taps (tubes) on either side of the diaphragm shall support the probe.

The axis of the probe shall be located on the centerline of the duct a minimum of 4 m (13 ft, 4 inches) downstream from the last turn in the duct, to ensure a nearly uniform velocity of flow across the duct cross-section. Positioning of the probe at another location shall be acceptable if it is shown that equivalent results are obtained. The pressure taps shall be connected to a pressure transducer having a minimum resolution of 0.025 Pa (0.001 $lb/in^2$).

The temperature of the exhaust gas shall be measured approximately 152 mm (6 inches) upstream from the probe on the centerline of the duct, using a 0.08 $mm^2$ (28 AWG) Type K thermocouple having an inconel sheath.

The maximum air movement within the enclosure, with only the intake and exhaust openings open, the exhaust fan on (if applicable), and the burner off, shall not exceed 1 m/s (3.3 ft/s), as measured in each of the following areas by means of a vane anemometer:

a) On the floor of the enclosure at the position occupied by the burner during the test;

b) 1.5 m (4.9 ft) above the floor of the enclosure at the position occupied by the cable tray during the test.

8.2.6.1.4 **Cable tray**

A steel ladder type of cable tray that is clean and free of residue and debris shall be securely mounted in a vertical position. The tray shall be 300 mm (12 inches) wide by 76 mm (3 inches) deep by 2400 mm (96 inches) long and shall have channel rungs as follows:

a) Each rung shall measure approximately 25 mm (1 inch) in the direction parallel to the length of the tray and approximately 13 mm (1/2 inch) in the direction of the depth of the tray.

b) The rungs shall be spaced approximately 230 mm (9 inches) apart (measured center to center).

c) The rungs shall be tack-welded to the side rails.

8.2.6.1.5 **Burner**

The test flame shall be supplied by means of a strip or ribbon type of propane-gas burner.* The flame-producing surface (face) of the burner shall consist essentially of a flat metal plate that is 341 mm (13-7/16 inches) long and 30 mm (1-5/32 inches) wide. The plate shall have an array of 242 holes drilled in it. The holes shall be 1.35 mm (1.35 mm metric drill size) [0.052 inch (No. 55 drill)] in diameter and shall be on 3.2 mm (0.125 inch) centers in three staggered rows of 81, 80, and 81 holes each, to form an array measuring 257 mm (10-1/8 inches) by 5 mm (3/16 inch). The array of holes shall be centered on the plate (see Figure 3).

* *A burner (catalog no. 10L 11-55) and venturi mixer (catalog no. 14-18) that facilitate compliance with the requirements in Clauses 8.2.6.1.5 and 8.2.6.2.5 are available from the AGF Burner Inc., 1955 Swarthmore Ave., Lakewood, NJ 08701, USA.*

The burner shall be mounted on a stand behind the vertical tray containing the cables, with the flame-producing surface (face) of the burner vertical and its long dimension horizontal. The 257 mm (10-1/8 inches) dimension of the array of holes shall be spaced 76 mm (3 inches) from the cables in the tray and shall be centered midway between the side rails of the tray. The centerpoint of the burner face shall be positioned 457 mm (18 inches) above the bottom end of the tray and cables and midway between two tray rungs.

8.2.6.1.6 **Flowmeters**

A flowmeter shall be inserted in each of the propane and air lines feeding the burner, to measure the flow rates of these gases during the test.

The propane flowmeter shall be capable of measuring a flow rate of $2.3 \times 10^{-4}$ $m^3/s$ (29 $ft^3/hr$), and the air flowmeter $13.3 \times 10^{-4}$ $m^3/s$ (170 $ft^3/hr$). Measurements shall be accurate within 3 percent. The use of a mass-flow controller with recorded output shall be optional.

8.2.6.1.7 **Air**

The air supplied to the burner shall be compressed air, either bottled or supplied through a compressed-air system. Contaminants shall be filtered out of the air supply.

8.2.6.1.8 **Propane**

The gas supplied to the burner shall be CP-grade propane (99 percent pure) having a nominal heating value of 93.0 $MJ/m^3$ or 22.2 kilocalories (thermochemical)/$m^3$ [2500 Btu (thermochemical) /$ft^3$].

8.2.6.1.9 **Gas flows**

The propane flow shall be 220 ± 8 $cm^3/s$ (28 ±1 $ft^3/hr$) when corrected to standard temperature and pressure (20°C, 101 kPa).

The airflow shall be 1280 ±80 $cm^3/s$ (163 ±10 $ft^3/hr$) when corrected to standard temperature and pressure.

8.2.6.1.10 **Smoke-measuring instruments**

The photometer system shall consist of a light source and photoelectric cell mounted on a horizontal section of the exhaust duct at a point at which the system is preceded by a straight run of duct that is at least twelve duct diameters or 4.88 m (16 ft) long, to ensure a nearly uniform velocity of flow across the duct cross-section. Positioning of the photometer system at another location shall be optional if it is shown that equivalent results are obtained. The light beam shall be directed horizontally along the diameter of the duct. A photoelectric cell whose output is directly proportional to the amount of light received shall be mounted over the light source and shall be connected to a recording device having an accuracy within ±1 percent of full scale for indicating changes in the attenuation of incident light resulting from the passage of smoke (particulate matter) and other effluents. The distance between the light-source lens and the photocell lens shall be 914 ±51 mm (36 ±2 inches). The cylindrical light beam shall pass through round openings 76 mm (3 inches) in diameter on opposite sides of the 406 mm (16 inches) duct, with the resultant light beam centered on the photocell.

The output signal from the photoelectric cell shall be processed into a continuous record of smoke obscuration, from which the optical density shall be calculated.

8.2.6.1.11 **Data acquisition**

A digital data-acquisition system shall be used to collect and record smoke and pressure measurements. The speed and capacity of the data system shall result in the collection of data every 5 s.

8.2.6.1.12 **Pretest calibration of equipment**

Prior to the start of each day of testing, the linearity of the photometer system shall be verified by interrupting the light beam with multiple calibrated neutral-density filters to cover the range of the recording instrument. Transmittance values measured by the photometer, using neutral-density filters, shall be within ±3 percent of the calibrated value for each filter.

8.2.6.1.13 **Test specimens**

8.2.6.1.13.1 **Cable mounting**

Two sets of specimens of each cable construction shall be tested [see Clause 5.12.6.2(d) concerning the testing of a third set]. Each set shall consist of multiple 2.44 m (96 inches) lengths of the finished cable.

The specimen lengths of cable shall be fastened in a single layer in the tray, by means of steel or copper wire not larger than 2.08 $mm^2$ (14 AWG), at their upper and lower ends and at two other equally spaced points along their lengths, with each cable vertical. As many cables shall be installed in the tray as will fit when spaced one-half cable diameter apart, filling the center 150 mm (6 inches) of the tray width. The number of specimen lengths to be tested is to be determined as

$$N = (102/D_{mm}) + 0.33$$

$$N = (4/D_{inches}) + 0.33$$

where

N is the number of cables (rounded up to the nearest whole number);

D is the diameter of the cable in millimeters (inches).

For a flat cable, the cable diameter shall be an equivalent diameter calculated as

$$D = 1.1284 \times (TW)^{1/2}$$

where

T is the length of the minor axis of the flat cable;

W is the length of the major axis of the flat cable.

8.2.6.1.13.2 **Conditioning**

Before the test is started, the test specimens shall be conditioned for at least 3 h in air whose temperature is 23 ± 5°C (73 ± 9°F). The test chamber shall be dry.

8.2.6.1.14 **Test procedure**

8.2.6.1.14.1 **Initial preparation**

At the start of the test, the cables, apparatus, and the air in the test area shall be in thermal equilibrium with one another at a temperature of at least 5°C (41°F).

The pretest calibration procedure described in Clause 8.2.6.1.12 shall be performed.

Power shall be applied to the digital data-acquisition equipment and to the computer.

A nominal exhaust flow rate of 0.65 ± 0.05 $m^3/s$ (23.0 ± 1.8 $ft^3/s$) shall be established in the duct.

8.2.6.1.14.2 **Procedure**

The prepared cable tray shall be positioned vertically inside the enclosure, with the open front of the cable tray facing the front of the enclosure. The cable tray shall be firmly secured in position.

The burner shall be ignited and the gas flows shall be adjusted to the values indicated in Clause 8.2.6.1.9. The burner shall be positioned behind the cable tray and 75 ± 5 mm (3.0 ± 0.2 inches) from the nearest cable surface.

The burner flame shall impinge on the specimens for a continuous period of 20 min.

At the end of the 20 min burn, the burner flame shall be extinguished and the cable fire (if any) shall be allowed to burn itself out.

Note shall be taken and a record kept of the flame height during the 20 min test, as well as the time in seconds that the cables continue to flame following removal of the burner flame.

The test procedure shall be conducted on the number of sets of cable specimens specified. Each procedure (burn) shall be conducted on previously untested specimens.

8.2.6.1.14.3 **Evaluation of damage**

The maximum height of damage on the cables shall be determined by measuring the blistering, char, and other damage upward from the bottom of the vertical tray, but ignoring soot that can be removed with a cloth, after the cables and tray have cooled to room temperature.

The limit of char shall be determined by pressing against a number of points on the cable surfaces with a sharp object. Where a cable surface (outer jacket, if any) changes from resilient to brittle (crumbling), the limit of char has been determined. Distortion of the outer surface of the cable, such as blistering or melting immediately above the char, shall be included in the damage measurement.

The cable damage shall be recorded to the nearest 25 mm (1 inch).

8.2.6.1.15 **Calculation of smoke release rate**

The smoke release rate (SRR) shall be calculated using the optical density per linear path length in the duct and the volumetric flow rate. The following equation is to be used to determine the SRR:

$$SRR = \frac{(OD \times M_1)}{0.4064}$$

where

SRR is the smoke release rate in meters squared per second;

OD is the optical density;

$M_1$ is the volumetric flow rate (in cubic meters per second) in the exhaust duct referred to 298K;

0.4064 is the path length in the duct in meters.

8.2.6.1.16 **Report**

The test report shall contain the following summary information:

a) A description of each set of specimens tested: the cable type letters and component makeup and the number of cable lengths in the set;

b) The number of burns;

c) The date on which the test was conducted.

8.2.6.2 **Alternate vertical-tray fire propagation and smoke release (FT4/IEEE 1202) (ST1)**

8.2.6.2.1 **Apparatus**

The test apparatus shall include the following main components:

a) Ignition source;

b) Collection hood and exhaust duct;

c) Velocity-measuring instrumentation;

d) Smoke-measuring instruments;

e) Data-acquisition system.

The cable test enclosure shall be located in a test building that has vents for the discharge of the combustion products and also has provisions for fresh-air intake.

8.2.6.2.2 **Cable test enclosure and exhaust duct**

The enclosure in which the cables are tested shall be as shown in Figure 1. The use of other enclosures shall be optional if they are shown to provide equivalent results and are of a size 2.4 $m^3$ (8 $ft^3$) or 3 $m^3$ such that the internal volume of the enclosure, exclusive of the pyramidal hood, is not less than 14.5 $m^3$ (512 $ft^3$) or greater than 36 $m^3$ (1272 $ft^3$), the floor area is not smaller than 6 $m^2$ (64 $ft^2$) or larger than 9 $m^2$ (97 $ft^2$), and the maximum air movement within the enclosure complies with Clause 8.2.6.2.3.

The walls of the structure shall be of concrete masonry having a density of 1698 kg/$m^3$ (106 lb/$ft^3$) and a thermal conductivity k at 21.1°C [70.0°F) of 0.055 W/(m·K] [0.38 Btu (thermochemical)·in/(hr·$ft^2$·°F)], with the interior surface painted flat black. The walls shall contain window(s), as shown in Figure 1, for observation of the fire test. Alternative construction materials for the structure walls shall meet the intent of this requirement if both of the following conditions are met:

a) The overall thermal conductivity, based on an inside wall temperature of 37.8°C (100.0°F) and an outside air temperature of 23.9°C (75.0°F), is 0.072 ± 0.043 W/(m·K) [0.50 ±0.30 Btu (thermochemical)·in/(hr·$ft^2$·°F)];

b) The construction materials withstand the high temperatures and open flame in the test enclosure.

The enclosure shall contain a steel access door. The door shall be provided with a wired-glass window and shall be located as shown in Figure 1. The door and hood shall have an overall thermal conductivity equal to that of the walls. Alternative construction materials shall meet the intent of these requirements if equivalent thermal conductivity is obtained.

A truncated-pyramid steel hood and a collection box, each formed as shown in Figure 1, shall be located on top of the enclosure walls. Compressible inorganic batting shall be used as a gasket between the hood and the walls.

The exhaust duct connected to the plenum on the hood shall consist of a steel pipe 406 mm (16 inches) in inside diameter, installed horizontally, as shown in Figure 1.

8.2.6.2.3 **Velocity-measuring instruments**

The velocity in the exhaust duct shall be determined by measuring the differential pressure in the flow path with the bi-directional probe shown in Figure 2. The probe shall be connected to an electronic pressure gauge or an equivalent measuring system. The probe shall be 44 mm (1.75 inches) long and shall have an outside diameter of 22 mm (0.875 inch). The pressure taps (tubes) on either side of the diaphragm shall support the probe.

The axis of the probe shall be located on the centerline of the duct a minimum of 4.0 m (13 ft, 4 inches) downstream from the last turn in the duct, to ensure a nearly uniform velocity of flow across the duct cross-section. The positioning of the probe at another location shall be optional if it is shown that equivalent results are obtained. The pressure taps shall be connected to a pressure transducer having a minimum resolution of 0.025 Pa (0.001 $lb/in^2$).

The temperature of the exhaust gas shall be measured approximately 152 mm (6 inches) upstream from the probe on the centerline of the duct, using a 0.08 $mm^2$ (28 AWG) Type K thermocouple having an inconel sheath.

The maximum air movement in the inlets at the floor of the enclosure, with the exhaust fan on, shall not exceed 1 m/s (3.3 ft/s).

The maximum air movement within the enclosure, with only the intake and exhaust openings open, the exhaust fan on (if applicable), and the burner off, shall not exceed 1 m/s (3.3 ft/s), as measured in each of the following areas by means of a vane anemometer:

a) On the floor of the enclosure at the position occupied by the burner during the test;

b) 1.5 m (4.9 ft) above the floor of the enclosure at the position occupied by the cable tray during the test.

8.2.6.2.4 **Cable tray**

A steel ladder type of cable tray as shown in Figure 4, clean and free of residue and debris, shall be used. The rungs shall be attached to the inside of the side channels. The tray shall be arranged so that the burner flame impinges on the cables midway between rungs.

8.2.6.2.5 **Burner**

The test flame shall be supplied by means of a strip or ribbon type of propane-gas burner. The flame-producing surface (face) of the burner shall consist essentially of a flat metal plate that is 341 mm (13-7/16 inches) long x 30 mm (1-5/32 inches) wide. The plate shall have an array of 242 holes drilled in it. The holes shall be 1.35 mm (1.35 mm metric drill size) [0.052 inch (No. 55 drill)] in diameter and shall be on 3.2 mm (0.125 inch) centers in three staggered rows of 81, 80, and 81 holes each, to form an array measuring 257 mm (10-1/8 inches) by 5 mm (3/16 inch). The array of holes shall be centered on the plate. See Figure 3 and footnote to Clause 8.2.6.1.5.

The burner shall be mounted on a stand and angled 20° ± 2° from the horizontal with the burner ports up (see Figure 4). The top of the burner shall be located 305 ± 25 mm (12 ± 1 inches) above the base of the cable tray and parallel to the cable-tray rungs. A guide shall be attached to the burner or stand so that the leading edge of the burner face can be accurately placed 76 ± 5 mm (3.0 ± 0.2 inches) horizontally from the nearest surface of the cables.

8.2.6.2.6 **Flowmeters**

A flowmeter shall be inserted in each of the propane and air lines feeding the burner, to measure the flow rates of these gases during the test.

The propane flowmeter shall be capable of measuring a flow rate of $2.3 \times 10^{-4}$ $m^3/s$ (29 $ft^3/hr$), and the air flowmeter $13.3 \times 10^{-4}$ $m^3/s$ (170 $ft^3/hr$). Measurements shall be accurate within 3 percent. A mass flow controller with recorded output shall be optional.

8.2.6.2.7 **Air**

The air supplied to the burner shall be compressed air, either bottled or supplied through a compressed-air system. Contaminants shall be filtered out of the air supply.

8.2.6.2.8 **Propane**

The gas supplied to the burner shall be CP-grade propane (99 percent pure) having a nominal heating value of 93.0 $MJ/m^3$ or 22.2 kilocalories (thermochemical)/$m^3$ [2500 Btu (thermochemical) /$ft^3$].

8.2.6.2.9 **Gas flows**

The propane flow shall be 220 ±8 $cm^3/s$ (28 ±1 $ft^3/hr$) when corrected to standard temperature and pressure (20°C, 101 kPa).

The airflow shall be 1280 ±80 $cm^3/s$ (163 ±10 $ft^3/hr$) when corrected to standard temperature and pressure.

8.2.6.2.10 **Smoke-measuring instruments**

The photometer system shall consist of a light source and photoelectric cell mounted on a horizontal section of the exhaust duct at a point at which the system is preceded by a straight run of duct that is at least twelve duct diameters or 4.88 m (16 ft) long, to ensure a nearly uniform velocity of flow across the duct cross-section. The light beam shall be directed horizontally along the diameter of the duct. A photoelectric cell whose output is directly proportional to the amount of light received shall be mounted over the light source and shall be connected to a recording device having an accuracy within ±1 percent of full scale for indicating changes in the attenuation of incident light resulting from the passage of smoke (particulate matter) and other effluents. The distance between the light-source lens and the photocell lens shall be 914 ±51 mm (36 ±2 inches). The cylindrical light beam shall pass through round openings 76 mm (3 inches) in diameter on opposite sides of the 406 mm (16 inches) duct, with the resultant light beam centered on the photocell.

The output signal from the photoelectric cell shall be processed into a continuous record of smoke obscuration, from which the optical density shall be calculated.

8.2.6.2.11 **Data acquisition**

A digital data-acquisition system shall be used to collect and record smoke and pressure measurements. The speed and capacity of the data system shall result in the collection of data every 5 s.

8.2.6.2.12 **Pretest calibration of equipment**

Prior to the start of each day of testing, the linearity of the photometer system shall be verified by interrupting the light beam with multiple calibrated neutral-density filters to cover the range of the recording instrument. Transmittance values measured by the photometer, using neutral-density filters, shall be within ± 3 percent of the calibrated value for each filter.

8.2.6.2.13 **Test specimens**

8.2.6.2.13.1 **Cable mounting**

Two sets of specimens of each cable construction shall be tested [see Clause 5.12.6.3(d) concerning the testing of a third set]. Each set shall consist of multiple 244 cm (96 inches) lengths of the finished cable. Depending upon the outside diameter of the individual cable, the test specimens shall be either separate, individual lengths or a bundle of individual lengths. The specimens or specimen bundles shall be centered between the side rails in a single layer. The lower end of each specimen or specimen bundle shall be located not more than 100 mm (4 inches) above the bottom end of the cable tray. Each specimen or specimen bundle shall be separately attached to each rung of the cable tray, using one wrap of copper or steel wire not larger than 2.08 $mm^2$ (14 AWG) in accordance with the following:

a) CABLES SMALLER THAN 13 mm: For cables smaller in diameter than 13 mm (0.51 inch), the specimens shall be grouped into untwisted bundles (nominally circular) as indicated in Table 37. The bundles shall be spaced one-half bundle diameter apart on the cable tray as measured at the point of attachment to the cable tray.

b) CABLES 13 mm AND LARGER: For cables 13 mm (0.51 inch) and larger in diameter, each specimen shall be individually attached to the cable tray with a separation of one-half cable diameter or 15 mm (0.59 inch) (whichever is less) between specimens. The tray loading shall comply with Table 38.

c) FLAT CABLES: For a flat cable, the equivalent cable diameter shall be calculated using the following formula:

$$D = 1.128 \times (TW)^{1/2}$$

where

D is the calculated cable diameter;

T is the length of the minor axis of the cable;

W is the length of the major axis of the cable.

8.2.6.2.13.2 **Conditioning**

Before the test is started, the test specimens shall be conditioned for at least 3 h in air whose temperature is 23 ±5°C (73 ±9°F). The test chamber shall be dry.

8.2.6.2.14 **Test procedure**

8.2.6.2.14.1 **Initial preparation**

At the start of the test, the lengths of cable in the tray, the apparatus, and the air in the test area shall be in thermal equilibrium with one another at a temperature of at least 5°C (41°F).

The pretest calibration procedure described in Clause 8.2.6.2.12 shall be performed.

Power shall be applied to the digital data-acquisition equipment and to the computer.

A nominal exhaust flow rate of 0.65 ±0.05 $m^3$/s (23.0 ±1.8 $ft^3$/s) shall be established in the duct.

8.2.6.2.14.2 **Procedure**

The prepared cable tray shall be positioned vertically inside the enclosure, with the open front of the cable tray facing the front of the enclosure. The cable tray shall be firmly secured in position.

The burner shall be ignited and the gas flows shall be adjusted to the values indicated in Clause 8.2.6.2.9. The burner shall be positioned in front of the cable tray at an angle of 20° and 75 ±5 mm (3.0 ±0.2 inches) from the nearest cable surface. See Figure 4 for the relative positions of the cable tray and burner in the room.

The burner flame shall impinge on the specimens for a continuous period of 20 min.

At the end of the 20 min burn, the burner flame shall be extinguished and the cable fire (if any) shall be allowed to burn itself out.

Note shall be taken and a record kept of the flame height during the 20 min test, as well as the time in seconds that the cables continue to flame following removal of the burner flame.

The test procedure shall be conducted on the number of sets of cable specimens specified. Each procedure (burn) shall be conducted on previously untested specimens.

8.2.6.2.14.3 **Evaluation of damage**

The maximum height of damage to the cables shall be determined by measuring the blistering, char, and other damage upward from the lower edge of the burner face, but ignoring soot that can be removed with a cloth, after the cables and tray have cooled to room temperature.

The limit of char shall be determined by pressing against a number of points on the cable surfaces with a sharp object. Where a cable surface (outer jacket, if any) changes from resilient to brittle (crumbling), the limit of char has been determined. Distortion of the outer surface of the cable, such as blistering or melting immediately above the char, shall be included in the damage measurement.

The cable damage shall be recorded to the nearest 25 mm (1 inch).

8.2.6.2.15 **Calculation of smoke release rate**

The smoke release rate (SRR) shall be calculated using the optical density per linear path length in the duct and the volumetric flow rate. The following equation shall be used to determine the SRR

$$SRR = \frac{(OD \times M_1)}{0.4064}$$

where

SRR is the smoke release rate in meters squared per second;

OD is the optical density;

$M_1$ is the volumetric flow rate (in cubic meters per second) in the exhaust duct referred to 298K;

0.4064 is the path length in the duct in meters.

8.2.6.2.16 **Report**

The test report shall contain the following summary information:

a) A description of each set of specimens tested: the cable type letters and component makeup and the number of cable lengths in the set;

b) The number of burns;

c) The date on which the test was conducted.

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

8.2.7.1 **Smoke emission**

8.2.7.1.1 **General**

This test establishes the method for determining the specific optical density and smoke obscuration generated by electrical conductors with an overall diameter no greater than 10 mm (0.40 inch) and in plaques 2 mm (0.08 inch) thick, for their individual components, and for cables with an overall diameter greater than 25.4 mm (1 inch).

8.2.7.1.2 **Apparatus and equipment**

The following apparatus shall be required:

a) Smoke density chamber, with integral or separate graphing capability (see Figure 5);

b) Insulated leather gloves;

c) Spatula;

d) Pliers;

e) Scissors;

f) Aluminum foil 0.038 ± 0.001 mm (0.0015 ±0.000040 inch) thick;

g) Flannel cloth;

h) Ethyl alcohol.

8.2.7.1.3 **Preparation of samples**

8.2.7.1.3.1 **Number of sets of samples**

A minimum of three sets of samples shall be required.

8.2.7.1.3.2 **Size**

The size of the specimens shall be adjusted to the dimensions of the trays used in the smoke chamber, which are cut squares 75 mm x 75 mm (3 inches x 3 inches), prepared in one of two of the following forms, as applicable:

a) A plaque 2 ±0.2 mm (0.08 ±0.008 inch) in thickness;

b) Samples from the finished product, with an overall diameter no greater than 10 mm (0.4 inch).

8.2.7.1.3.3 **Conditioning**

The test material shall be left in a dry environment for 24 h at 60 ±3°C (140 ±5°F) and afterwards set in balanced conditions at a room temperature of 23 ±3°C (73 ±5°F) and a relative humidity of 50 ± 5 percent.

8.2.7.1.3.4 **Mounting**

Place the test material in the tray in the following manner:

a) Wrap the sample with a sheet of aluminum foil, leaving the opaque part in contact with the sample.

b) Carefully cut the foil to leave free the surface that will be exposed during the test.

c) Place the inorganic thermal insulation plaque of the tray in the rear and adjust the sample with the clamp.

8.2.7.1.4 **Procedures**

8.2.7.1.4.1 **Preparation and start-up of equipment**

The following requirements shall apply:

a) Cleaning: the smoke chamber, and particularly the viewing area of the optical system, shall be free of contaminants and shall be cleaned using ethyl alcohol or other adequate cleaner.

b) Characteristics of gas: the gas provided to the chamber shall be a mixture of compressed air and propane having the following characteristics:

i) Filtered compressed air: for radiometric calibration of the electrical voltage of the oven, compressed air 0.103 – 0.172 MPa (710 – 1185 $lbf/in^2$) shall be required, to maintain the temperature of the radiometer casing at 93 ±3°C (200 ±5°F). During the test, a constant flow of 500 $cm^3$/min (30 $in^3$/min) shall be required.

ii) Propane that is 95 percent pure, maintaining its flow at 50 $cm^3$/min (3 $in^3$/min) inside the chamber over the course of the test, shall be required.

c) Sealing: close the smoke extraction system, the ventilation window, and the chamber door. Pressurize the chamber until reaching 7.62 cm (3 inches) of water, introducing air through the (flame air) duct (see [1] of Figure 5), and taking the measurement with a pressure gauge. Cut off the entrance of air and measure the time to lower the pressure to 5.08 cm (2 inches) water on the pressure gauge, which shall not take less than 5 min.

If the chamber does not adequately maintain pressure, the safety seal of aluminum foil shall be changed (see [2] of Figure 5).

d) Position of trays: the tray shall be placed in front of the oven, and shall contain the inorganic thermal insulation plaque only during the heating of the chamber.

e) Heating of the smoke chamber: in order to reach the test temperature in the chamber, perform the following:

i) Connect the equipment.

ii) Close the smoke extraction system (see [7] of Figure 5).

iii) Open the ventilation window (see [8] of Figure 5).

iv) Turn on the equipment switch (see [9] of Figure 5).

v) Close the lamp switch (see [5] of Figure 5).

vi) Turn on the microphotometer, placing the graphing pen at 100 percent transmittance, using the fine-adjustment knob. Variations in the adjustments are normal; therefore, before initiating the test, it shall be adjusted again to 100 percent.

vii) Close the heating switch (see [10] of Figure 5), and gradually heat using the electrical voltage adjustment knob (see [11] of Figure 5), until reaching the necessary corresponding voltage at the previous oven calibration, to obtain a radiation potency of 2.5 $\pm$0.05 $W/cm^2$ (16.1 $\pm$0.3 $W/in^2$).

viii) Once the aforementioned conditions are established, permit a minimum heating time of 1 h so that the measurement of the temperature of the chamber (see [12] of Figure 5); reaches 35 $\pm$2°C (95 $\pm$4°F), which is the test temperature.

8.2.7.1.4.2 **Calibration of optical system**

To calibrate the optical system, perform the following procedures:

a) Verify that the choke of the photomultiplier tube (see [3] of Figure 5) is closed, that the ND-2 filter (see [4] of Figure 5) is in position of the light trajectory, and that the lamp switch is closed (see [5] of Figure 5).

b) Verify that the positions of the photomultiplier switches (see [6] of Figure 5) are as follows:

i) Starter switch on;

ii) Multiplier switch set to 100;

iii) Relative intensity switch on.

c) Adjust to 0 percent transmittance on the scale, with the obscuration knob at zero, until reaching a stable zero reading in each one of the multiplier scales.

d) Reset the multiplier on 100.

e) Open the stopper of the photomultiplier tube.

f) Adjust one stable reading from 100 percent transmittance, using the relative intensity knob.

g) When the plotter is used (at 50 mV plus 100 scale), adjust the recorder that exists at the rear of the photomultiplier so that the reading of 100 is placed in the desired position on the plotter.

8.2.7.1.4.3 **Calibration of oven**

Once the temperature of the wall of the chamber reaches 35 ±2°C (95 ±4°F), calibrate the potency of radiation from the oven by using the radiometer in accordance with the following procedure:

a) Connect a high-impedance 10 mV meter or grapher to the contacts located on the switchboard (see [13] of Figure 5).

b) Place the radiometer on the support bars near the tray.

c) Place the thermometer on the radiometer.

d) Remove the top of the electrical connector from the radiometer on the floor of the chamber; connect the air tube from the radiometer and the electrical conductor to the appropriate connections.

e) Place the radiometer directly in front of the oven, setting aside the trays that contain the inorganic thermal insulation plaque, and close the door of the chamber.

f) When the thermometer reads between 81°C and 87°C (178°F and 189°F), open the air valve from the radiometer, adjusting the volume with the needle valve.

g) Stabilize the temperature to 93 ±3°C (200 ±5°F) and take the signal reading of the radiometer from the meter or grapher. This value shall be equal to the value specified in the inspection report provided by the radiometer supplier or to the re-calibration value, with a tolerance of ± 0.05 mV.

h) Turn the electrical voltage adjustment knob until the meter or grapher shows the value specified in Item g). After each adjustment, allow the desired reading to remain steady for 10 min.

i) When the millivolt level has been calibrated to ± 0.05 mV, and with the thermometer indicating 93 ±3°C (200 ±5°F), ensure that the radiation potency of the oven is equal to 2.5 $W/cm^2$ (16.1 $W/in^2$).

j) If necessary, vary the air flow and the oven's electrical voltage in order to achieve stability in oven radiation, maintaining the temperature at 93 ±3°C (200 ±5°F).

k) Record the air flow, the electrical voltage applied to the oven in volts, and the temperature of the chamber. Ensure that the voltage applied to the oven is kept steady during the entire test, until it is re-calibrated again.

l) Remove the radiometer from in front of the oven.

m) Shut off the air flow.

n) Remove the air connections from the radiometer and from the electrical conductor.

o) Remove the radiometer from the chamber.

p) Place the top back on the electrical conductor connection in the bottom of the chamber.

8.2.7.1.4.4 **Installation and lighting of the gas burner**

Perform the following procedures:

a) Center the trays having the inorganic thermal insulation plaque in front of the oven.

b) Connect the burner to the air/propane line of the chamber and tighten the connection.

c) Make sure that the position of the horizontal burners is 6.35 mm (0.25 inch) above the opening of the trays and is at a distance of 6.35 mm (0.25 inch) horizontally from the trays. Tighten the nut.

d) Open the valve of the burner (see [15] of Figure 5).

e) Light the burner and adjust the flow to 50 $cm^3$/min (3 $in^3$/min) and open the air valve of the burner until reaching 500 $cm^3$/min (30 $in^3$/min).

8.2.7.1.5 Test procedure

8.2.7.1.5.1 Before initiating the evaluation of one sample, verify the following:

a) The conditions of the smoke chamber are stable.

b) The oven and the burner or pilot have been calibrated, and the air/gas flows are in accordance with the values obtained during the calibration.

c) The preparation and mounting of the samples in the trays are completely vertical, to avoid erroneous results.

8.2.7.1.5.2 Initiate the test under the following procedure:

a) Turn the handle from the smoke extraction system to the closed position (See [16] of Figure 5).

b) Make sure that the ventilation window is completely closed when the photomultiplier indicates the presence of smoke.

**Note:** *The pressure increase in the chamber due to combustion changes the air and propane flows of the flame, making it necessary to readjust the values specified to maintain the correct flow.*

c) Place the trays with one or more test specimens with the inorganic thermal insulation plaque.

d) Push the tray with the test specimen(s) toward the front of the oven using the positioning knob (see [17] of Figure 5).

e) Immediately activate the grapher and close the door to the chamber.

f) Completely close the ventilation window when the photomultiplier indicates a reduction in the percentage of transmittance.

g) Upon the reduction of percentage of transmittance, increase the sensitivity of the microphotometer when the indicator is lowered to 10 percent, which will require making the change for each scale. If the level of transmittance falls to one-quarter scale, cover the window of the door to avoid effect in the measurement coming from the outside.

h) To record sensitivity under the 0.1 scale, take the following into account:

i) Change the photomultiplier to the 1 scale.

ii) Remove the ND-2 filter from the lighted trajectory.

iii) In the case where the 10 percent scale is reached, change the photomultiplier to the 0.1 scale

i) Continue the test for 3 minutes after the minimum transmittance, or after 20 minutes of testing, whichever occurs first.

8.2.7.1.5.3 To end the test, do the following:

a) Stop the plotter.

b) Return the scale to 100.

c) Purge the chamber by opening the smoke extraction system and the ventilation window.

d) Measure the final transmittance after purging and before cleaning the chamber.

e) Remove the trays when the smoke has been extracted and let them cool.

f) Allow the chamber to ventilate for a few minutes to make sure maximum transmittance has been achieved.

g) Clean the optical system windows with ethyl alcohol.

8.2.7.1.5.4 To test remaining samples, repeat the previous procedure.

When the results for any of the three sets of prepared samples are such that they exceed the minimum result by more than 50 percent without any apparent reason, three other sets of additional samples shall be tested, and the average of the six samples tested shall be reported.

If one or more of the three tests show any abnormal results, such as the sample falling from the tray, melted material totally covering the tray, spontaneous combustion, temporary extinguishing of the flame, or movement of the sample from the irradiation zone, three other sets of additional samples shall be tested, and in this case only the results of the tests that do not show these problems shall be reported.

8.2.7.1.6 **Calculations**

With the values of percent transmittance obtained from the graph during each minute of the test, the specific optical densities shall be determined, using Table 39.

The maximum specific optical density $D_m$ corresponds to the minimum percent transmittance.

The optical value at the first 4 minutes $VOF_4$ (smoke obscuration value) is calculated using the following formula:

$$VOF_4 = d_1 + d_2 + d_3 + \frac{d_4}{2}$$

where

$d_1$, $d_2$, $d_3$, and $d_4$ are the corresponding specific optical densities at each of the first 4 min.

8.2.7.2 **Fire propagation**

8.2.7.2.1 **Equipment and instruments**

8.2.7.2.1.1 **Chamber**

The dimensions of the chamber shall be in accordance with Figure 6, and shall contain the following:

a) Three doors, packed to provide a hermetic seal;

b) Windows installed in each of the doors;

c) Vents located at the lower ends of the lateral doors, which regulate air velocity;

d) Metallic structure that permits vertical sliding of the electrical oven in a manner that allows for 2 positions (upper and lower). Dimensions are illustrated in Figure 7 and Figure 8;

e) Extractor mounted in the upper end of the chamber, whose intake shall be located along the chamber axis;

f) Electrical oven comprising essentially a tube of aluminum silicate having an inside diameter of 100 ±3 mm (4 inches), an outside diameter of 115 ±3.5 mm (4-1/2 inches), and a length of 203 ±6 mm (8 inches), on which a 1.30 $mm^2$ (16 AWG) ceramic insulated nickel-chromium resistance wire is wound;

g) Power supply that delivers required current;

h) Two gas burners provided with a V-shaped deflector in accordance with Figure 9. The burners shall produce a flame 15 mm ±5 mm (0.6 ±0.2 inch) in diameter and a blue cone 20 mm ±5 mm (0.8 ±0.2 inch) in length, and shall be fixed in a mechanism that keeps a constant distance E in conformance with the test procedures;

i) Metallic chimney with an internal diameter of between 120 and 125 mm (4.8 and 5 inches) along the same axis as the oven, attached to the metallic structure and at 30 mm ±1 mm (1.2 ±0.04 inches) above the high position of the oven, and having three series of slots in the periphery, separated 120° as indicated in Figure 10;

j) Stainless steel tube with the dimensions indicated in Figure 11;

k) Thermometer to measure the temperature; a pyrometer with a range of 0 – 1200°C (32 – 2192°F) that includes an adequate thermocouple attached to the stainless steel tube shall be used;

l) Copper bar with 99 percent or greater purity and with measurements in accordance with Figure 12;

m) Insulation millboard that completely covers the upper end of the oven.

8.2.7.2.1.2 **Anemometer**

An anemometer shall be used for measurement of the velocity of air that passes through the chimney.

8.2.7.2.1.3 **Gas line**

A gas line shall be connected to the burners in the chamber.

8.2.7.2.1.4 **Chronometer**

A chronometer shall be used to measure time intervals.

8.2.7.2.2 **Calibration**

8.2.7.2.2.1 **General**

It is recommended that the oven be calibrated every six months, or sooner, depending on the frequency of use. During oven calibration and adjustment of air velocity, the air surrounding the chamber shall be calm and at a temperature greater than 15°C (60°F).

8.2.7.2.2.2 **Calibration of electrical oven**

To calibrate the oven, use the copper bar referred to in Clause 8.2.7.2.2.3. Suspend the bar from the metallic structure in such a way that, when the oven is at its high position, the bar is centered on the axis of the oven and has a temperature between 35°C and 55°C (95°F and 131°F). Slide the oven to its lower position, cover the upper end with the inorganic thermal insulation plaque, and heat it until the temperature measured with the thermocouple attached to the stainless steel bar is stabilized. Stabilization is logged when the temperature recorded does not vary by more than 5°C (9°F) in an hour.

Once the oven temperature has been stabilized, uncover the oven and slide it to its upper position in less than 5 s. Record the temperature rise on the reference bar at 5 s and 35 s. Calculate the rate of temperature rise with the following formula:

$$V = \frac{T_{35} - T_5}{K}$$

where

V is the rate of temperature rise, in °C/s;

$T_{35}$ is the recorded temperature after 35 s, in °C;

$T_5$ is the recorded temperature after 5 s, in °C;

K is the interval between the two measurements, in s = 30 s.

Ensure that the rate of temperature rise is equal to 3.3 ± 1°C/s (6 ± 2°F/s). If the calculated rate is not equal to this, modify the electrical supply of the oven and re-calculate until the correct value is obtained. Once the electrical supply is found to be adequate, re-attach the thermocouple to the stainless steel bar and drop the oven to its lower position.

The temperature that is reached when the oven is stabilized is the stabilized test temperature; it is generally greater than 780°C (1436°F).

8.2.7.2.2.3 **Reference bar**

The bar shall be copper greater than 99 percent pure, darkened on all its surface by applying various coats of colloidal graphite paint with a coefficient of emissivity greater than 0.80, or by applying various black layers of smoke by passing the bar over the flame of a candle at least 7 times. The construction of the bar and the thermocouple shall be in accordance with Figure 12.

8.2.7.2.2.4 **Adjusting the air velocity**

To measure the air velocity, an anemometer with an accuracy of ±3 percent and with fins having a diameter of 95 mm ±5 mm (3.74 ±0.2 inches) shall be used. The anemometer shall be placed between the bottom of the chimney and the oven in its high position (while it is turned off). The extractor shall be turned on and the lower vents regulated until a velocity of 120 ±10 m/min (394 ±33 ft/min) is established. The measurement of air velocity shall be the mean of three determinations, each one with a duration of 5 min, performed at 5 min intervals. The measurements shall be made 10 min after the extractor is turned on.

8.2.7.2.3 **Preparation of specimens**

Two identical specimens 1600 mm (63 inches) in length shall be prepared, constructed of one or various conductors of completed product in accordance with the following:

a) If the diameter of the conductor is larger than 25 mm (1 inch) and less than or equal to 70 mm (2.75 inches), the specimen shall consist solely of a conductor.

b) If the conductor diameter is greater than 15 mm (0.6 inch) and less than or equal to 25 mm (1 inch), the specimen shall be made up of three conductors tied, arranged in parallel, and held by metallic strands at each end, at a level in the middle of the oven and at a level in the middle part of the chimney. The specimen shall be arranged such that one of the conductors is placed toward the back side of the chamber, according to Figure 13.

c) If the diameter of the conductor is less than or equal to 15 mm (0.6 inch), the specimen shall be made up of 7, 12, 19, or more conductors tied together such that the total diameter of the bundle falls between 30 – 45 mm (1.2 – 1.75 inches). The bundle shall be twisted as tightly as possible such that the lay of twist is approximately 15 times the diameter of the bundle. It shall be held in accordance with Item b).

8.2.7.2.4 **Test procedure**

Use the following procedure:

a) It is very important, during testing, that the circulating air surrounding the chamber be calm and at a temperature greater than 15°C (60°F).

b) With the oven in the low position and the inorganic thermal insulation covering in place, apply heat until the stabilized temperature described in Clause 8.2.7.2.2.2 is reached.

c) Once having stabilized the oven, tighten the test specimen in a vertical position, with help from the suspension hooks.

d) Close the chimney, light the burners, and adjust the flame and distance E to the surface of the specimen as calculated by the following formula:

$$E = D + d + 10$$

where

E is the distance between the axes of the flame, in mm;

D is the diameter of the specimen, in mm;

d is the diameter of the flames, in mm.

e) Remove the inorganic thermal insulation plaque covering from the oven and slide the oven to its upper position in less than 5 s.

f) Turn on the extractor and start the chronometer.

g) After 10 min of initiating the test, turn off the extractor for 1 min, after which time, start the extractor again.

h) After 30 min, slide the oven to its lower position and turn it off, keeping the extractor on.

i) Turn off the burners and wait until any remaining flame on the specimen is extinguished.

8.2.7.2.5 **Results**

The specimens tested shall be inspected visually to determine the highest degradation from the bottom end of the chimney. It is very important to mark the specimen at the bottom of the chimney to serve as a reference.

Only the carbonized portion of the specimen shall be considered as having been degraded by the fire. Eventual deposits produced from combustion, as well as melting, softening, and blisters in the insulation caused by the flames and by heating of the conductor, shall be excluded.

If there is doubt as to whether a particular portion shall be taken into account, the specimen shall be cleaned; afterwards, a cut shall be made with a knife in the zone in question. If the insulation is broken or cracked, this shall be considered true damage, and shall be taken into account as a portion that is degraded.

8.2.7.3 **Halogen acid gas emission**

8.2.7.3.1 **Application and requirement**

When tested during pyrolysis in accordance with Clauses 8.2.7.3.2 through 8.2.7.3.5, each nonmetallic component of insulated conductor shall not be more than 20 percent (by weight) halogen acid gas (except hydrogen fluoride) when calculated as a corresponding percentage of HCl.

8.2.7.3.2 **Apparatus and equipment**

8.2.7.3.2.1 The apparatus and components are shown in Figure 14. A detailed illustration of the quartz combustion tube with means for entrance and exit of gases is shown in Figure 15.

8.2.7.3.2.2 Equipment and materials used to qualify gases collected in wash traps shall include the following:

a) 600 ml and 250 ml beakers;

b) Pipet;

c) Volume flask of 500 ml;

d) 5 ml or 10 ml pipets;

e) 100 ml volumetric pipets;

f) 300 ml Bersilius flask;

g) 25 ml graduated buret;

h) Universal support;

i) Pliers for buret;

j) Potentiometer (mV);

k) Measuring electrode (silver);

l) Calomel reference electrode;

m) Magnetic agitator;

n) Magnetic bar.

8.2.7.3.2.3 The reactants shall include:

a) Distilled water;

b) 0.1 Normal solution of sodium hydroxide (NaOH 0.1 N);

c) Concentrated nitric acid ($HNO_3$ 0.1 N);

d) 0.1 Normal solution of silver nitrate ($AgNO_3$ 0.1 N);

e) Chrome solution (dissolve 6 g potassium dichromate in a minimum amount of distilled water and afterward very carefully and slowly add 200 ml of concentrated sulfuric acid).

8.2.7.3.3 **Preparation of sample**

In order to perform this test, individual component material from the electrical conductor shall be analyzed, taking into account that the portion of this material has not been pre-treated or subjected to any testing.

A quantity of material sufficient for performing at least three tests shall be used.

Any contamination upon the test specimen shall be avoided.

8.2.7.3.4 **Procedure**

Use the following procedure:

a) Weigh 0.5 – 1 ±0.001 g of the sample into the crucible (combustion bay).

b) Install the systems for combustion and capturing of gases in accordance with Figure 14.

c) Insert the crucible (combustion bay) with the sample inside the combustion tube in such a way that it is aligned in the center of the oven.

d) Ensure that the wash traps (see item [12] of Figure 14) contain 100 ml of NaOH 0.1 N, and that the second and third traps are provided with a sinterized glass diffuser.

e) Initiate and stabilize the dry air flow through the system within 110 ±25 ml/min. Take special care to ensure that there are no leaks in the air system. This can be verified when no bubbles form in the packaging of the system when soapy water is applied to it with a brush. Regulate the air flow from the system with the flow controller, and measure the air flow by means of the flowmeter and the chronometer.

f) Install the heating element (see Figure 14) in the part of the system located between the combustion oven and the first trap of NaOH. Ensure that the heating element maintains a minimum temperature of 150°C on the surface of the glass ducting during the test.

g) Set the temperature of the oven to 800°C ±10°C within 20°C/min. Once this temperature is reached, maintain it for 20 min and afterward steady the heating system.

h) At the conclusion of the 20 min period, disconnect the wash flasks (wash traps) from the system, beginning with the one that is furthest from the oven.

i) Disconnect the dry air flow.

j) Allow the system to cool.

k) Remove the crucible (containing solid residue) from the combustion tube, not allowing the solid residue to contaminate the combustion tube.

l) Combine the contents in the wash traps into a volumetric flask of 500 ml.

m) Wash the inside of the combustion tube, the wash traps, and the system connections with distilled water, add this volume to the volume from the wash traps, and empty up to 500 ml in the volumetric flask.

n) Take an aliquot of the 100 ml of the problem solution obtained, placing it into a 300 ml Bersilius flask, and add 1 ml of concentrated nitric acid.

o) Using a potentiometer, titrate with 0.1 normal silver nitrate solution, steadily agitating during the entire titration.

p) Construct a graph on millimetric paper for each one of the specimens and null titrations, plotting milliliters on the X axis, and the millivolts recorded from the potentiometer on the Y axis.

q) For each specimen analyzed, tests equal to that of a blank test (i.e., without a sample) shall be performed in triplicate. Report the average of the three determinations.

8.2.7.3.5 **Calculations**

The quantity of halogen gas (H) shall be expressed in milligrams of hydrogen chloride per gram of sample, or as a percentage of hydrogen chloride follows:

$$H = \frac{36.5 \times (a-b) \times N \frac{V_f}{A}}{m}$$

$$\%HCl = \frac{36.5 \times (a-b) \times N \frac{V_f}{A}}{m \times 10}$$

where

a is the volume of silver nitrate solution used in the determination of the sample (in ml);

b is the volume of silver nitrate solution used in the null test (in ml);

N is the normality of the silver nitrate solution;

m is the mass of the sample (in grams);

$V_f$ is the volumetric flask (500 ml);

A is the aliquot (100 ml).

The volume of silver nitrate solution used in the determination (volume of silver nitrate at the point of equivalency) shall be obtained from the titration graph.

8.2.7.3.6 **Description of titration**

8.2.7.3.6.1 **Titration of the sample**

Graph 1 illustrates the typical titration curve. In Graph 2, achievement of the point of equivalency is observed (volume of silver nitrate solution assigned in the calculation).

8.2.7.3.6.2 **Null titration**

The achievement of a curve similar to the one shown in Graph 3 (undefined potential at the beginning of the curve) indicates the absence of halogens in the solution under analysis; in the initial part of the corresponding curve, therefore, there appears to be no defined potential, such as that which is clearly observed to the left of the point of equivalency in Graph 2.

**Notes:**

1) *For a rapid control test, the combustion tube may be preheated to* 800°C*, the air flow adjusted, and the crucible containing the specimen advanced slowly into the combustion area. The results of such a test serve only as a guide toward the intended value, not as precise values for the specimen under study.*

2) *Crucibles should be treated for* 2 h *at the maximum test temperature to be used and should not be employed for more than eight acid tests.*

3) *Cleaning of the sintered glass diffusers using chromic solution is optional.*

## Tables

**Table 1**
**Conductor Sizes and Stranding**
**(See Clauses 4.1.5.1, 6.1.3.1, and E2.)**

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

Table 1 Continued on Next Page

## Table 1 Continued

| Wire type | Metal | Conductor size range | | Assembly |
|---|---|---|---|---|
| | | mm² | AWG or kcmil | |
| | Aluminum | 3.31 – 1010 | 12 – 2000 | Concentric and compressed |
| | Aluminum | 3.31 – 507 | 12 – 1000 | Compact |
| | Aluminum | 3.31 – 107 | 12 – 4/0 | Solid |
| | Aluminum | 13.3 – 107 | 6 – 4/0 | Combination unilay |

## Table 2
## Conductor Stranding
## (See Clauses 4.1.5.2.1 and E2.)

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

[a] *Copper only.*

[b] *In the United States, conductors with a lesser number of strands shall be allowed, based on an evaluation for connectability and bending. In Canada and Mexico, this note does not apply.*

[c] *In Canada, single input wire strands shall be in accordance with ASTM B 835 and ASTM B 836. In the United States, conductors with a lesser number of strands shall be allowed, based on an evaluation for connectability and bending. In Mexico, conductors with a lesser number of strands shall be allowed.*

## Table 3
## Length of Lay of Strands in a Bunch-Stranded Conductor Twisted as a Single Bunch[a]
## (See Clause 4.1.5.2.4.)

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

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

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

**Table 4**
**Diameters over Solid Conductors and Cross-Sectional Area for All Solid and Stranded Conductors**
**(See Clause 4.1.6.1.)**

| Size of conductor | | Nominal diameter of solid conductor | | Nominal cross-sectional area of conductor | |
|---|---|---|---|---|---|
| $mm^2$ | AWG or kcmil | mm | mils | $mm^2$ | cmil or kcmil |
| 2.08 | 14 AWG | 1.63 | 64.1 | 2.08 | 4110 cmil |
| 3.31 | 12 | 2.05 | 80.8 | 3.31 | 6530 |
| 5.26 | 10 | 2.588 | 101.9 | 5.261 | 10380 |
| 8.37 | 8 | 3.264 | 128.5 | 8.37 | 16510 |
| 13.3 | 6 | 4.115 | 162.0 | 13.3 | 26240 |
| 21.2 | 4 | 5.189 | 204.3 | 21.2 | 41740 |
| 26.7 | 3 | 5.827 | 229.4 | 26.67 | 52620 |
| 33.6 | 2 | 6.543 | 257.6 | 33.6 | 66360 |
| 42.4 | 1 | 7.348 | 289.3 | 42.4 | 83690 |
| 53.5 | 1/0 | 8.252 | 324.9 | 53.5 | 105600 |
| 67.4 | 2/0 | 9.266 | 364.8 | 67.4 | 133100 |
| 85.0 | 3/0 | 10.40 | 409.6 | 85.0 | 167800 |
| 107 | 4/0 | 11.68 | 460.0 | 107 | 211600 |
| 127 | 250 kcmil | – | – | 127 | 250 kcmil |
| 152 | 300 | – | – | 152 | 300 |
| 177 | 350 | – | – | 177 | 350 |
| 203 | 400 | – | – | 203 | 400 |
| 228 | 450 | – | – | 228 | 450 |
| 253 | 500 | – | – | 253 | 500 |
| 279 | 550 | – | – | 279 | 550 |
| 304 | 600 | – | – | 304 | 600 |
| 329 | 650 | – | – | 329 | 650 |
| 355 | 700 | – | – | 355 | 700 |
| 380 | 750 | – | – | 380 | 750 |
| 405 | 800 | – | – | 405 | 800 |
| 456 | 900 | – | – | 456 | 900 |
| 507 | 1000 | – | – | 507 | 1000 |
| 557 | 1100 | – | – | 557 | 1100 |
| 608 | 1200 | – | – | 608 | 1200 |
| 633 | 1250 | – | – | 633 | 1250 |
| 659 | 1300 | – | – | 659 | 1300 |
| 709 | 1400 | – | – | 709 | 1400 |
| 760 | 1500 | – | – | 760 | 1500 |
| 811 | 1600 | – | – | 811 | 1600 |

Table 4 Continued on Next Page

## Table 4 Continued

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

## Table 5
## Diameters over Round Compact-Stranded Conductors
## (See Clause 4.1.6.1.)

| Conductor size | | Nominal diameter | |
|---|---|---|---|
| mm$^2$ | AWG or kcmil | mm | inch |
| 3.31 | 12 | 2.16 | 0.085 |
| 5.26 | 10 | 2.72 | 0.107 |
| 8.37 | 8 | 3.40 | 0.134 |
| 13.3 | 6 | 4.29 | 0.169 |
| 21.2 | 4 | 5.41 | 0.213 |
| 26.7 | 3 | 6.02 | 0.238 |
| 33.6 | 2 | 6.81 | 0.268 |
| 42.4 | 1 | 7.59 | 0.299 |
| 53.5 | 1/0 | 8.53 | 0.336 |
| 67.4 | 2/0 | 9.55 | 0.376 |
| 85.0 | 3/0 | 10.74 | 0.423 |
| 107 | 4/0 | 12.07 | 0.475 |
| 127 | 250 kcmil | 13.21 | 0.520 |
| 152 | 300 | 14.48 | 0.570 |
| 177 | 350 | 15.65 | 0.616 |
| 203 | 400 | 16.74 | 0.659 |
| 228 | 450 | 17.78 | 0.700 |
| 253 | 500 | 18.69 | 0.736 |
| 279 | 550 | 19.69 | 0.775 |
| 304 | 600 | 20.65 | 0.813 |
| 329 | 650 | 21.46 | 0.845 |
| 355 | 700 | 22.28 | 0.877 |
| 380 | 750 | 23.06 | 0.908 |
| 405 | 800 | 23.83 | 0.938 |
| 456 | 900 | 25.37 | 0.999 |
| 507 | 1000 | 26.92 | 1.060 |

**Table 6**
**Diameters over Round Compressed Concentric-Lay-Stranded Conductors for Classes B, C, and D**
**(See Clauses 4.1.6.1 and 4.1.6.2.)**

| Conductor size | | Nominal diameter | |
|---|---|---|---|
| $mm^2$ | AWG or kcmil | mm | inches |
| 2.08 | 14 AWG | 1.80 | 0.071 |
| 3.31 | 12 | 2.26 | 0.089 |
| 5.26 | 10 | 2.87 | 0.113 |
| 8.37 | 8 | 3.61 | 0.142 |
| 13.3 | 6 | 4.52 | 0.178 |
| 21.2 | 4 | 5.72 | 0.225 |
| 26.7 | 3 | 6.40 | 0.252 |
| 33.6 | 2 | 7.19 | 0.283 |
| 42.4 | 1 | 8.18 | 0.322 |
| 53.5 | 1/0 | 9.19 | 0.362 |
| 67.4 | 2/0 | 10.3 | 0.405 |
| 85.0 | 3/0 | 11.6 | 0.456 |
| 107 | 4/0 | 13.0 | 0.512 |
| 127 | 250 kcmil | 14.2 | 0.558 |
| 152 | 300 | 15.5 | 0.611 |
| 177 | 350 | 16.8 | 0.661 |
| 203 | 400 | 17.9 | 0.706 |
| 226 | 450 | 19.0 | 0.749 |
| 253 | 500 | 20.0 | 0.789 |
| 279 | 550 | 21.1 | 0.829 |
| 304 | 600 | 22.0 | 0.866 |
| 329 | 650 | 22.9 | 0.901 |
| 355 | 700 | 23.7 | 0.935 |
| 380 | 750 | 24.6 | 0.968 |
| 405 | 800 | 25.4 | 1.000 |
| 456 | 900 | 26.9 | 1.060 |
| 507 | 1000 | 28.4 | 1.117 |
| 557 | 1100 | 29.8 | 1.173 |
| 608 | 1200 | 31.1 | 1.225 |
| 633 | 1250 | 31.8 | 1.250 |
| 659 | 1300 | 32.4 | 1.275 |
| 709 | 1400 | 33.6 | 1.323 |
| 760 | 1500 | 34.8 | 1.370 |
| 811 | 1600 | 35.9 | 1.415 |
| 861 | 1700 | 37.1 | 1.459 |
| 887 | 1750 | 37.6 | 1.480 |
| 912 | 1800 | 38.2 | 1.502 |
| 963 | 1900 | 39.2 | 1.542 |
| 1010 | 2000 | 40.2 | 1.583 |

## Table 7
## Diameters over Round Compressed Unidirectional or Unilay-Stranded Conductors for Class B
## (See Clause 4.1.6.1.)

| Conductor size | | Nominal diameter | |
|---|---|---|---|
| $mm^2$ | AWG | mm | inches |
| 42.4 | 1 AWG | 7.95 | 0.313 |
| 53.5 | 1/0 | 8.94 | 0.352 |
| 67.4 | 2/0 | 10.03 | 0.395 |
| 85.0 | 3/0 | 11.25 | 0.443 |
| 107 | 4/0 | 12.65 | 0.498 |
| 127 | 250 kcmil | 13.77 | 0.542 |
| 152 | 300 | 15.09 | 0.594 |
| 177 | 350 | 16.28 | 0.641 |
| 203 | 400 | 17.40 | 0.685 |
| 226 | 450 | 18.47 | 0.727 |
| 253 | 500 | 19.46 | 0.766 |
| 279 | 550 | 20.42 | 0.804 |
| 304 | 600 | 21.34 | 0.840 |
| 329 | 650 | 22.20 | 0.874 |
| 355 | 700 | 23.04 | 0.907 |
| 380 | 750 | 23.85 | 0.939 |
| 405 | 800 | 24.61 | 0.969 |
| 456 | 900 | 26.11 | 1.028 |
| 507 | 1000 | 27.53 | 1.084 |
| 557 | 1100 | 28.88 | 1.137 |
| 608 | 1200 | 30.15 | 1.187 |
| 633 | 1250 | 30.78 | 1.212 |
| 659 | 1300 | 31.39 | 1.236 |
| 709 | 1400 | 32.56 | 1.282 |
| 760 | 1500 | 33.71 | 1.327 |
| 811 | 1600 | 34.82 | 1.371 |
| 861 | 1700 | 35.89 | 1.413 |
| 887 | 1750 | 36.42 | 1.434 |
| 912 | 1800 | 33.71 | 1.327 |
| 963 | 1900 | 37.95 | 1.494 |
| 1010 | 2000 | 38.94 | 1.533 |

**Table 8**
**Diameter over Round Concentric-Lay-Stranded Conductors for Classes B, C, and D**
**(See Clause 4.1.6.1.)**

| Conductor size | | Nominal diameter | |
|---|---|---|---|
| $mm^2$ | AWG or kcmil | mm | inches |
| 2.08 | 14 AWG | 1.85 | 0.0727 |
| 3.31 | 12 | 2.32 | 0.0915 |
| 5.26 | 10 | 2.95 | 0.116 |
| 8.37 | 8 | 3.71 | 0.146 |
| 13.3 | 6 | 4.67 | 0.184 |
| 21.2 | 4 | 5.89 | 0.232 |
| 26.7 | 3 | 6.60 | 0.260 |
| 33.6 | 2 | 7.42 | 0.292 |
| 42.4 | 1 | 8.43 | 0.332 |
| 53.5 | 1/0 | 9.45 | 0.372 |
| 67.4 | 2/0 | 10.62 | 0.418 |
| 85.0 | 3/0 | 11.94 | 0.470 |
| 107 | 4/0 | 13.41 | 0.528 |
| 127 | 250 kcmil | 14.6 | 0.575 |
| 152 | 300 | 16.00 | 0.630 |
| 177 | 350 | 17.30 | 0.681 |
| 203 | 400 | 18.49 | 0.728 |
| 228 | 450 | 19.61 | 0.772 |
| 253 | 500 | 20.65 | 0.813 |
| 279 | 550 | 21.72 | 0.855 |
| 304 | 600 | 22.68 | 0.893 |
| 329 | 650 | 23.60 | 0.929 |
| 355 | 700 | 24.49 | 0.964 |
| 380 | 750 | 25.35 | 0.998 |
| 405 | 800 | 26.16 | 1.030 |
| 456 | 900 | 27.79 | 1.094 |
| 507 | 1000 | 29.26 | 1.152 |
| 557 | 1100 | 30.71 | 1.209 |
| 608 | 1200 | 32.08 | 1.263 |
| 633 | 1250 | 32.74 | 1.289 |
| 659 | 1300 | 33.38 | 1.314 |
| 709 | 1400 | 34.67 | 1.365 |
| 760 | 1500 | 35.86 | 1.412 |
| 811 | 1600 | 37.06 | 1.459 |
| 861 | 1700 | 38.20 | 1.504 |

Table 8 Continued on Next Page

## Table 8 Continued

| Conductor size | | Nominal diameter | |
|---|---|---|---|
| $mm^2$ | AWG or kcmil | mm | inches |
| 887 | 1750 | 38.76 | 1.526 |
| 912 | 1800 | 39.32 | 1.548 |
| 963 | 1900 | 40.39 | 1.590 |
| 1010 | 2000 | 41.45 | 1.632 |

## Table 9
## Strand and Conductor Dimensions for 19-Wire Combination Round-Wire Unilay-Stranded Conductors
## (See Clause 4.1.6.1.)

| Conductor size | | Nominal strand dimensions | | | | | | | | Nominal conductor diameter E = 3A + 2C | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Large strand | | | | Small strand | | | | | |
| | | Diameter (A) | | Cross-sectional area | | Diameter (C) | | Cross-sectional area | | | |
| $mm^2$ | AWG | mm | inch | $mm^2$ | cmil | mm | inch | $mm^2$ | cmil | mm | inch |
| 2.08 | 14 | 0.4 | 0.0159 | 0.128 | 253 | 0.3 | 0.0117 | 0.069 | 137 | 1.80 | 0.071 |
| 3.31 | 12 | 0.5 | 0.0210 | 0.223 | 441 | 0.4 | 0.0147 | 0.110 | 217 | 2.29 | 0.090 |
| 5.26 | 10 | 0.6 | 0.0253 | 0.324 | 640 | 0.5 | 0.0185 | 0.173 | 342 | 2.87 | 0.113 |
| 8.37 | 8 | 0.8 | 0.0319 | 0.515 | 1018 | 0.6 | 0.0234 | 0.277 | 548 | 3.63 | 0.143 |
| 13.3 | 6 | 1.0 | 0.0402 | 0.818 | 1616 | 0.7 | 0.0294 | 0.437 | 864 | 4.55 | 0.179 |
| 21.2 | 4 | 1.3 | 0.0507 | 1.301 | 2570 | 0.9 | 0.0371 | 0.696 | 1376 | 5.74 | 0.226 |
| 26.7 | 3 | 1.4 | 0.0570 | 1.644 | 3249 | 1.1 | 0.0417 | 0.880 | 1739 | 6.45 | 0.254 |
| 33.6 | 2 | 1.6 | 0.0640 | 2.073 | 4096 | 1.2 | 0.0468 | 1.108 | 2190 | 7.26 | 0.286 |
| 42.4 | 1 | 1.8 | 0.0718 | 2.609 | 5155 | 1.3 | 0.0526 | 1.400 | 2767 | 8.15 | 0.321 |
| 53.5 | 1/0 | 2.1 | 0.0807 | 3.296 | 6512 | 1.5 | 0.0591 | 1.768 | 3493 | 9.14 | 0.360 |
| 67.4 | 2/0 | 2.3 | 0.0906 | 4.154 | 8208 | 1.7 | 0.0663 | 2.225 | 4396 | 10.26 | 0.404 |
| 85.0 | 3/0 | 2.6 | 0.1017 | 5.234 | 10343 | 1.9 | 0.0745 | 2.809 | 5550 | 11.53 | 0.454 |
| 107 | 4/0 | 2.9 | 0.1142 | 6.600 | 13042 | 2.1 | 0.0836 | 3.537 | 6989 | 12.95 | 0.510 |

## Table 10
## Insulation Thickness,
## Average and Minimum at Any Point
## (See Clauses 4.2.4 and 7.2.2.)

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

## Table 11
## Physical Properties of PVC Insulation
## (See Clauses 4.2.5.1.1, 4.2.5.3.2, and 4.2.5.3.3.)

<table>
<tr><th>Minimum properties</th><th>TW, TWU</th><th>TWU75</th><th>THW or TW75</th><th>THW-2</th><th>THW-LS</th><th>THHW, THHN, THWN-2, THHW-LS, T90 Nylon</th><th>THWN or TWN75</th></tr>
<tr><td>Before aging:<br>Tensile strength, MPa (lbf/in²)</td><td>10.3 (1500)</td><td colspan="2">12.4 (1800)</td><td colspan="4">13.8 (2000)</td></tr>
<tr><td>Elongation, percent, minimum increase in distance between 25 mm (1 inch) gauge marks</td><td>100</td><td colspan="6">150</td></tr>
<tr><td>After aging:<br>at 100°C, 7d</td><td colspan="7"></td></tr>
<tr><td>Retention of tensile strength, percent</td><td>Min. 65</td><td colspan="6">–</td></tr>
<tr><td>Retention of elongation, percent</td><td>65/45[a]</td><td colspan="6">–</td></tr>
<tr><td>After aging:<br>at 121°C, 7d</td><td colspan="7"></td></tr>
<tr><td>Retention of tensile strength, percent</td><td>–</td><td colspan="2">75</td><td>–</td><td>75</td><td>–</td><td>75</td></tr>
<tr><td>Retention of elongation, percent</td><td>–</td><td colspan="2">65/45[a]</td><td>–</td><td>65/45[a]</td><td>–</td><td>65/45[a]</td></tr>
<tr><td>After aging:<br>at 136°C, 7d</td><td colspan="7"></td></tr>
<tr><td>Retention of tensile strength, percent</td><td colspan="3">–</td><td>75</td><td>–</td><td>75</td><td>–</td></tr>
<tr><td>Retention of elongation, percent</td><td colspan="3">–</td><td>65/45[a]</td><td>–</td><td>65/45[a]</td><td>–</td></tr>
</table>

Table 11 Continued on Next Page

## Table 11 Continued

| Minimum properties | TW, TWU | TWU75 | THW or TW75 | THW-2 | THW-LS | THHW, THHN, THWN-2, THHW-LS, T90 Nylon | THWN or TWN75 |
|---|---|---|---|---|---|---|---|
| [a] *The 45 percent applies only to samples aged in die-cut form.* | | | | | | | |

## Table 12
## Worksheet for Determination of Physical Properties of Insulation Having Characteristics Different from Those Indicated in Table 11[a]
## (See Clause 4.2.5.3.4.)

| Condition of specimens at time of measurement | Minimum ultimate elongation (25 mm (1 inch) benchmarks) | Minimum tensile strength |
|---|---|---|
| Unaged | b | b |
| Insulation from wires rated 90°C (covering, if present, removed before aging):<br>Aged in a full-draft circulating-air oven for 168 h at 136 ± 1° C | b | b |
| Insulation from wires rated 75°C (covering, if present, removed before aging):<br>Aged in a full-draft circulating-air oven for 168 h at 121 ± 1° C | b | b |
| Insulation from wires rated 60°C (covering, if present, removed before aging):<br>Aged in a full-draft circulating-air oven for 168 h at 100 ± 1° C | b | b |

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

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

## Table 13
## Thickness of Jacket over Types THHN, THWN, TWN75, THWN-2, and T90 Nylon
## (See Clause 4.3.2.)

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

**Table 14**
**Maximum Direct-Current Resistance at 20°C of Solid Conductors of Aluminum and Bare Copper**
**(See Clauses 5.2 and E3.)**

| Size of conductor | | Aluminum | | Bare copper | |
|---|---|---|---|---|---|
| mm$^2$ | AWG | Ohms per km | Ohms per 1000 ft | Ohms per km | Ohms per 1000 ft |
| 2.08 | 14 | – | – | 8.45 | 2.57 |
| 3.31 | 12 | 8.71 | 2.65 | 5.31 | 1.62 |
| 5.26 | 10 | 5.48 | 1.67 | 3.34 | 1.02 |
| 8.37 | 8 | 3.45 | 1.05 | 2.10 | 0.641 |
| 13.3 | 6 | 2.17 | 0.661 | 1.32 | 0.403 |
| 21.2 | 4 | 1.36 | 0.416 | 0.832 | 0.254 |
| 26.7 | 3 | 1.08 | 0.330 | 0.660 | 0.201 |
| 33.6 | 2 | 0.857 | 0.261 | 0.523 | 0.159 |
| 42.4 | 1 | 0.680 | 0.207 | 0.415 | 0.126 |
| 53.5 | 1/0 | 0.539 | 0.164 | 0.329 | 0.100 |
| 67.4 | 2/0 | 0.428 | 0.130 | 0.261 | 0.0795 |
| 85.0 | 3/0 | 0.339 | 0.103 | 0.207 | 0.0631 |
| 107 | 4/0 | 0.269 | 0.0820 | 0.16 | 0.0500 |

**Table 15**
**Maximum Direct-Current Resistance at 20°C of Aluminum and Bare Copper Conductors – Concentric-Stranded Classes B, C, and D; Compact-Stranded; and Compressed-Stranded**
**(See Clauses 5.2 and E3.)**

| Size of conductor | | Aluminum | | Bare copper | |
|---|---|---|---|---|---|
| mm$^2$ | AWG or kcmil | Ohms per km | Ohms per 1000 ft | Ohms per km | Ohms per 1000 ft |
| 2.08 | 14 AWG | – | – | 8.62 | 2.62 |
| 3.31 | 12 | 8.88 | 2.71 | 5.43 | 1.65 |
| 5.26 | 10 | 5.59 | 1.70 | 3.41 | 1.04 |
| 8.37 | 8 | 3.52 | 1.07 | 2.14 | 0.653 |
| 13.3 | 6 | 2.21 | 0.674 | 1.35 | 0.411 |
| 21.2 | 4 | 1.39 | 0.424 | 0.848 | 0.259 |
| 26.7 | 3 | 1.10 | 0.336 | 0.673 | 0.205 |
| 33.6 | 2 | 0.875 | 0.267 | 0.534 | 0.163 |
| 42.4 | 1 | 0.693 | 0.211 | 0.423 | 0.130 |
| 53.5 | 1/0 | 0.550 | 0.168 | 0.335 | 0.102 |
| 67.4 | 2/0 | 0.436 | 0.133 | 0.266 | 0.0811 |
| 85.0 | 3/0 | 0.346 | 0.106 | 0.211 | 0.0643 |
| 107 | 4/0 | 0.274 | 0.0836 | 0.167 | 0.0510 |
| 127 | 250 kcmil | 0.232 | 0.0708 | 0.142 | 0.0432 |
| 152 | 300 | 0.194 | 0.0590 | 0.118 | 0.0360 |
| 177 | 350 | 0.166 | 0.0505 | 0.101 | 0.0308 |
| 203 | 400 | 0.145 | 0.0442 | 0.0885 | 0.0270 |
| 228 | 450 | 0.129 | 0.0393 | 0.0787 | 0.0240 |
| 253 | 500 | 0.116 | 0.0354 | 0.0709 | 0.0216 |

Table 15 Continued on Next Page

## Table 15 Continued

| Size of conductor | | Aluminum | | Bare copper | |
|---|---|---|---|---|---|
| mm$^2$ | AWG or kcmil | Ohms per km | Ohms per 1000 ft | Ohms per km | Ohms per 1000 ft |
| 279 | 550 | 0.106 | 0.0322 | 0.0644 | 0.0196 |
| 304 | 600 | 0.0967 | 0.0295 | 0.0590 | 0.0180 |
| 329 | 650 | 0.0893 | 0.0272 | 0.0545 | 0.0166 |
| 355 | 700 | 0.0829 | 0.0253 | 0.0506 | 0.0154 |
| 380 | 750 | 0.0774 | 0.0236 | 0.0472 | 0.0144 |
| 405 | 800 | 0.0725 | 0.0221 | 0.0443 | 0.0135 |
| 456 | 900 | 0.0645 | 0.0197 | 0.0393 | 0.0120 |
| 507 | 1000 | 0.0580 | 0.0177 | 0.0354 | 0.0108 |
| 557 | 1100 | 0.0528 | 0.0161 | 0.0322 | 0.00981 |
| 608 | 1200 | 0.0484 | 0.0147 | 0.0295 | 0.00899 |
| 633 | 1250 | 0.0464 | 0.0142 | 0.0283 | 0.00863 |
| 659 | 1300 | 0.0447 | 0.0136 | 0.0272 | 0.00823 |
| 709 | 1400 | 0.0415 | 0.0126 | 0.0253 | 0.00771 |
| 760 | 1500 | 0.0387 | 0.0118 | 0.0236 | 0.00719 |
| 811 | 1600 | 0.0363 | 0.0111 | 0.0221 | 0.00674 |
| 861 | 1700 | 0.0341 | 0.0104 | 0.0208 | 0.00635 |
| 887 | 1750 | 0.0332 | 0.0101 | 0.0202 | 0.00617 |
| 912 | 1800 | 0.0322 | 0.00983 | 0.0197 | 0.00600 |
| 963 | 1900 | 0.0306 | 0.00931 | 0.0186 | 0.00568 |
| 1010 | 2000 | 0.0290 | 0.00884 | 0.0177 | 0.00540 |

**Note:** *Nominal strand configuration and number of wires are found in ASTM B 8 or NMX-J-012-ANCE for copper conductors, and ASTM B 231 or NMX-J-032-ANCE for aluminum conductors.*

## Table 16
## Maximum Direct-Current Resistance at 20°C of Copper Conductors, Concentric-Stranded Class B with Each Strand Coated with Tin or a Tin Alloy and Compressed-Stranded Class B with Each Strand Coated
## (See Clause 5.2.)

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

Table 16 Continued on Next Page

## Table 16 Continued

| Size of conductor | | | |
|---|---|---|---|
| mm² | AWG or kcmil | Ohms per km | Ohms per 1000 ft |
| 67.4 | 2/0 | 0.277 | 0.0843 |
| 85.0 | 3/0 | 0.219 | 0.0669 |
| 107 | 4/0 | 0.172 | 0.0525 |
| 127 | 250 kcmil | 0.147 | 0.0449 |
| 152 | 300 | 0.123 | 0.0374 |
| 177 | 350 | 0.105 | 0.0320 |
| 203 | 400 | 0.0911 | 0.0278 |
| 228 | 450 | 0.0810 | 0.0247 |
| 253 | 500 | 0.0729 | 0.0222 |
| 279 | 550 | 0.0669 | 0.0204 |
| 304 | 600 | 0.0614 | 0.0187 |
| 329 | 650 | 0.0561 | 0.0171 |
| 355 | 700 | 0.0520 | 0.0159 |
| 380 | 750 | 0.0486 | 0.0148 |
| 405 | 800 | 0.0455 | 0.0139 |
| 456 | 900 | 0.0405 | 0.0123 |
| 507 | 1000 | 0.0364 | 0.0111 |
| 557 | 1100 | 0.0331 | 0.0101 |
| 608 | 1200 | 0.0303 | 0.00925 |
| 633 | 1250 | 0.0292 | 0.00888 |
| 659 | 1300 | 0.0280 | 0.00854 |
| 709 | 1400 | 0.0260 | 0.00793 |
| 760 | 1500 | 0.0243 | 0.00740 |
| 811 | 1600 | 0.0228 | 0.00694 |
| 861 | 1700 | 0.0214 | 0.00653 |
| 887 | 1750 | 0.0208 | 0.00635 |
| 912 | 1800 | 0.0202 | 0.00617 |
| 963 | 1900 | 0.0192 | 0.00584 |
| 1010 | 2000 | 0.0182 | 0.00555 |

**Note:** *Nominal strand configuration and number of wires are found in ASTM B 8 or NMX-J-012-ANCE.*

## Table 17
## Maximum Direct-Current Resistance at 20°C of Copper Conductors Concentric-Stranded Classes C and D with Each Strand Coated with Tin or a Tin Alloy and Compressed-Stranded Classes C and D with Each Strand Coated
## (See Clause 5.2.)

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

**Note:** *Nominal strand configuration and number of wires are found in ASTM B 8 or NMX-J-012-ANCE.*

**Table 18**
**Maximum Direct-Current Resistance at 20°C of 19-Wire Combination Round-Wire Unilay-Stranded Copper Conductors**
**(See Clause 5.2.)**

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

**Table 19**
**Maximum Direct-Current Resistance at 20°C of 19-Wire Combination Round-Wire Unilay-Stranded Aluminum Conductors**
**(See Clause 5.2.)**

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

## Table 20
## Maximum Direct-Current Resistance at 20°C of Solid Copper Conductors Coated with Tin or a Tin Alloy
## (See Clause 5.2.)

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

## Table 21
## Maximum Direct-Current Resistance at 20°C of Class G Stranded Conductors
## (See Clause 5.2.)

| Size of conductor | | Bare copper | | Coated copper (each strand coated with tin or a tin alloy) | | Aluminum | |
|---|---|---|---|---|---|---|---|
| $mm^2$ | AWG or kcmil | Ohms per km | Ohms per 1000 ft | Ohms per km | Ohms per 1000 ft | Ohms per km | Ohms per 1000 ft |
| 2.08 | 14 AWG | 8.70 | 2.65 | 9.24 | 2.82 | – | – |
| 3.31 | 12 | 5.48 | 1.67 | 5.81 | 1.77 | – | – |
| 5.26 | 10 | 3.45 | 1.05 | 3.66 | 1.11 | – | – |
| 8.37 | 8 | 2.16 | 0.660 | 2.30 | 0.701 | – | – |
| 13.3 | 6 | 1.37 | 0.415 | 1.42 | 0.431 | 2.23 | 0.680 |
| 21.2 | 4 | 0.857 | 0.261 | 0.890 | 0.271 | 1.41 | 0.428 |
| 26.7 | 3 | 0.679 | 0.207 | 0.707 | 0.215 | 1.11 | 0.340 |
| 33.6 | 2 | 0.539 | 0.164 | 0.560 | 0.170 | 0.883 | 0.369 |
| 42.4 | 1 | 0.431 | 0.132 | 0.449 | 0.137 | 0.707 | 0.215 |
| 53.5 | 1/0 | 0.342 | 0.104 | 0.355 | 0.108 | 0.560 | 0.170 |
| 67.4 | 2/0 | 0.271 | 0.0826 | 0.282 | 0.0860 | 0.445 | 0.136 |
| 85.0 | 3/0 | 0.215 | 0.0656 | 0.223 | 0.0681 | 0.353 | 0.107 |
| 107 | 4/0 | 0.170 | 0.0520 | 0.177 | 0.0541 | 0.279 | 0.0853 |
| 127 | 250 kcmil | 0.145 | 0.0443 | 0.151 | 0.0460 | 0.238 | 0.0725 |
| 152 | 300 | 0.121 | 0.0368 | 0.125 | 0.0384 | 0.198 | 0.0604 |
| 177 | 350 | 0.104 | 0.0316 | 0.108 | 0.0328 | 0.170 | 0.0518 |
| 203 | 400 | 0.0917 | | | | | |

Table 21 Continued on Next Page

## Table 21 Continued

| Size of conductor | | Bare copper | | Coated copper (each strand coated with tin or a tin alloy) | | Aluminum | |
|---|---|---|---|---|---|---|---|
| $mm^2$ | AWG or kcmil | Ohms per km | Ohms per 1000 ft | Ohms per km | Ohms per 1000 ft | Ohms per km | Ohms per 1000 ft |
| 226 | 450 | 0.0806 | 0.0246 | 0.0838 | 0.0255 | 0.132 | 0.0403 |
| 253 | 500 | 0.0725 | 0.0221 | 0.0755 | 0.0230 | 0.119 | 0.0362 |
| 279 | 550 | 0.0663 | 0.0202 | 0.0690 | 0.0210 | 0.108 | 0.0332 |
| 304 | 600 | 0.0607 | 0.0186 | 0.0631 | 0.0193 | 0.0996 | 0.0304 |
| 329 | 650 | 0.0561 | 0.0171 | 0.0583 | 0.0177 | 0.0919 | 0.0280 |
| 355 | 700 | 0.0520 | 0.0159 | 0.0542 | 0.0165 | 0.0834 | 0.0260 |
| 380 | 750 | 0.0486 | 0.0148 | 0.0505 | 0.0154 | 0.0797 | 0.0243 |
| 405 | 800 | 0.0456 | 0.0139 | 0.0473 | 0.0145 | 0.0747 | 0.0227 |
| 456 | 900 | 0.0405 | 0.0123 | 0.0421 | 0.0129 | 0.0664 | 0.0202 |
| 507 | 1000 | 0.0364 | 0.0111 | 0.0379 | 0.0115 | 0.0598 | 0.0183 |
| 557 | 1100 | 0.0332 | 00.0101 | 0.0345 | 0.0105 | 0.0543 | 0.0165 |
| 608 | 1200 | 0.0304 | 0.00926 | 0.0316 | 0.00963 | 0.0498 | 0.0152 |
| 633 | 1250 | 0.0292 | 0.00888 | 0.0303 | 0.00924 | 0.0478 | 0.0146 |
| 659 | 1300 | 0.0280 | 0.00855 | 0.0292 | 0.00888 | 0.0460 | 0.0140 |
| 709 | 1400 | 0.0260 | 0.00794 | 0.0270 | 0.00825 | 0.0426 | 0.0131 |
| 760 | 1500 | 0.0243 | 0.00741 | 0.0253 | 0.00770 | 0.0398 | 0.0121 |
| 811 | 1600 | 0.0230 | 0.00701 | 0.0239 | 0.00729 | 0.0377 | 0.0115 |
| 861 | 1700 | 0.0216 | 0.00660 | 0.0225 | 0.00686 | 0.0355 | 0.0108 |
| 887 | 1750 | 0.0210 | 0.00641 | 0.0218 | 0.00666 | 0.0345 | 0.0105 |
| 912 | 1800 | 0.0204 | 0.00623 | 0.0212 | 0.00648 | 0.0335 | 0.0102 |
| 963 | 1900 | 0.0194 | 0.00591 | 0.0201 | 0.00614 | 0.0317 | 0.00968 |
| 1010 | 2000 | 0.0184 | 0.00561 | 0.0192 | 0.00583 | 0.0302 | 0.00919 |

**Note:** *Nominal strand configuration and number of wires are found in ASTM B 173 or NMX-J-013-ANCE.*

## Table 22
## Maximum Direct-Current Resistance at 20°C of Class M Stranded Conductors
## (See Clause 5.2.)

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

**Note:** *Nominal strand configuration and number of wires are found in ASTM B 172 or NMX-J-014-ANCE.*

**Table 23**
**Minimum Insulation Resistance at Elevated Temperature in Water**
**(See Clauses 5.4, 5.5.1.1, and 5.5.2.)**

| Conductor size | | GΩ·m | | | | | MΩ·1000 ft | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| mm² | AWG or kcmil | 50 or 60°C test | | 75 or 90°C test | | | 50 or 60°C test | | 75 or 90°C test | | |
| | | TW | TWU | TWU75 (75°C test) | THW[a], THW-LS, THHW, THHW-LS or TW75 (75°C test), THW-2 (90°C test) | Type THWN or TWN75 (75°C test), THWN-2 (90°C test) | TW | TWU | TWU75 (75°C test) | THW[a], THW-LS, THHW, THHW-LS or TW75 (75°C test), THW-2 (90°C test) | Type THWN or TWN75 (75°C test), THWN-2 (90°C test) |
| 2.08 | 14 AWG | 0.030 | 0.042 | 0.042 | 0.120 | 0.035 | 0.095 | 0.138 | 0.138 | 0.380 | 0.115 |
| 3.31 | 12 | 0.025 | 0.036 | 0.036 | 0.100 | 0.030 | 0.080 | 0.118 | 0.118 | 0.320 | 0.095 |
| 5.26 | 10 | 0.025 | 0.030 | 0.030 | 0.085 | 0.035 | 0.065 | 0.098 | 0.098 | 0.265 | 0.100 |
| 8.37 | 8 | 0.025 | 0.032 | 0.032 | 0.085 | 0.035 | 0.070 | 0.105 | 0.105 | 0.270 | 0.100 |
| 13.3 | 6 | 0.025 | 0.027 | 0.027 | 0.090 | 0.030 | 0.070 | 0.089 | 0.089 | 0.285 | 0.085 |
| 21.2 | 4 | 0.020 | 0.022 | 0.022 | 0.075 | 0.030 | 0.060 | 0.072 | 0.072 | 0.240 | 0.085 |
| 26.7 | 3 | 0.020 | 0.020 | 0.020 | 0.070 | 0.025 | 0.050 | 0.066 | 0.066 | 0.215 | 0.080 |
| 33.6 | 2 | 0.015 | 0.0185 | 0.0185 | 0.060 | 0.025 | 0.050 | 0.061 | 0.061 | 0.195 | 0.070 |
| 42.4 | 1 | 0.020 | 0.0195 | 0.0195 | 0.070 | 0.025 | 0.055 | 0.064 | 0.064 | 0.225 | 0.075 |
| 53.5 | 1/0 | 0.020 | 0.0175 | 0.0175 | 0.065 | 0.025 | 0.050 | 0.057 | 0.057 | 0.205 | 0.070 |
| 67.4 | 2/0 | 0.015 | 0.0160 | 0.0160 | 0.060 | 0.020 | 0.045 | 0.052 | 0.052 | 0.185 | 0.065 |
| 85.0 | 3/0 | 0.015 | 0.0145 | 0.0145 | 0.055 | 0.020 | 0.040 | 0.048 | 0.048 | 0.165 | 0.055 |
| 107 | 4/0 | 0.015 | 0.0130 | 0.0130 | 0.050 | 0.020 | 0.035 | 0.043 | 0.043 | 0.150 | 0.050 |
| 127 | 250 kcmil | 0.015 | 0.0140 | 0.0140 | 0.050 | 0.020 | 0.040 | 0.046 | 0.046 | 0.160 | 0.055 |
| 152 | 300 | 0.015 | 0.0130 | 0.0130 | 0.050 | 0.020 | 0.035 | 0.043 | 0.043 | 0.150 | 0.050 |
| 177 | 350 | 0.015 | 0.0120 | 0.0120 | 0.045 | 0.015 | 0.035 | 0.039 | 0.039 | 0.140 | 0.050 |
| 203 | 400 | 0.010 | 0.0110 | 0.0110 | 0.040 | 0.015 | 0.030 | 0.036 | 0.036 | 0.130 | 0.045 |
| 226 | 450 | 0.010 | 0.0105 | 0.0105 | 0.040 | 0.015 | 0.030 | 0.034 | 0.034 | 0.125 | 0.045 |
| 253 | 500 | 0.010 | 0.00100 | 0.0100 | 0.040 | 0.015 | 0.030 | 0.033 | 0.033 | 0.115 | 0.040 |
| 279 | 550 | 0.010 | – | – | 0.040 | 0.015 | 0.030 | – | – | 0.130 | 0.045 |
| 304 | 600 | 0.010 | 0.0105 | 0.0105 | 0.040 | 0.015 | 0.030 | 0.034 | 0.034 | 0.125 | 0.045 |
| 329 | 650 | 0.010 | – | – | 0.040 | 0.015 | 0.030 | – | – | 0.120 | 0.040 |
| 355 | 700 | 0.010 | 0.0100 | 0.0100 | 0.040 | 0.015 | 0.030 | 0.033 | 0.033 | 0.115 | 0.040 |
| 380 | 750 | 0.010 | 0.0097 | 0.0097 | 0.035 | 0.015 | 0.025 | 0.032 | 0.032 | 0.115 | 0.040 |
| 405 | 800 | 0.010 | 0.0094 | 0.0094 | 0.035 | 0.015 | 0.025 | 0.031 | 0.031 | 0.110 | 0.040 |
| 456 | 900 | 0.010 | 0.0089 | 0.0089 | 0.035 | 0.010 | 0.025 | 0.029 | 0.029 | 0.105 | 0.035 |
| 507 | 1000 | 0.010 | 0.0085 | 0.0085 | 0.030 | 0.010 | 0.025 | 0.028 | 0.028 | 0.100 | 0.030 |
| 557 | 1100 | 0.010 | – | – | 0.030 | – | 0.020 | – | – | 0.0.95 | – |
| 608 | 1200 | 0.010 | – | – | 0.030 | – | 0.020 | – | – | 0.090 | – |
| 633 | 1250 | 0.010 | 0.0085 | 0.0085 | 0.030 | – | 0.020 | 0.028 | 0.028 | 0.090 | – |
| 659 | 1300 | 0.010 | – | – | 0.030 | – | 0.020 | – | – | 0.090 | – |

Table 23 Continued on Next Page

## Table 23 Continued

| Conductor size | | GΩ·m | | | | | MΩ·1000 ft | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| mm² | AWG or kcmil | 50 or 60°C test | | 75 or 90°C test | | | 50 or 60°C test | | 75 or 90°C test | | |
| | | TW | TWU | TWU75 (75°C test) | THW[a], THW-LS, THHW, THHW-LS or TW75 (75°C test), THW-2 (90°C test) | Type THWN or TWN75 (75°C test), THWN-2 (90°C test) | TW | TWU | TWU75 (75°C test) | THW[a], THW-LS, THHW, THHW-LS or TW75 (75°C test), THW-2 (90°C test) | Type THWN or TWN75 (75°C test), THWN-2 (90°C test) |
| 709 | 1400 | 0.010 | – | – | 0.030 | – | 0.020 | – | – | 0.085 | – |
| 760 | 1500 | 0.010 | 0.0078 | 0.0078 | 0.030 | – | 0.020 | 0.026 | 0.026 | 0.085 | – |
| 811 | 1600 | 0.010 | – | – | 0.025 | – | 0.020 | – | – | 0.080 | – |
| 861 | 1700 | 0.010 | – | – | 0.025 | – | 0.020 | – | – | 0.080 | – |
| 887 | 1750 | 0.010 | 0.0073 | 0.0073 | 0.025 | – | 0.015 | 0.024 | 0.024 | 0.075 | – |
| 912 | 1800 | 0.010 | – | – | 0.025 | – | 0.015 | – | – | 0.075 | – |
| 963 | 1900 | 0.010 | – | – | 0.025 | – | 0.015 | – | – | 0.075 | – |
| 1010 | 2000 | 0.005 | 0.0068 | 0.0068 | 0.025 | – | 0.015 | 0.022 | 0.022 | 0.070 | – |

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

## Table 24
## Minimum Acceptable Long-Term Insulation Resistance in Air of Types THHN and T90 at 97.0°C (206.6°F)
## (See Clause 5.6.3.)

| Size of conductor | | GΩ·m | MΩ·1000 ft |
|---|---|---|---|
| mm² | AWG or kcmil | | |
| 2.08 | 14 AWG | 0.080 | 0.260 |
| 3.31 | 12 | 0.070 | 0.220 |
| 5.26 | 10 | 0.070 | 0.230 |
| 8.37 | 8 | 0.075 | 0.235 |
| 13.3 | 6 | 0.060 | |
| 21.2 | 4 | 0.065 | 0.200 |
| 26.7 | 3 | 0.060 | 0.185 |
| 33.6 | 2 | 0.050 | 0.160 |
| 42.4 | 1 | 0.055 | 0.180 |
| 53.5 | 1/0 | 0.050 | 0.160 |
| 67.4 | 2/0 | 0.045 | 0.145 |
| 85.0 | 3/0 | 0.040 | 0.130 |
| 107 | 4/0 | 0.040 | 0.115 |
| 127 | 250 kcmil | 0.040 | 0.130 |
| 152 | 300 | 0.040 | 0.115 |
| 177 | 350 | 0.035 | 0.110 |
| 203 | 400 | 0.035 | 0.100 |
| 226 | 450 | 0.035 | 0.100 |
| 253 | 500 | 0.030 | 0.095 |

Table 24 Continued on Next Page

## Table 24 Continued

| Size of conductor | | GΩ·m | MΩ·1000 ft |
|---|---|---|---|
| mm$^2$ | AWG or kcmil | | |
| 279 | 550 | 0.035 | 0.100 |
| 304 | 600 | 0.035 | 0.100 |
| 329 | 650 | 0.030 | 0.095 |
| 355 | 700 | 0.030 | 0.090 |
| 380 | 750 | 0.030 | 0.090 |
| 405 | 800 | 0.030 | 0.090 |
| 456 | 900 | 0.030 | 0.080 |
| 507 | 1000 | 0.025 | 0.075 |

## Table 25
## Mandrel Diameters[a]
## (See Clauses 5.9 and 5.10.1.)

| Size of conductor | | A (Heat shock) | | B (Room temperature and cold bend) | |
|---|---|---|---|---|---|
| mm$^2$ | AWG | mm | inches | mm | inches |
| 2.08 | 14 | 3 | 0.133 | 8 | 0.313 |
| 3.31 | 12 | 4 | 0.148 | 9 | 0.375 |
| 5.26 | 10 | 4 | 0.168 | 14 | 0.563 |
| 8.37 | 8 | 6 | 0.228 | 17 | 0.688 |
| 13.3 | 6 | 16 | 0.646 | 32 | 1.250 |
| 21.2 | 4 | 19 | 0.744 | 35 | 1.375 |
| 26.7 | 3 | 20 | 0.802 | 37 | 1.458 |
| 33.6 | 2 | 22 | 0.866 | 40 | 1.563 |
| 42.4 | 1 | 26 | 1.016 | 68 | 2.688 |
| 53.5 | 1/0 | 28 | 1.098 | 73 | 2.875 |
| 67.4 | 2/0 | 30 | 1.190 | 76 | 3.000 |
| 85.0 | 3/0 | 33 | 1.294 | 83 | 3.250 |
| 107 | 4/0 | 36 | 1.410 | 89 | 3.500 |
| 127 | 250 kcmil | 100 | 3.940 | 160 | 6.304 |
| 152 | 300 | 107 | 4.215 | 171 | 6.744 |
| 177 | 350 | 114 | 4.475 | 182 | 7.160 |
| 203 | 400 | 120 | 4.710 | 191 | 7.536 |
| 228 | 450 | 125 | 4.935 | 201 | 7.904 |
| 253 | 500 | 131 | 5.145 | 209 | 8.232 |
| 279 | 550 | 140 | 5.515 | 280 | 11.030 |
| 304 | 600 | 145 | 5.715 | 290 | 11.430 |
| 329 | 650 | 150 | 5.895 | 299 | 11.790 |
| 355 | 700 | 154 | 6.070 | 308 | 12.140 |
| 380 | 750 | 159 | 6.245 | 317 | 12.490 |
| 405 | 800 | 163 | 6.410 | 326 | 12.820 |
| 456 | 900 | 171 | 6.725 | 342 | 13.450 |

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## Table 25 Continued

| Size of conductor | | A (Heat shock) | | B (Room temperature and cold bend) | |
|---|---|---|---|---|---|
| mm² | AWG | mm | inches | mm | inches |
| 507 | 1000 | 178 | 7.020 | 357 | 14.040 |
| 608 | 1200 | 197 | 7.745 | 393 | 15.490 |
| 633 | 1250 | 200 | 7.885 | 401 | 15.770 |
| 659 | 1300 | 204 | 8.025 | 408 | 16.050 |
| 709 | 1400 | 210 | 8.270 | 420 | 16.540 |
| 760 | 1500 | 216 | 8.510 | 432 | 17.020 |
| 811 | 1600 | 222 | 8.745 | 444 | 17.490 |
| 861 | 1700 | 228 | 8.970 | 456 | 17.940 |
| 887 | 1750 | 231 | 9.085 | 462 | 18.170 |
| 912 | 1800 | 233 | 9.190 | 267 | 18.380 |
| 963 | 1900 | 239 | 9.400 | 478 | 18.800 |
| 1010 | 2000 | 244 | 9.610 | 488 | 19.220 |

[a] When the mandrel specified is not available, it shall be permitted to use a mandrel with a smaller diameter. However, in the case of noncompliant result, the wire or cable shall be re-tested using the specified mandrel.

## Table 26
## Deformation Load Requirements
## (See Clause 5.11.)

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

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

**Table 27**
**Minimum Insulation Resistance at 15°C in Water**
**(See Clause 5.24.)**

| Conductor size | | GΩ·m | | | | MΩ·1000 ft | | | |
|---|---|---|---|---|---|---|---|---|---|
| mm$^2$ | AWG or kcmil | Type TW, TW75 | Types TWU, TWU75 | Types THW-2, THHW, THHW-LS, THW, TWN75, and THW-LS | Types THWN-2, THWN, THHN, and T90 Nylon | Type TW, TW75 | Types TWU, TWU75 | Types THW-2, THHW, THHW-LS, THW, TWN75, and THW-LS | Types THWN-2, THWN, THHN, and T90 Nylon |
| 2.08 | 14 AWG | 45 | 65 | 175 | 205 | 140 | 205 | 570 | 655 |
| 3.31 | 12 | 40 | 55 | 150 | 175 | 120 | 175 | 485 | 560 |
| 5.26 | 10 | 35 | 45 | 125 | 180 | 100 | 150 | 405 | 580 |
| 8.37 | 8 | 35 | 50 | 130 | 185 | 105 | 155 | 415 | 595 |
| 13.3 | 6 | 35 | 40 | 135 | 155 | 105 | 130 | 435 | 495 |
| 21.2 | 4 | 30 | 35 | 115 | 155 | 90 | 110 | 360 | 505 |
| 26.7 | 3 | 25 | 30 | 110 | 145 | 80 | 100 | 325 | 465 |
| 33.6 | 2 | 25 | 30 | 95 | 130 | 75 | 90 | 295 | 415 |
| 42.4 | 1 | 30 | 30 | 105 | 140 | 85 | 95 | 340 | 455 |
| 53.5 | 1/0 | 25 | 25 | 95 | 130 | 75 | 85 | 310 | 415 |
| 67.4 | 2/0 | 25 | 25 | 85 | 115 | 70 | 80 | 280 | 370 |
| 85.0 | 3/0 | 20 | 20 | 80 | 105 | 60 | 70 | 250 | 330 |
| 107 | 4/0 | 20 | 20 | 70 | 95 | 55 | 65 | 225 | 300 |
| 127 | 250 kcmil | 20 | 20 | 80 | 105 | 60 | 70 | 245 | 330 |
| 152 | 300 | 20 | 20 | 70 | 95 | 55 | 65 | 225 | 300 |
| 177 | 350 | 20 | 20 | 65 | 90 | 50 | 60 | 210 | 285 |
| 203 | 400 | 15 | 15 | 65 | 80 | 50 | 55 | 200 | 255 |
| 226 | 450 | 15 | 15 | 60 | 80 | 45 | 50 | 190 | 255 |
| 253 | 500 | 15 | 15 | 55 | 75 | 45 | 50 | 180 | 240 |
| 279 | 550 | 15 | – | 65 | 80 | 50 | – | 200 | 255 |
| 304 | 600 | 15 | 15 | 60 | 80 | 45 | 50 | 190 | 255 |
| 329 | 650 | 15 | – | 60 | 75 | 45 | – | 185 | 240 |
| 355 | 700 | 15 | 15 | 55 | 70 | 45 | 50 | 180 | 225 |
| 380 | 750 | 15 | – | 55 | 70 | 40 | – | 170 | 225 |
| 405 | 800 | 15 | 15 | 55 | 70 | 40 | 45 | 165 | 225 |
| 456 | 900 | 15 | 15 | 50 | 65 | 40 | 45 | 155 | 210 |
| 507 | 1000 | 15 | 15 | 50 | 60 | 35 | 40 | 150 | 195 |
| 557 | 1100 | 15 | – | 45 | – | 35 | – | 140 | – |
| 608 | 1200 | 10 | – | 45 | – | 30 | – | 135 | – |
| 633 | 1250 | 10 | 15 | 45 | – | 30 | 40 | 135 | – |
| 659 | 1300 | 10 | – | 45 | – | 30 | – | 135 | – |
| 709 | 1400 | 10 | – | 40 | – | 30 | – | 125 | – |
| 760 | 1500 | 10 | 10 | 40 | – | 30 | 40 | 125 | – |
| 811 | 1600 | 10 | – | 40 | – | 30 | – | 120 | – |

Table 27 Continued on Next Page

## Table 27 Continued

| Conductor size | | GΩ·m | | | | MΩ·1000 ft | | | |
|---|---|---|---|---|---|---|---|---|---|
| mm² | AWG or kcmil | Type TW, TW75 | Types TWU, TWU75 | Types THW-2, THHW, THHW-LS, THW, TWN75, and THW-LS | Types THWN-2, THWN, THHN, and T90 Nylon | Type TW, TW75 | Types TWU, TWU75 | Types THW-2, THHW, THHW-LS, THW, TWN75, and THW-LS | Types THWN-2, THWN, THHN, and T90 Nylon |
| 861 | 1700 | 10 | – | 40 | – | 30 | – | 120 | – |
| 887 | 1750 | 10 | 10 | 35 | – | 25 | 35 | 110 | – |
| 912 | 1800 | 10 | – | 35 | – | 25 | – | 110 | – |
| 963 | 1900 | 10 | – | 35 | – | 25 | – | 110 | – |
| 1010 | 2000 | 10 | 10 | 35 | – | 25 | 35 | 105 | – |

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

*a) for Type TW: 500;*

*b) for Type THW: 2000;*

*c) for Type THWN: 4000.*

## Table 28
## Smallest Acceptable Size of Optional Equipment Grounding Conductors in Deep-Well Submersible Water Pump Cables with Copper Circuit Conductors
## (See Clause 7.2.1.)

| Size of copper circuit conductors | | Smallest acceptable size of equipment grounding conductor, AWG or kcmil | | | | | |
|---|---|---|---|---|---|---|---|
| mm² | AWG or kcmil | Conductor temperature rating, °C | | | | | |
| | | 90 | | 75 | | 60 | |
| | | Copper | Aluminum | Copper | Aluminum | Copper | Aluminum |
| 2.08 | 14 | 14 | 12 | 14 | 12 | 14 | 12 |
| 3.31 | 12 | 12 | 10 | 12 | 10 | 12 | 10 |
| 5.26 | 10 | 10 | 8 | 10 | 8 | 10 | 8 |
| 8.37 | 8 | 10 | 8 | 10 | 8 | 10 | 8 |
| 13.3 | 6 | 8 | 6 | 8 | 6 | 10 | 8 |
| 21.2 | 4 | 8 | 6 | 8 | 6 | 8 | 6 |
| 26.7 | 3 | 6 | 4 | 8 | 6 | 8 | 6 |
| 33.6 | 2 | 6 | 4 | 6 | 4 | 8 | 6 |
| 42.4 | 1 | 6 | 4 | 6 | 4 | 6 | 4 |
| 53.5 | 1/0 | 6 | 4 | 6 | 4 | 6 | 4 |
| 67.4 | 2/0 | 6 | 4 | 6 | 4 | 6 | 4 |
| 85.0 | 3/0 | 4 | 2 | 6 | 4 | 6 | 4 |
| 107 | 4/0 | 4 | 2 | 4 | 2 | 6 | 4 |
| 127 | 250 | 4 | 2 | 4 | 2 | 4 | 2 |
| 152 | 300 | 3 | 1 | 4 | 2 | 4 | 2 |
| 177 | 350 | 3 | 1 | 3 | 1 | 4 | 2 |
| 203 | 400 | 3 | 1 | 3 | 1 | 4 | 2 |
| 253 | 500 | 2 | 1/0 | 3 | 1 | 3 | 1 |

**Table 29**
**Smallest Acceptable Size of Optional Equipment Grounding Conductors in Deep-Well Submersible Water Pump Cables with Aluminum Circuit Conductors**
**(See Clause 7.2.1.)**

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

**Table 30**
**Insulated Conductors Used in Deep-Well Submersible Water Pump Cable**
**(See Clauses 7.2.2 and 7.2.3.)**

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

## Table 31
## Integral Jacket Thickness for Group I Deep-Well Submersible Water Pump Cables
## (See Clause 7.2.2 and 7.2.3.)

| Conductor size | | Jacket thickness | | | |
|---|---|---|---|---|---|
| $mm^2$ | AWG | Minimum average | | Minimum at any point | |
| | | mm | mils | mm | mils |
| 2.08 – 8.37 | 14 – 8 | 0.38 | 15 | 0.31 | 12 |
| 13.3 and larger | 6 and larger | 0 | 0 | 0 | 0 |

## Table 32
## Polyethylene Insulation Thickness and Dielectric Withstand Voltage for Deep-Well Submersible Water Pump Cable
## (See Clauses 7.2.2, 7.4.1, and 7.4.2.)

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

## Table 33
## Properties of Polyethylene Insulation Used in Deep-Well Submersible Water Pump Cables
## (See Clauses 7.2.2 and 7.4.1.)

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

## Table 34
## Thickness of Overall Jacket Other Than Polyethylene, for Deep-Well Submersible Water Pump Cables
## (See Clause 7.2.3.)

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

## Table 35
## Thickness of Overall Polyethylene Jacket for Deep-Well Submersible Water Pump Cables
## (See Clause 7.2.3.)

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

## Table 36
## Physical Properties of PVC Jackets for Deep-Well Submersible Water Pump Cables
## (See Clause 7.2.3.)

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

**Table 37**
**Tray Loading for Circular Cables Smaller than 13 mm (0.5 inch) in Diameter**
**(See Clause 8.2.6.2.13.1.)**

| Cable diameter, mm (inch) | | Number of cables in each bundle | Number of bundles in tray |
|---|---|---|---|
| From | But less than | | |
| | 3 (0.12) | 19 | 13 |
| 3 (0.12) | 5 (0.20) | 19 | 8 |
| 5 (0.20) | 6 (0.24) | 7 | 9 |
| 6 (0.24) | 9 (0.35) | 3 | 10 |
| 9 (0.35) | 11 (0.43) | 3 | 8 |
| 11 (0.43) | 13 (0.51) | 3 | 7 |

**Table 38**
**Tray Loading for Circular Cables 13 mm (0.5 inch) in Diameter and Larger**
**(See Clause 8.2.6.2.13.1.)**

| Cable diameter, mm (inches) | | Number of cables in tray |
|---|---|---|
| From | But less than | |
| 13 (0.51) | 15 (0.59) | 11 |
| 15 (0.59) | 19 (0.75) | 9 |
| 19 (0.75) | 21 (0.83) | 8 |
| 21 (0.83) | 26 (1.0) | 7 |
| 26 (1.0) | 28 (1.1) | 6 |
| 28 (1.1) | 39 (1.5) | 5 |
| 39 (1.5) | 52 (2.0) | 4 |
| 52 (2.0) | 73 (2.9) | 3 |
| 73 (2.9) | 120 (4.7) | 2 |

**Table 39**
**Conversion of Percent Transmittance to Specific Optical Density**
**(See Clause 8.2.7.1.6.)**

| Parameters and range of transmittance (T) | Percent T | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Specific optical density (D) | | | | | | | | | |
| Multiplier 100 with ND-2 filter 100 at 10 percent T | 90 | 6 | 5 | 5 | 4 | 4 | 3 | 2 | 2 | 1 | 1 |
| | 80 | 13 | 12 | 11 | 11 | 10 | 9 | 9 | 8 | 7 | 7 |
| | 70 | 20 | 20 | 19 | 18 | 17 | 16 | 16 | 15 | 14 | 14 |
| | 60 | 29 | 28 | 27 | 26 | 26 | 25 | 24 | 23 | 22 | 21 |
| | 50 | 40 | 39 | 37 | 36 | 35 | 34 | 33 | 32 | 31 | 30 |
| | 40 | 53 | 51 | 50 | 48 | 47 | 46 | 45 | 43 | 42 | 41 |
| | 30 | 69 | 67 | 65 | 64 | 62 | 60 | 59 | 57 | 55 | 54 |
| | 20 | 92 | 89 | 87 | 84 | 82 | 79 | 77 | 75 | 73 | 71 |
| | 10 | 132 | 127 | 122 | 117 | 113 | 109 | 105 | 102 | 98 | 95 |

Table 39 Continued on Next Page

## Table 39 Continued

| Parameters and range of transmittance (T) | Percent T | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Specific optical density (D) | | | | | | | | | |
| Multiplier 10 with ND-2 filter 10 at 1 percent T | 90x10$^{-1}$ | 138 | 137 | 137 | 136 | 136 | 135 | 134 | 134 | 133 | 133 |
| | 80 | 145 | 144 | 143 | 143 | 142 | 141 | 141 | 140 | 139 | 139 |
| | 70 | 152 | 152 | 151 | 150 | 149 | 148 | 148 | 147 | 146 | 146 |
| | 60 | 161 | 160 | 159 | 158 | 158 | 157 | 156 | 155 | 154 | 153 |
| | 50 | 172 | 171 | 169 | 168 | 167 | 166 | 165 | 164 | 163 | 162 |
| | 40 | 185 | 183 | 182 | 180 | 179 | 178 | 177 | 175 | 174 | 173 |
| | 30 | 201 | 199 | 197 | 196 | 194 | 192 | 191 | 189 | 187 | 186 |
| | 20 | 224 | 221 | 219 | 216 | 214 | 211 | 209 | 207 | 205 | 203 |
| | 10 | 264 | 259 | 254 | 249 | 245 | 241 | 237 | 234 | 230 | 227 |
| Multiplier 10 with ND-2 filter 1 at 0.1 percent T | 90x10$^{-2}$ | 270 | 269 | 269 | 268 | 268 | 267 | 266 | 266 | 265 | 265 |
| | 80 | 277 | 276 | 275 | 275 | 274 | 273 | 273 | 272 | 271 | 271 |
| | 70 | 284 | 284 | 283 | 282 | 281 | 280 | 280 | 279 | 278 | 278 |
| | 60 | 293 | 292 | 291 | 290 | 290 | 289 | 288 | 287 | 286 | 285 |
| | 50 | 304 | 303 | 301 | 300 | 299 | 298 | 297 | 296 | 295 | 294 |
| | 40 | 317 | 315 | 314 | 312 | 311 | 310 | 309 | 307 | 306 | 305 |
| | 30 | 333 | 331 | 329 | 328 | 326 | 324 | 323 | 321 | 319 | 318 |
| | 20 | 356 | 353 | 351 | 348 | 346 | 343 | 341 | 339 | 337 | 335 |
| | 10 | 396 | 391 | 386 | 381 | 377 | 373 | 369 | 366 | 362 | 359 |
| Multiplier 0.1 with ND-2 filter 0.1 at 0.01 percent T | 90x10$^{-3}$ | 402 | 401 | 401 | 400 | 400 | 399 | 398 | 398 | 397 | 397 |
| | 80 | 409 | 408 | 407 | 407 | 406 | 405 | 405 | 404 | 403 | 403 |
| | 70 | 416 | 416 | 415 | 414 | 413 | 412 | 412 | 411 | 410 | 410 |
| | 60 | 425 | 424 | 423 | 422 | 422 | 421 | 420 | 419 | 418 | 417 |
| | 50 | 436 | 435 | 433 | 432 | 431 | 430 | 429 | 428 | 427 | 426 |
| | 40 | 449 | 447 | 446 | 444 | 443 | 442 | 441 | 439 | 438 | 437 |
| | 30 | 465 | 463 | 461 | 460 | 458 | 456 | 455 | 453 | 451 | 450 |
| | 20 | 488 | 485 | 483 | 480 | 478 | 475 | 473 | 471 | 469 | 467 |
| | 10 | 528 | 523 | 518 | 513 | 509 | 505 | 501 | 498 | 494 | 491 |
| Multiplier 1 without ND-2 filter 0.01 at 0.001 percent T | 90x10$^{-4}$ | 534 | 533 | 533 | 532 | 532 | 531 | 530 | 530 | 529 | 529 |
| | 80 | 541 | 540 | 539 | 539 | 538 | 537 | 537 | 536 | 535 | 535 |
| | 70 | 548 | 548 | 547 | 546 | 545 | 544 | 544 | 543 | 542 | 542 |
| | 60 | 557 | 556 | 555 | 554 | 554 | 553 | 552 | 551 | 550 | 549 |
| | 50 | 568 | 567 | 565 | 564 | 563 | 562 | 561 | 560 | 559 | 558 |
| | 40 | 581 | 579 | 578 | 576 | 575 | 574 | 573 | 571 | 570 | 569 |
| | 30 | 597 | 595 | 593 | 592 | 50 | 588 | 587 | 585 | 583 | 582 |
| | 20 | 620 | 617 | 615 | 612 | 610 | 607 | 605 | 603 | 601 | 599 |
| | 10 | 660 | 655 | 650 | 645 | 641 | 637 | 633 | 630 | 626 | 623 |
| Multiplier 0.1 without ND-2 filter 0.001 at 0.00001 percent T | 90x10$^{-5}$ | 666 | 665 | 665 | 664 | 664 | 663 | 662 | 662 | 661 | 661 |
| | 80 | 673 | 672 | 671 | 671 | 670 | 669 | 669 | 668 | 667 | 667 |
| | 70 | 680 | 680 | 679 | 678 | 677 | 676 | 676 | 675 | 674 | 674 |
| | 60 | 689 | 688 | 687 | 686 | 686 | 685 | 684 | 683 | 682 | 681 |
| | 50 | 700 | 699 | 697 | 696 | 695 | 694 | 693 | 692 | 691 | 690 |
| | 40 | 713 | 711 | 710 | 708 | 707 | 706 | 705 | 703 | 702 | 701 |
| | 30 | 729 | 727 | 725 | 724 | 722 | 720 | 719 | 717 | 715 | 714 |
| | 20 | 752 | 749 | 747 | 744 | 742 | 739 | 737 | 735 | 733 | 731 |
| | 10 | 792 | 787 | 782 | 777 | 773 | 769 | 765 | 762 | 758 | 755 |
| | 00 | – | 924 | 885 | 861 | 845 | 832 | 821 | 812 | 805 | 798 |

**Table 40**
**A-C Spark Test Potential**
**(See Clause 5.22.)**

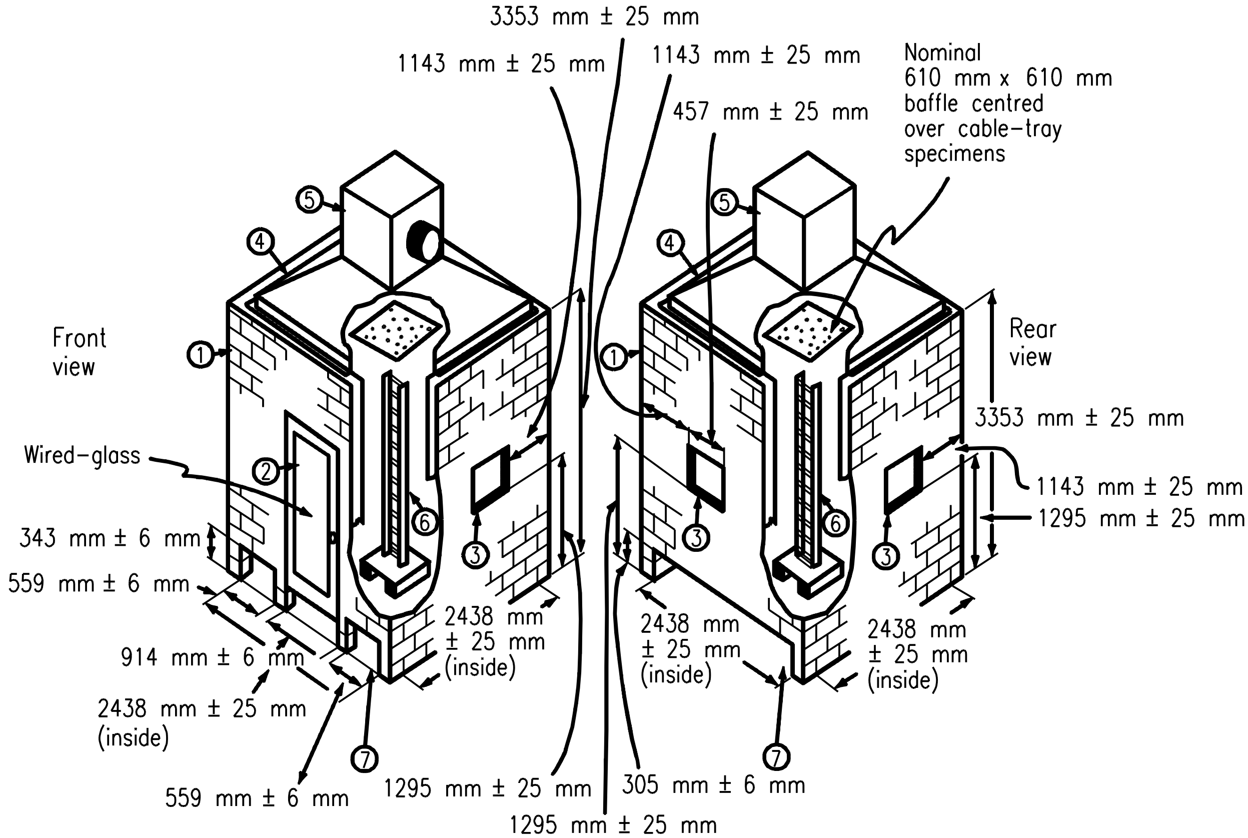
| Conductor size, $mm^2$ (AWG or kcmil) | A-C test potential (kV) |
|---|---|
| 2.08 – 5.26 (14 – 10) | 7.5 |
| 8.37 – 33.6 (8 – 2) | 10.0 |
| 42.4 – 107 (1 – 4/0) | 12.5 |
| 127 – 253 (250 – 500) | 15.0 |
| 279 – 507 (550 – 1000) | 17.5 |
| 557 – 1010 (1100 – 2000) | 20.0 |

**Table 41**
**A-C Test Voltages for Dielectric Voltage-Withstand**
**(See Clause 5.23.1.)**

| 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 |

## Figures

**Figure 1**
**Cable Test Enclosure and Exhaust Duct**
(See Clauses 8.2.6.1.2 and 8.2.6.2.2.)




Legend:

1 – Enclosure constructed of concrete blocks laid up with mortar. The blocks shall be nominally 203 mm high x 406 mm long x 152 mm thick (8 in x 16 in x 6 in).

2 – Steel–framed wired–glass door for access and observation. The overall size of the door shall be nominally 0.9 m wide x 2.1 m high (36 in x 84 in).

3 – Square steel–framed wired–glass observation window(s) nominally 457 mm (18 in) on a side.

4 – Truncated–pyramid stainless–steel hood. Each side shall be sloped 40°.

5 – Collection box with exhaust duct centered in one side. The box shall be a cube with each face a 914 mm (36 in) square.

6 – Cable tray mounted vertically in the center of the enclosure. The tray base stand shall be optional and shall not be higher than 152 mm (6 in).

7 – Air–intake openings.

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**Figure 2**
**Bi-directional Probe**
(See Clauses 8.2.6.1.3 and 8.2.6.2.3.)

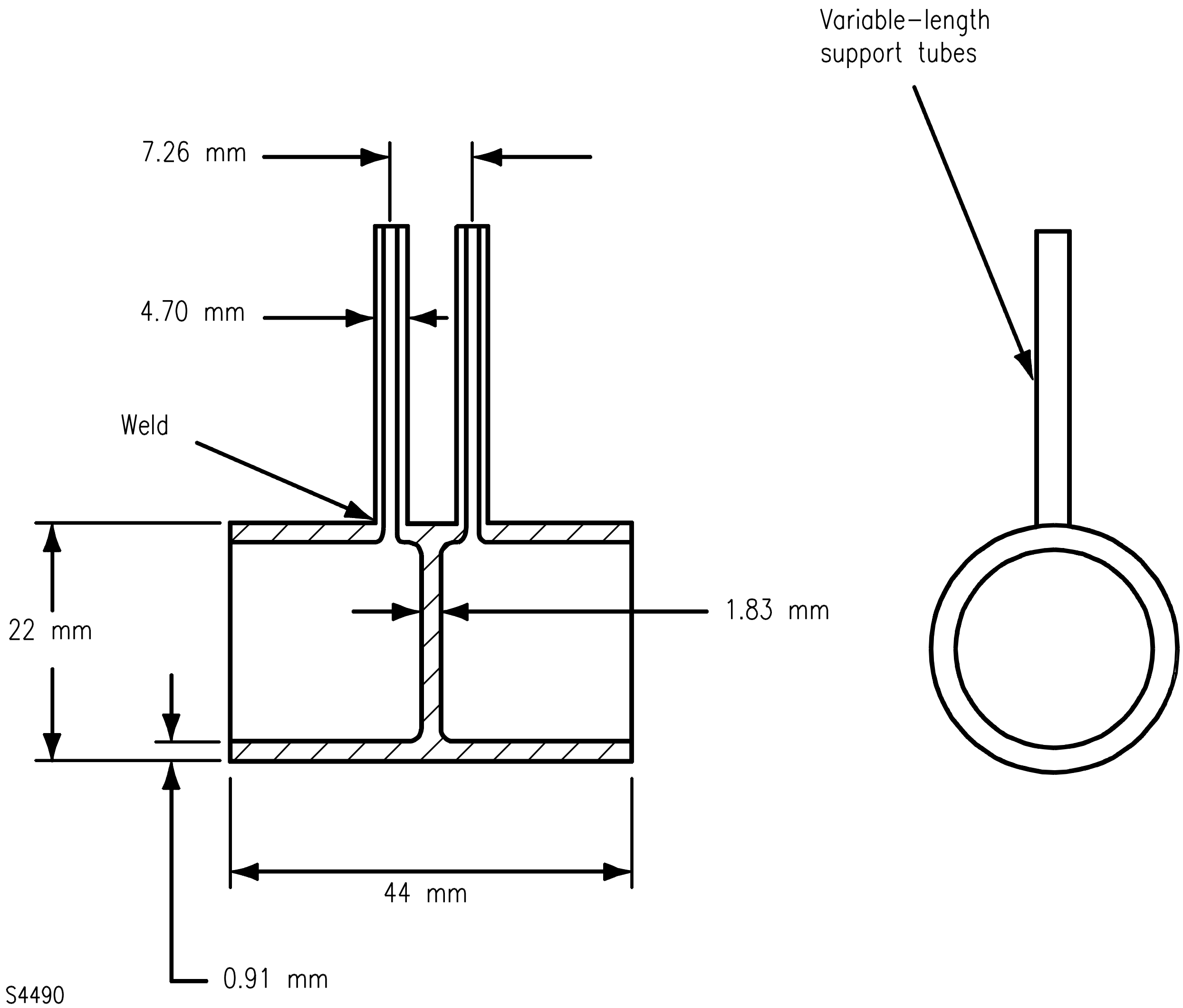

**Figure 3**
**Burner Holes**
(See Clauses 8.2.6.1.5 and 8.2.6.2.5.)

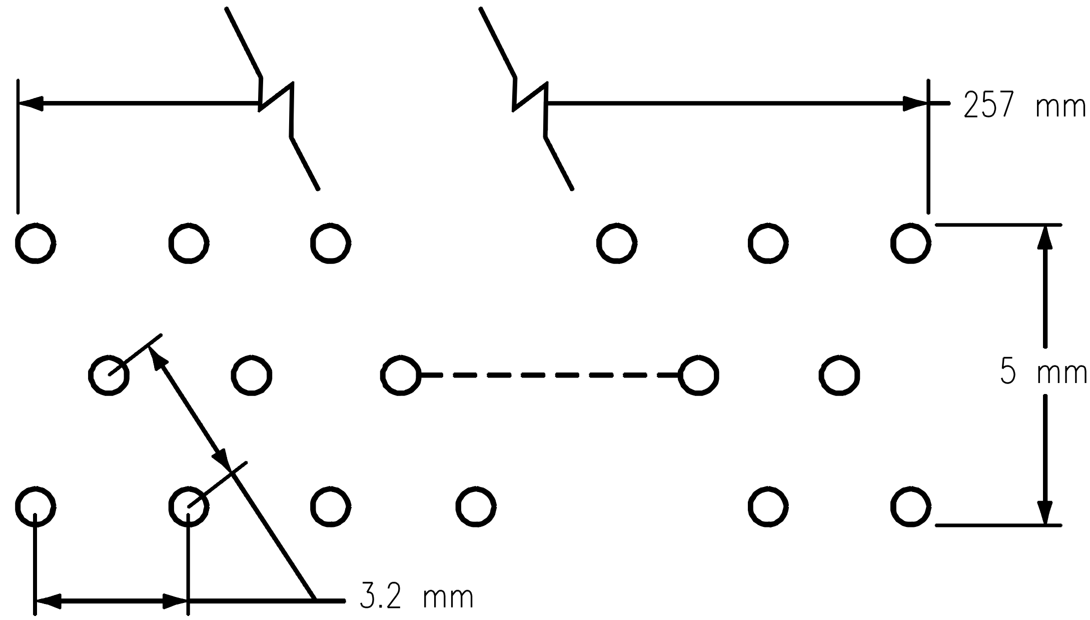


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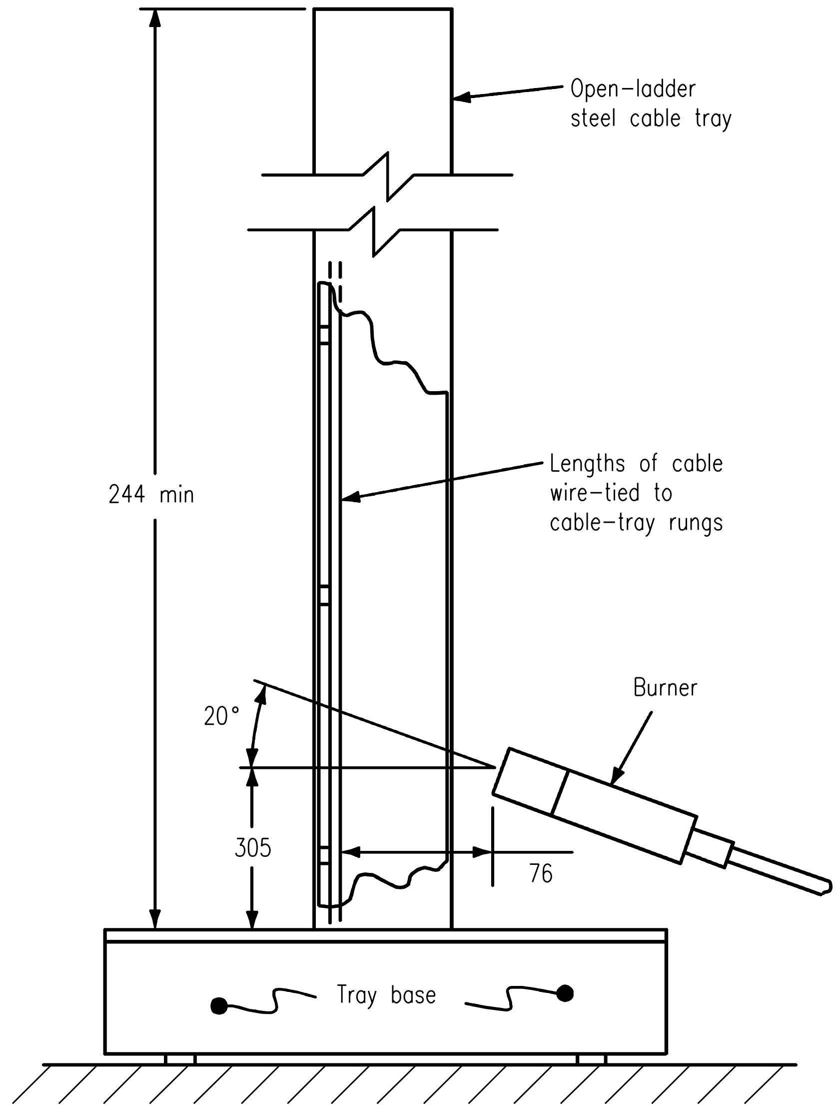
**Figure 4**
**Cable Tray, Specimen, and Burner Details**
(See Clauses 8.2.6.2.4, 8.2.6.2.5, and 8.2.6.2.14.2.)




**Notes:**

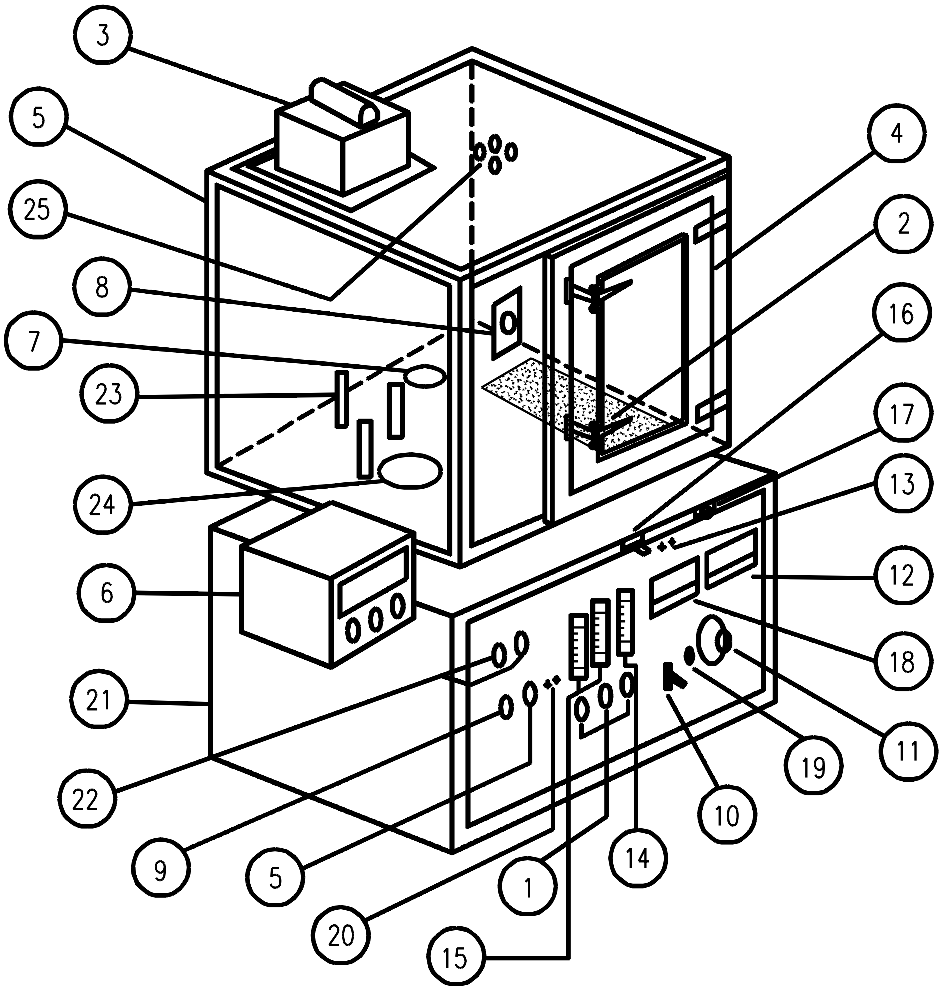
**(1)** *Cable tray – Nominally* 305 mm *wide x* 76 mm *deep x* 2440 mm *long with steel rungs nominally* 25 ± 6 mm *wide and spaced* 229 mm *on centers.*

**(2)** *Burner –* 254 mm *(10 inches) wide ribbon-type burner with an air/gas venturi mixer.*

**(3)** *Tray Base – Optional.* 152 mm *maximum height.*

**(4)** *Dimensions are in millimeters.*

**Figure 5**
**Chamber for Smoke Emission Test**
(See Clauses 8.2.7.1.2, 8.2.7.1.4, and 8.2.7.1.5.2.)




**Legend:**

1 Burner air valve and rotator
2 Safety seal (aluminum foil)
3 Photomultiplier tube stopper
4 Photomultiplier tube filter
5 Lamp switch
6 Photomultiplier
7 Smoke extraction system
8 Ventilator window
9 Main switch
10 Heater switch
11 Voltage adjustment knob
12 Measurer of chamber wall temperature
13 Inlet for millivolt measurement from radiometer
14 Radiometer air valve and rotator
15 Gas valve and rotator (burner)
16 Smoke extraction system control
17 Positioning rod knob
18 Measuring equipment of voltage from oven radiation
19 Fuses
20 Lamp supply inlets
21 Cabinet base
22 Indicator lamps
23 Optical system bars
24 Floor window of optical system
25 Access doors

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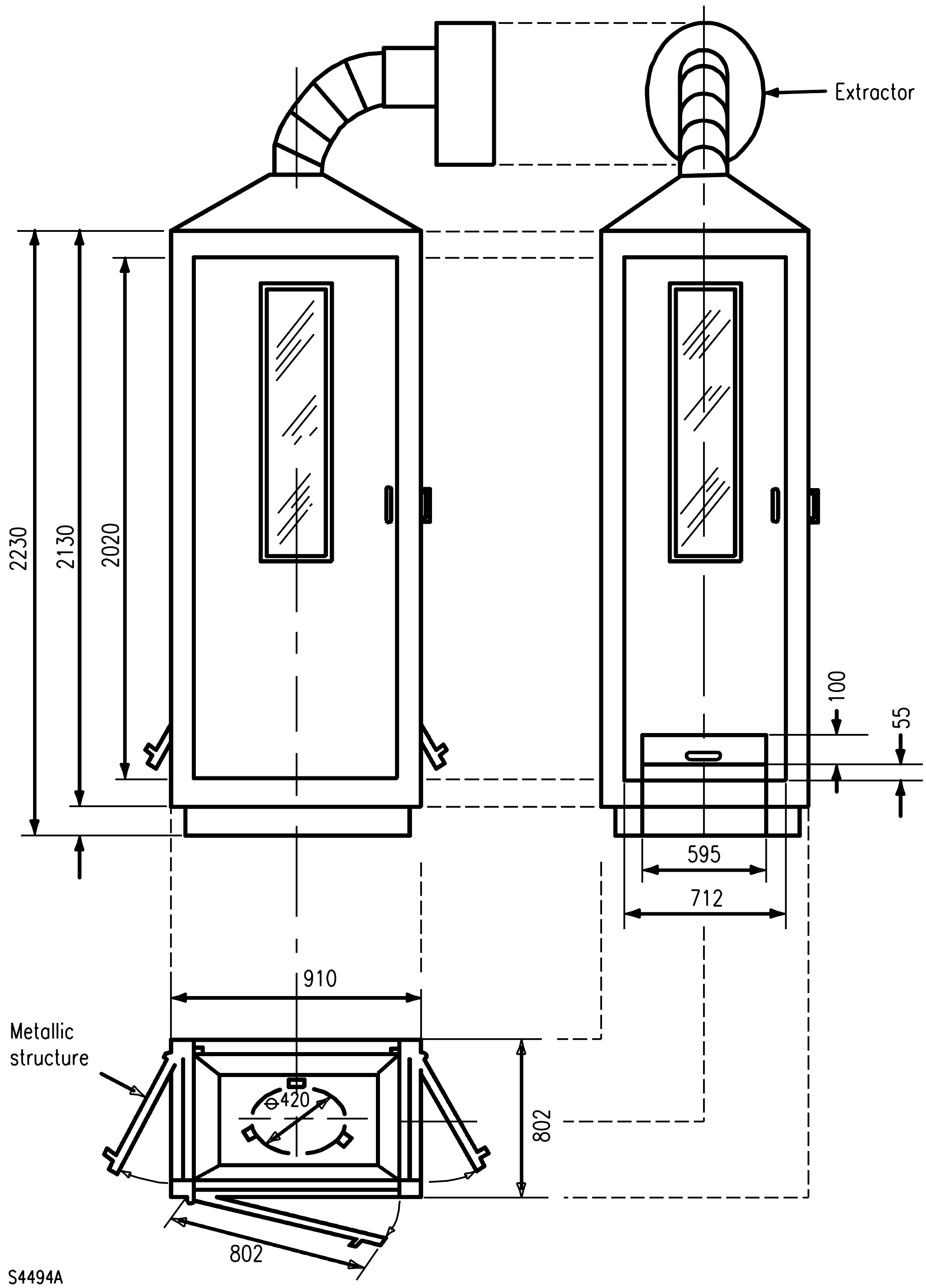
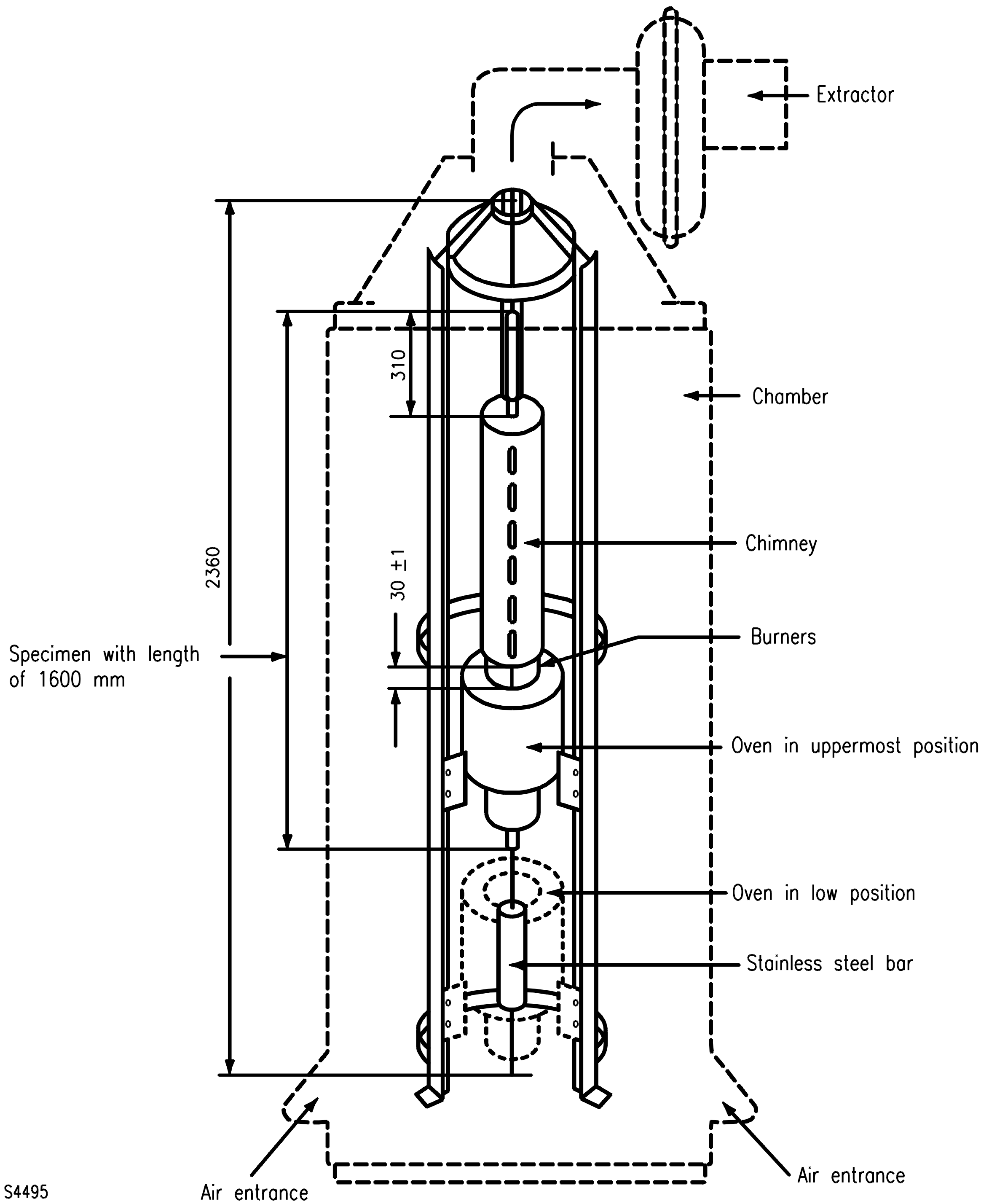
**Figure 6**
**Chamber for Fire Propagation Test**
(See Clause 8.2.7.2.1.1.)



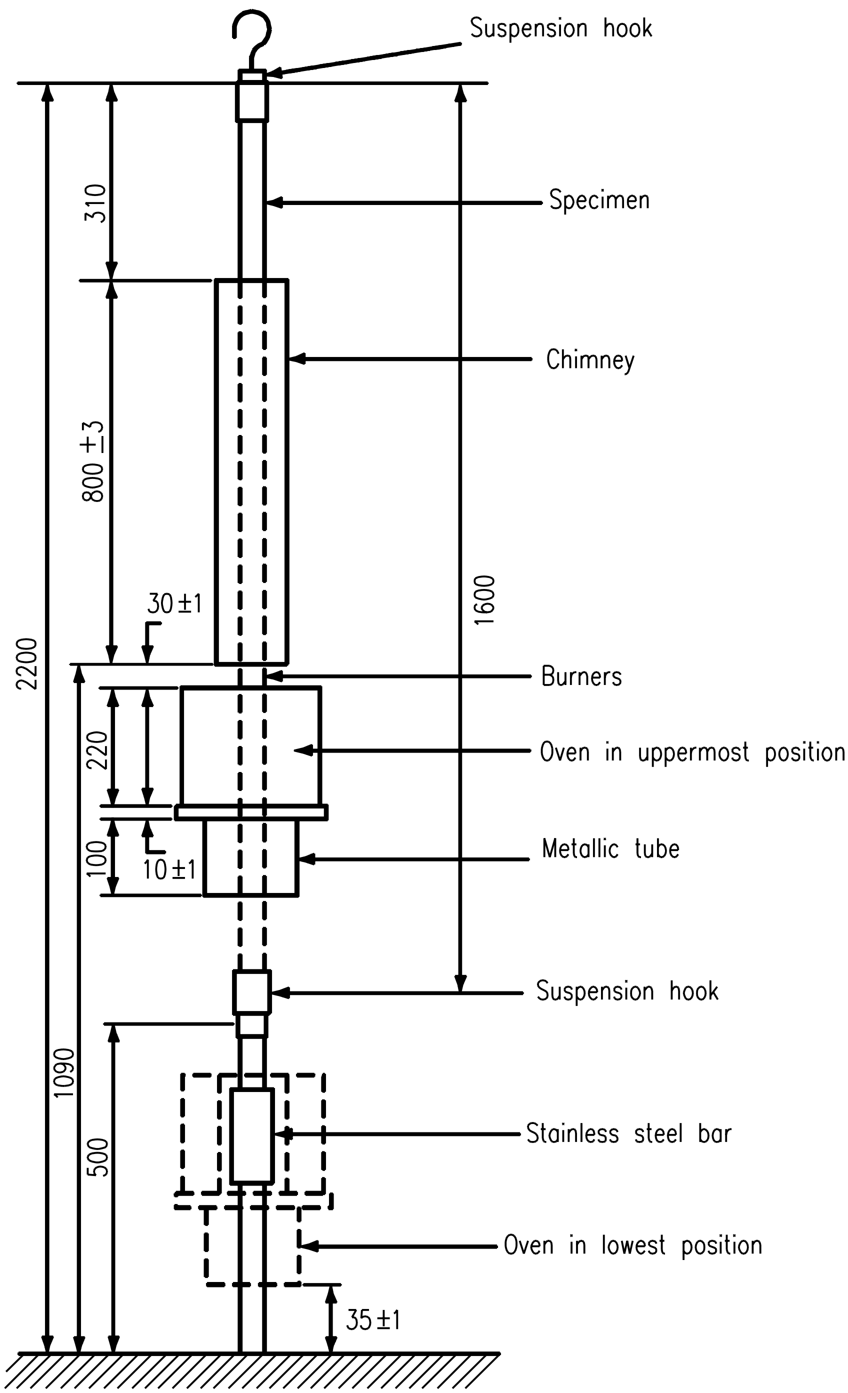

**Note:** *Dimensions in millimeters.*

**Figure 7**
**Detail 1 of Dimensions for Fire Propagation Test Chamber**
(See Clause 8.2.7.2.1.1.)




**Note:** *Dimensions in millimeters.*

**Figure 8**
**Detail 2 of Dimensions for Fire Propagation Test Chamber**
(See Clause 8.2.7.2.1.1.)

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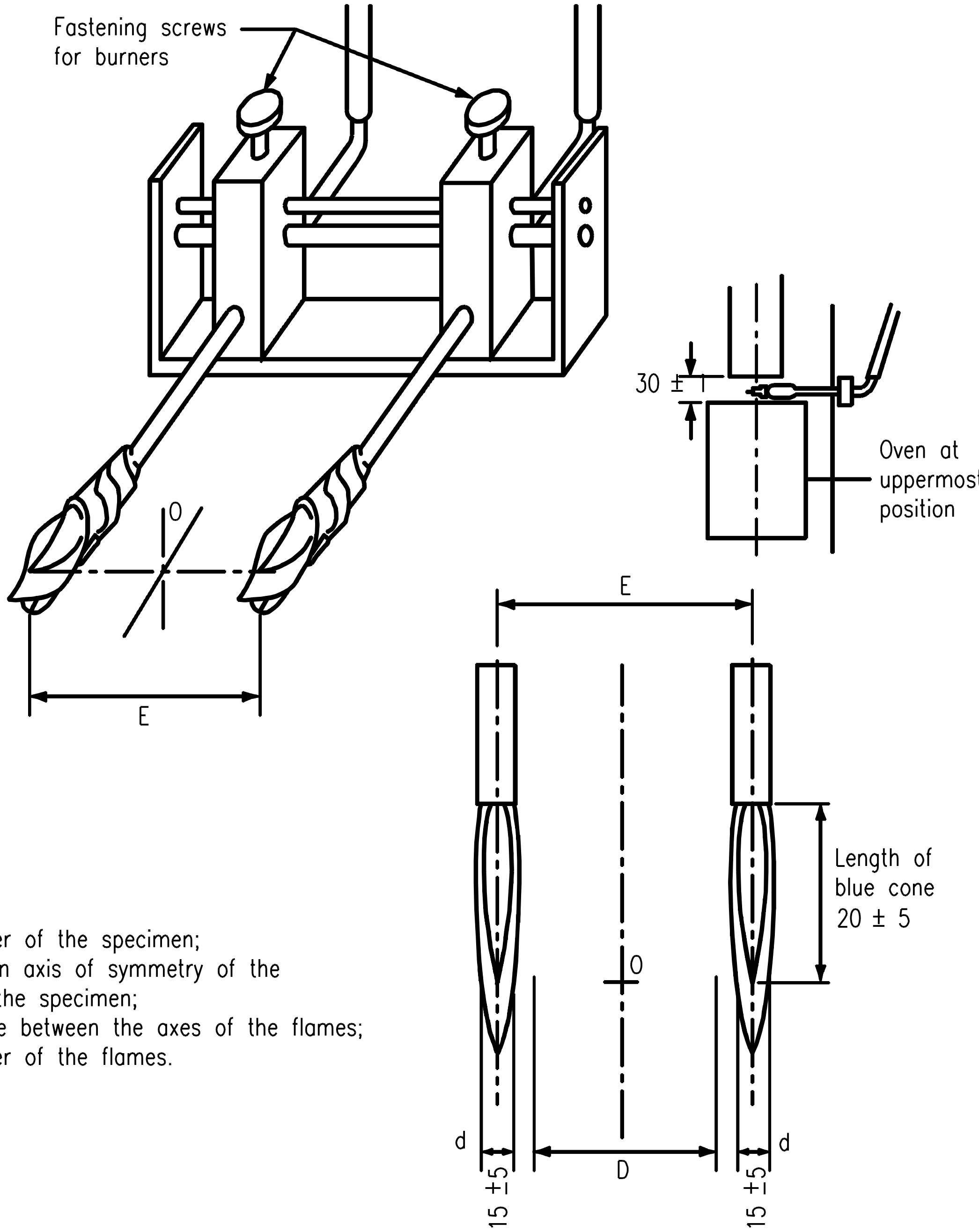
**Note:** *Dimensions in millimeters.*

**Figure 9**
**Burners for Fire Propagation Test**
(See Clause 8.2.7.2.1.1.)




**Legend:**
D is the diameter of the specimen;
O is the common axis of symmetry of the chimney and the specimen;
E is the distance between the axes of the flames;
d is the diameter of the flames.

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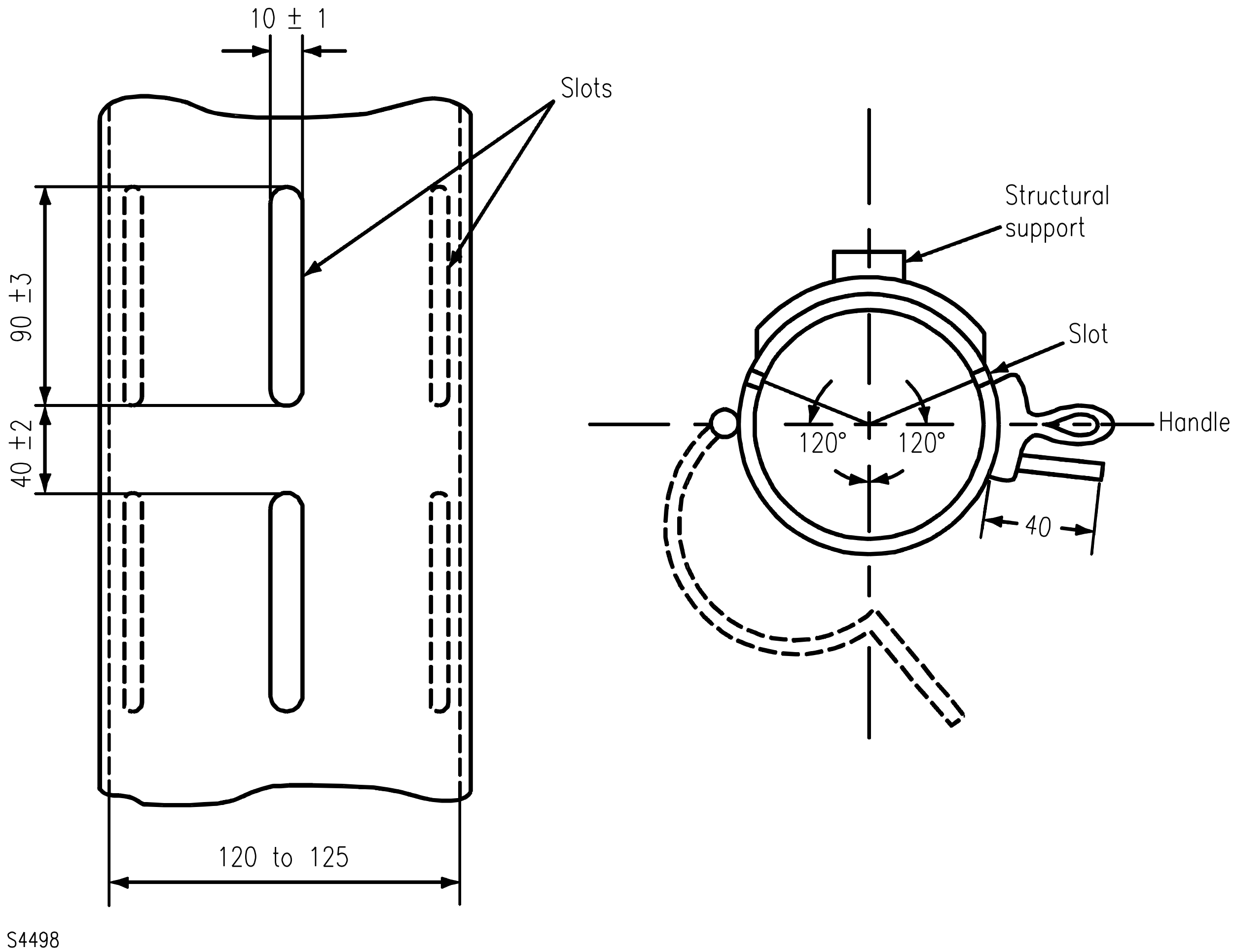
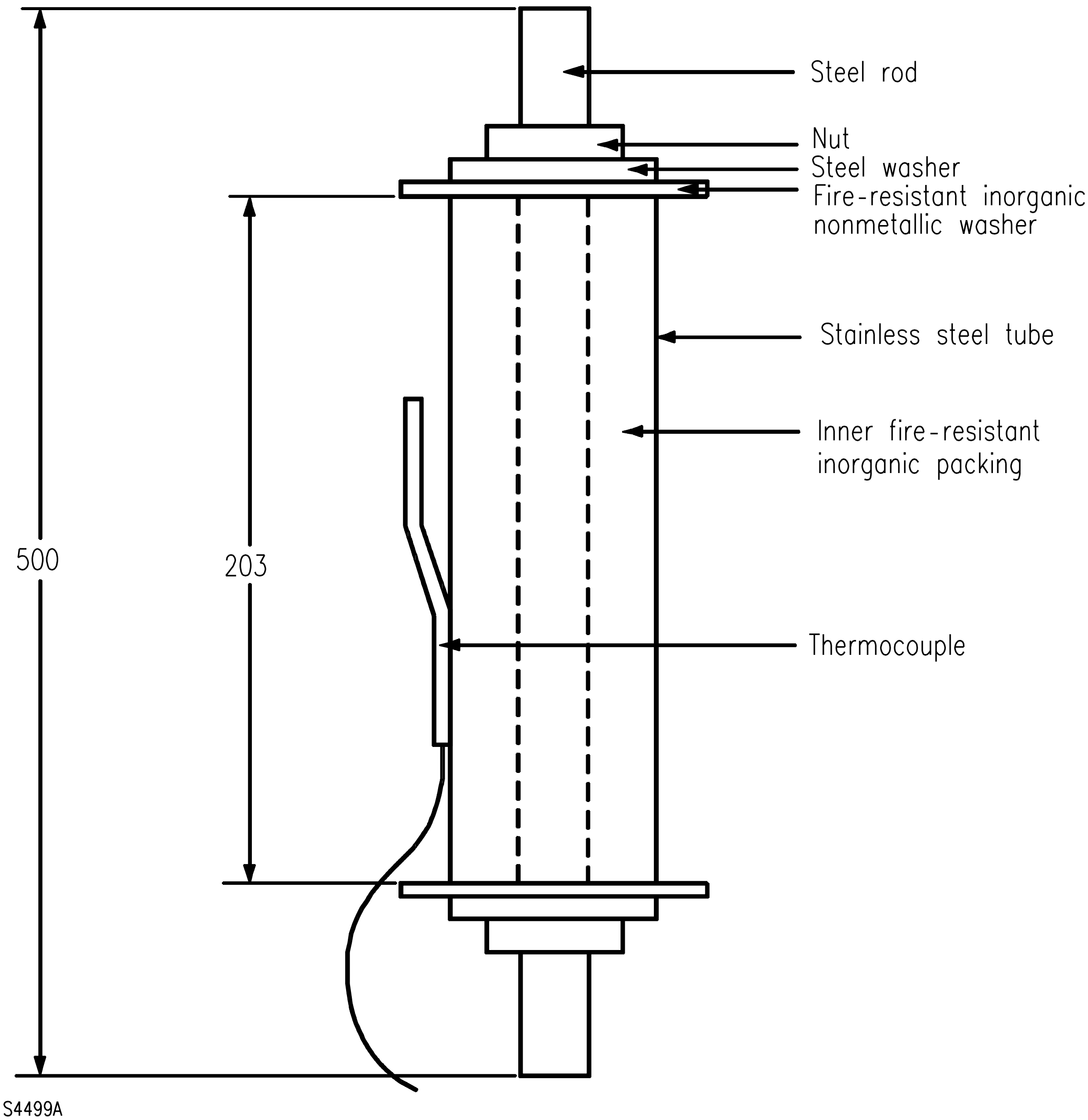
**Note:** *Dimensions in millimeters.*

**Figure 10**
**Metallic Chimney of Fire Propagation Test Chamber**
(See Clause 8.2.7.2.1.1.)



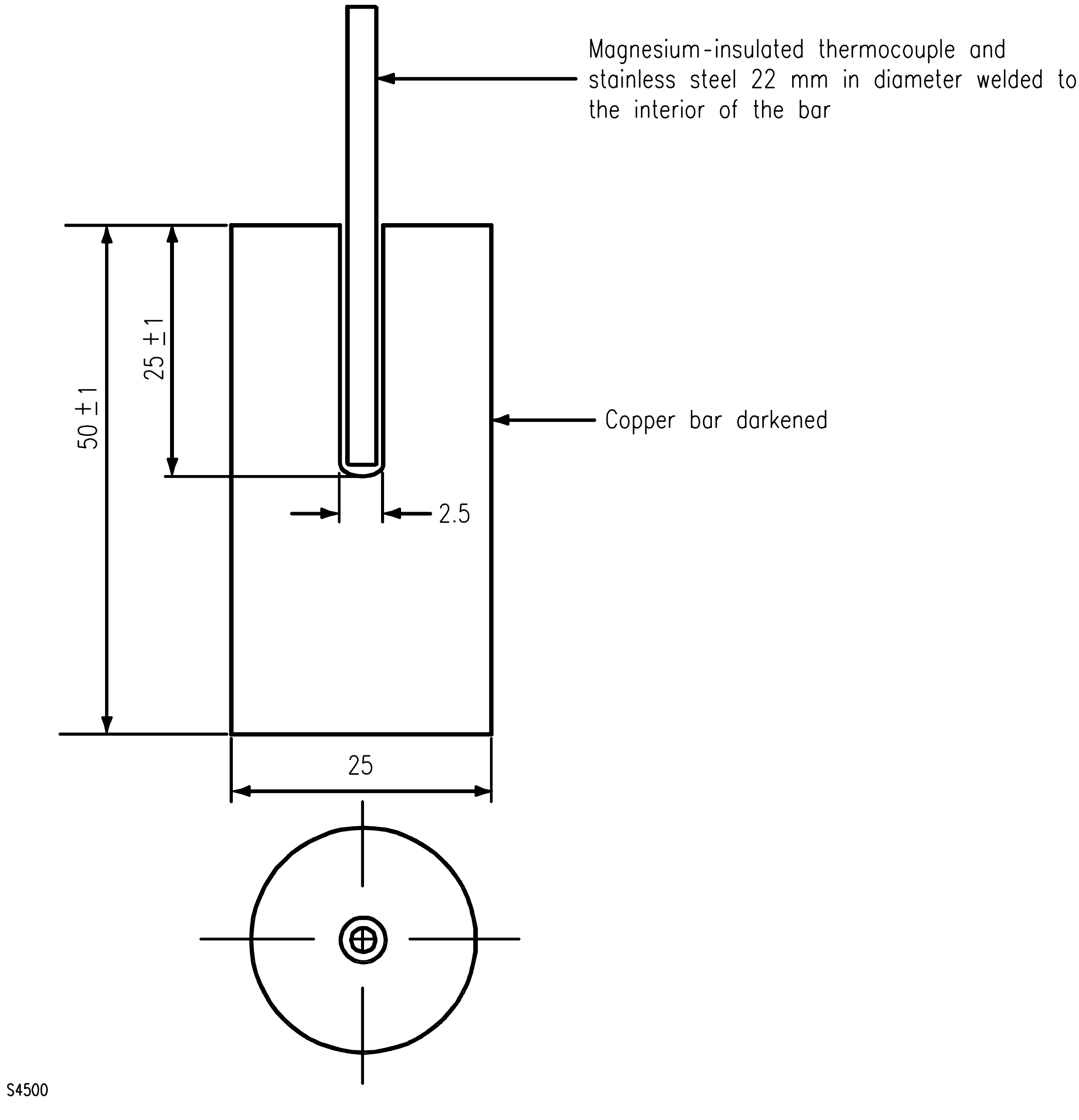

**Note:** *Dimensions in millimeters.*

**Figure 11**
**Stainless Steel Tube in Fire Propagation Test Chamber**
(See Clause 8.2.7.2.1.1.)



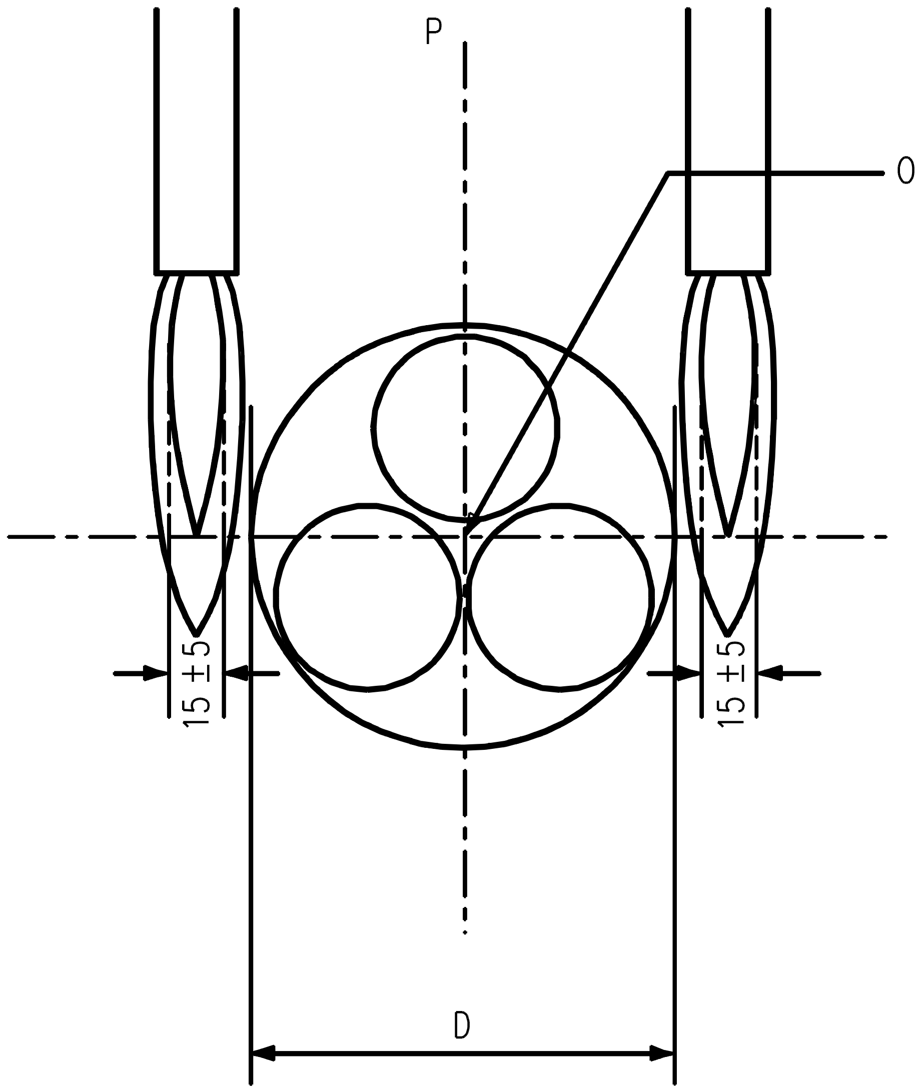

**Note:** *Dimensions in millimeters.*

**Figure 12**
**Copper Bar for Flame Temperature Calibration in Fire Propagation Test**
(See Clauses 8.2.7.2.1.1 and 8.2.7.2.2.3.)




**Note:** *Dimensions in millimeters.*

**Figure 13**
**Arrangement of Specimen between Burners Used in Fire Propagation Test Chamber**
(See Clause 8.2.7.2.3.)




**Legend:**
O is the common axis of symmetry between chimney and oven;
P is the plane of symmetry of the valves;
D is the diameter of the specimen.

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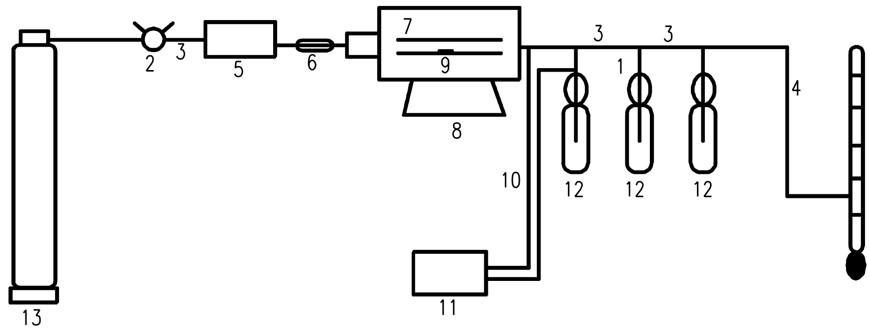
**Note:** *Dimensions in millimeters.*

**Figure 14**
**Combustion System for Halogen Acid Gas Emission Test Procedure**
(See Clauses 8.2.7.3.2.1 and 8.2.7.3.4.)




Legend:

[1] Dry air tank
[2] Regulator
[3] Silicone tubing
[4] Latex tubing
[5] Flow controller (lever or knob)
[6] Connector
[7] Combustion tube
[8] Tubular oven with uniform temperature rise control capable of reaching 1000°C: minimum 30 cm in length
[9] Crucible (combustion bay) approximately 7.6 x 1.0 x 0.9 cm
[10] Heating element 2.5 x 120 cm with glass fiber insulation, capable of maintaining a temperature of 200°C in the glass ducting
[11] Rheostat
[12] Wash traps 5.5 ±0.5cm in diameter
[13] Flowmeter with 0–200 ml/min capacity

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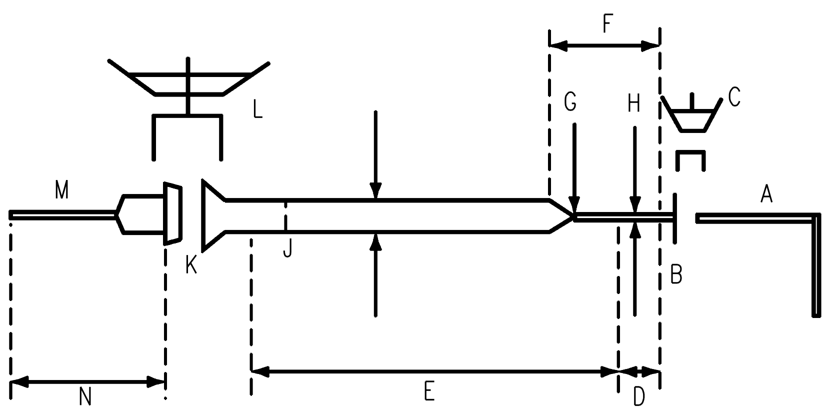
**Figure 15**
**Quartz Combustion Tube**
(See Clause 8.2.7.3.2.1.)




Legend:

A) Connection between borosilicate and circular packing
B) Circular packing 29/9 male and female
C) Pliers for circular packing
D) Length of tube overhanging from the oven, 30–50 mm
E) Portion of tube inside the oven (length of oven)
F) Length of low diameter (100–120 mm)
G) Internal diameter, 13 mm
H) Outside diameter, 17 mm
I) Outside diameter, 25 mm
J) Inside diameter, 19 mm
K) Circular packing, 35/25 male and female
L) Pliers for circular packing No. 35
M) Connection between borosilicate and circular packing
N) Length of borosilicate connection, 50–100 mm

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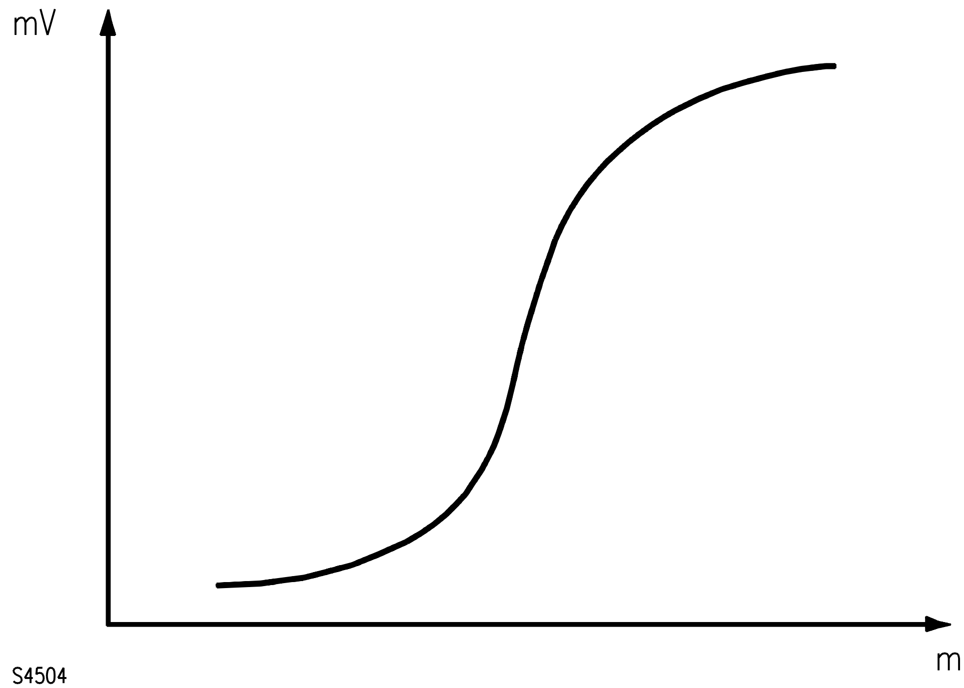
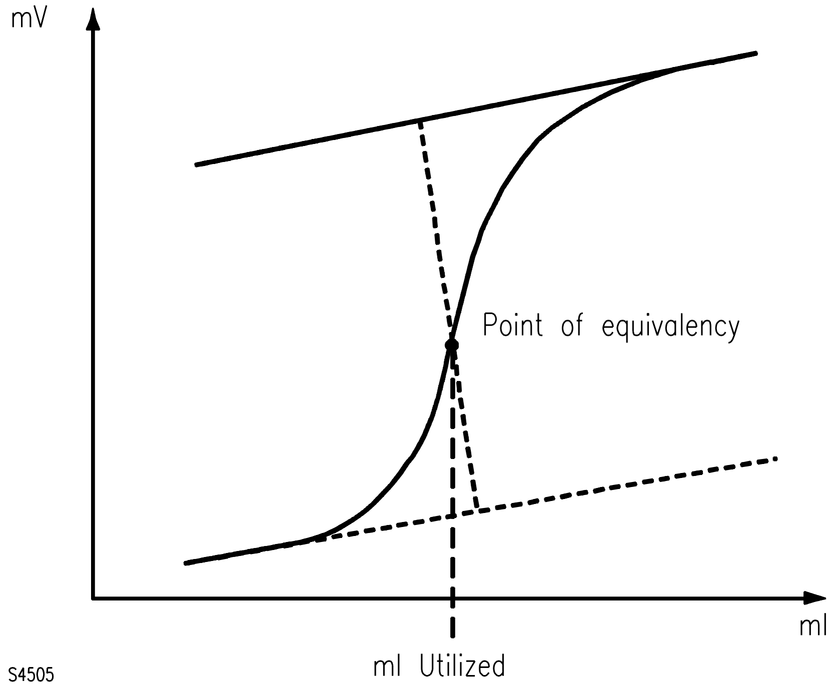
## Graphs

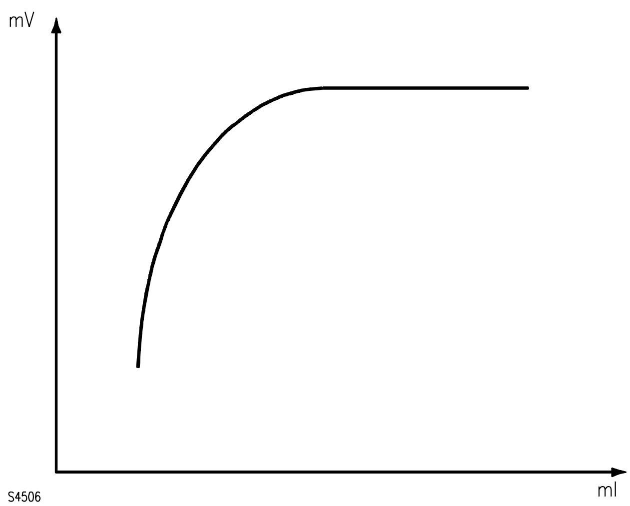
**Graph 1**
**Typical Titration Graph for Halogen Acid Gas Emission**
(See Clauses 8.2.7.3.6.1.)



**Graph 2**
**Geometric Determination of the Point of Equivalency of Halogen Acid Gas Emission**
(See Clauses 8.2.7.3.6.1 and 8.2.7.3.6.2.)




**Graph 3**
**Typical Null Titration Curve for Halogen Acid Gas Emission**
(See Clause 8.2.7.3.6.2.)




**Note:** *As shown in this graph, a similar response to the upper end of the curve of Graph 2 is obtained; that is to say, the curve records the behavior the reaction represented in Graph 2 exhibits after the point of equivalency. Given that halogens do not appear in the solution in the blank titration, the potential will be given only for the calculated quantity of silver nitrate solution.*

## Annex A (informative)
## Wire Type and Electrical Code Cross-Reference and Summary of Applications

(See Clause 1.1.)

### Table A1
### Wire Type/Electrical Code Cross-Reference Chart
### (See Clause 1.1.)

| Wire type designation | Electrical code | | |
|---|---|---|---|
| | **Canada** ***Canadian Electrical Code (CEC)*** | **Mexico** ***Standard for Electrical Installations* (NOM-001-SEDE)** | **United States** ***National Electrical Code (NEC)*** |
| TW | YES | YES | YES |
| TWU | YES | NO | NO |
| TWU75 | YES | NO | NO |
| THW | NO | YES | YES |
| TW75 | YES | NO | NO |
| THW-2 | NO | YES | YES |
| THW-LS | NO | YES | NO |
| THHW | NO | YES | YES |
| THHW-LS | NO | YES | NO |
| THHN | NO | YES | YES |
| T90 NYLON | YES | NO | NO |
| THWN-2 | NO | YES | YES |
| THWN | NO | YES | YES |
| TWN75 | YES | NO | NO |

**Note:**

**(1)** *This table is accurate at the date of publication. Subsequent changes in any national code will supersede this table. See Clause 6.1.3.2 for multiple type designation markings.*

## Annex B (normative for Mexico)
## Multiple-Conductor Thermoplastic-Insulated and -Jacketed Cables

(See Clause 1.3.)

**Note:** *In Canada and the United States, this Annex does not apply.*

### B1 Scope

### B1.1 General

This Annex specifies the requirements for multiple-conductor thermoplastic-insulated and -jacketed cables rated 600 V.

### B1.2 Single conductors

Single conductors composing the multiple-conductor cables shall be of the Types specified in Table 1 of this Standard.

### B2 Lay of cabled conductors

B2.1 Two or more conductors in a multiple-conductor cable shall be assembled in accordance with Clauses B2.2 and B2.3.

B2.2 The component wires or cables of a two-conductor cable shall be assembled as follows:

a) all cables in sizes larger than 13.3 $mm^2$ (6 AWG) cabled in accordance with Clause B2.3;

b) all cables in sizes 13.3 $mm^2$ (6 AWG) and smaller cabled in accordance with Clause B2.3 or parallel.

B2.3 A multiple-conductor cable, other than two-conductor parallel cable, shall have the finished insulated conductors cabled together with a length of lay not greater than indicated in Table B1. The direction of lay shall be allowed to 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.

The following requirements shall apply:

a) Each area in which the lay is right- or left-hand for a minimum of 5 complete twists (full 360° cycles) shall have the insulated conductors cable with a length of lay not greater than that indicated in Table B1;

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 B1.

The overall diameter of the assembly, where required, shall be calculated as outlined in Clause B7.2.

If the assembly consists of number of layers of insulated conductors, the direction of lay of the outer layer is either left-hand or right-hand, and the direction of lay of successive layers is reversed.

### B3 Equipment-grounding conductor

Equipment-grounding conductors shall not be smaller than the sizes shown in Table B2. Where multiple equipment-grounding conductors are employed, they shall have a combined area not less than the sizes given in Table B2. 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 stranding class as that of the accompanying circuit conductors or of a more flexible stranding class.

### B4 Conductor identification

#### B4.1 Color of insulated grounding conductor

A single-conductor insulated wire or cable intended for use as an equipment- grounding conductor and any insulated equipment-grounding conductor provided in an assembly containing two or more insulated circuit conductors 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. No circuit conductor in the cable shall be green.

#### B4.2 Identification of ungrounded (phase) conductor(s)

Each ungrounded (phase) conductor in the cable shall be finished to show a color other than white, gray, or green.

#### B4.3 Identification of grounded conductor(s)

If one or more conductors are intended for use as a grounded circuit conductor, they shall be finished to show the color white or light gray throughout the entire length and all the circumference of its outer surface.

### B5 Fillers

Fillers when used in a multiple-conductor cable or assembly shall be of non-hygroscopic material and shall not have any deleterious effect on other cable components.

### B6 Jacket separators

B6.1 A polymeric tape of non-hygroscopic material having a thickness of not less than 0.02 mm shall be optional for use under the jacket. The separator and other wire or cable components shall not have any deleterious effect on each other.

B6.2 The tape shall be applied either helically or longitudinally to completely cover the underlying components so that it has an overlap of not less than 25 percent.

### B7 Jackets

#### B7.1 General

A multiple-conductor cable shall have a protective jacket applied over the cabled conductors or over a jacket separator. The physical properties of the jacket shall comply with Table B3.

### B7.2 Jacket thickness

The average and minimum thickness of a jacket shall not be less than indicated in Table B4 when determined by the method described in UL 1581, Section 240; CSA C22.2 No. 0.3, Clause 4.2.1; or NMX-J-177-ANCE. The minimum thickness measured at any point shall not be less than 80 percent of the nominal thickness.

## B8 Marking

### B8.1 Marking on product

Multiple-conductor cables shall be legibly and durably marked to indicate the following:

a) Manufacturer’s identification;

b) Conductor type;

c) Number of circuit conductors;

d) Conductor size in $mm^2$ (AWG or kcmil);

e) Voltage rating, volts;

f) Maximum operating dry and wet temperature rating of insulation,°C;

g) Optional markings where applicable* (e.g., LS, CT, etc.).

** Corresponding tests shall be performed on the finished cable.*

### B8.2 Marking on package

Each package of multiple-conductor cable shall be tagged or marked legibly and durably to indicate the following:

a) Manufacturer’s identification;

b) Number of circuit conductors;

c) Conductor size in $mm^2$ (AWG or kcmil);

d) Conductor type designation;

e) Material of the jacket;

f) Voltage rating, volts;

g) Maximum operating dry and wet temperature rating of insulation,°C.

**Table B1**
**Maximum Length of Lay for Multiple-Conductor Cables**
**(See Clause B2.3.)**

| Number of conductors | Maximum length of lay |
|---|---|
| 2 | 30 times diameter of finished insulated conductor |
| 3 | 35 times diameter of finished insulated conductor |
| 4 | 40 times diameter of finished insulated conductor |
| 5 or more, or assemblies with more than one conductor size | 15 times the overall diameter of the assembly, except that in a multiple layer cable, the length of lay of the conductors in any inner layer shall be not more than 20 times the overall diameter of that layer. |

**Table B2**
**Minimum Size of Equipment-Grounding Conductor**
**(See Clause B3.)**

| Size of circuit conductor (phase) | | Minimum size of grounding conductor | |
|---|---|---|---|
| Cross-sectional area $mm^2$ | AWG or kcmil | Cross-sectional area $mm^2$ | AWG |
| 2.08 – 5.26 | 14 – 10 | The same size as circuit conductor | |
| 8.37 | 8 | 5.26 | 10 |
| 13.3 – 21.2 | 6 – 4 | 8.37 | 8 |
| 33.6 – 67.4 | 2 – 2/0 | 13.3 | 6 |
| 85.0 – 203 | 3/0 – 400 | 33.6 | 2 |
| 253 – 507 | 500 – 1000 | 42.4 | 1 |

**Table B3**
**Physical Properties of Thermoplastic Jackets**
**(See Clause B7.1.)**

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

## Table B4
## Jacket Thickness
## (See Clause B7.2.)

| Calculated diameter under jacket of round cable or calculated length of major axis under jacket of 2-conductor flat parallel. | | Thickness of jacket | | | |
|---|---|---|---|---|---|
| mm | inches | Average | | Minimum at any point | |
| | | mm | mils | mm | mils |
| 0 – 10.80 | 0 – 0.425 | 1.14 | 45 | 0.91 | 36 |
| 10.81 – 17.80 | 0.426 – 0.700 | 1.52 | 60 | 1.22 | 48 |
| 17.81 – 38.10 | 0.701 – 1.500 | 2.03 | 80 | 1.62 | 64 |
| 38.11 – 63.50 | 1.501 – 2.500 | 2.79 | 110 | 2.23 | 88 |
| Over 63.50 | Over 2.500 | 3.56 | 140 | 2.85 | 112 |

## Annex C (informative)
## Summary of Requirements

### Table C1
### (See Clause 3.3.)

| **Wire Type Designation →** | **TW** | **THW or TW75, THW-2, THHW, THW-LS, THHW-LS** | **THWN or TWN75, THWN-2** | **THHN or T90 Nylon** | **TWU** | **TWU75** |
|---|---|---|---|---|---|---|
| **Requirement ↓** | | | | | | |
| **Maximum temperature** | 60°C dry or wet | THW or TW75 75°C dry or wet; THW-2 90°C dry or wet; THHW 90°C dry or 75°C wet | THWN or TWN75 75°C dry or wet; THWN-2 90°C dry or wet | 90°C dry | 60°C dry or wet | 75°C dry or wet |
| **Maximum voltage** | 600 V | | | | | |
| **Number of conductors** | (1.1 – 1.2) | | | | | |
| **Conductor metal** | (4.1.1 – 4.1.4) | | | | | |
| **Conductor size** | (4.1.5.1, Table 1) | | | | | |
| **Conductor stranding** | (4.1.5.2, Tables 1, 2 and 3) | | | | | |
| **Conductor diameter** | (4.1.6, Tables 4 – 9) | | | | | |
| **Conductor joints** | (4.1.7) | | | | | |
| **Conductor separator** | (4.1.8) | | | | | |
| **Insulation (4.2)** | PVC | | | | | |
| **Nylon jacket** | optional | | required | | optional | |
| **Insulation - general** | (4.2.1) | | | | | |
| **Polarity identification** | (4.2.3.2 and 4.2.3.3) | | | | | |
| **Insulation thickness** | (4.2.4, Table 10) | | | | | |
| **Physical properties of insulation** | (4.2.5,Table 11) | | | | | |
| **Nylon jacket thickness (4.3)** | – | | Table 13 | | – | |
| **Assemblies** | (4.4) | | | | | |
| **Conductor resistance** | (5.2) | | | | | |
| **Aluminum conductors – physical properties** | (5.3.1) | | | | | |

Table C1 Continued on Next Page

## Table C1 Continued

| Wire Type Designation → | TW | THW or TW75, THW-2, THHW, THW-LS, THHW-LS | THWN or TWN75, THWN-2 | THHN or T90 Nylon | TWU | TWU75 |
|---|---|---|---|---|---|---|
| **Requirement ↓** | | | | | | |
| **Aluminum conductors – high current heat cycling** | (5.3.2) | | | | | |
| **Short-term insulation resistance at elevated temperature in water** | (5.4, Table 23) | | | Not required | (5.4, Table 23) | |
| **Long-term insulation resistance in water** | (5.5, Table 23) | | | Not required | (5.5, Table 23) | |
| **Long-term insulation resistance in air for 90°C rated conductors** | – | | | (5.6, Table 24) | – | |
| **Capacitance and relative permittivity** | (5.7) | | | Not required | (5.7) | |
| **Flexibility at room temperature after aging** | (5.8) | | | | | |
| **Heat shock** | (5.9) | | | | | |
| **Cold bend** | (5.10.1) | | | | | |
| **Cold impact (optional)** | (5.10.2) | | | | | |
| **Deformation** | (5.11) | | | | | |
| **Vertical flame** | (5.12.1) | | | | | |
| **FT1 (optional)** | (5.12.2) | | | | | |
| **VW-1 (optional)** | (5.12.3) | | | | | |
| **Vertical tray (optional)** | (5.12.4) | | | | | |
| **FT4 vertical tray (optional)** | (5.12.5) | | | | | |
| **ST1 limited smoke (optional)** | (5.12.6) | | | | | |
| **LS (low smoke): flame, smoke, and acid gas release for types marked ″LS″ (5.12.7)** | – | Required for THW-LS and THHW-LS | – | | | |

Table C1 Continued on Next Page

## Table C1 Continued

<table>
<tr><th>Wire Type Designation →</th><th>TW</th><th>THW or TW75, THW-2, THHW, THW-LS, THHW-LS</th><th>THWN or TWN75, THWN-2</th><th>THHN or T90 Nylon</th><th>TWU</th><th>TWU75</th></tr>
<tr><td>Requirement ↓</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Weather resistance (optional)</td><td colspan="6">(5.13)</td></tr>
<tr><td>Oil resistance (optional)</td><td colspan="6">(5.14)</td></tr>
<tr><td>Gasoline and oil resistance (optional)</td><td colspan="6">(5.15)</td></tr>
<tr><td>Abrasion resistance</td><td colspan="2">–</td><td colspan="4">(5.16)</td></tr>
<tr><td>Crushing resistance</td><td colspan="2">–</td><td colspan="4">(5.17)</td></tr>
<tr><td>Impact resistance</td><td colspan="2">–</td><td colspan="4">(5.18)</td></tr>
<tr><td>Durability of ink printing</td><td colspan="6">(5.19)</td></tr>
<tr><td>Color coating</td><td colspan="6">(5.20)</td></tr>
<tr><td>Spark test</td><td colspan="6">(5.22)</td></tr>
<tr><td>Dielectric voltage-withstand in water</td><td colspan="6">(5.23)</td></tr>
<tr><td>Insulation resistance in water at 15°C</td><td colspan="6">(5.24)</td></tr>
<tr><td>Electrical continuity</td><td colspan="6">(5.25)</td></tr>
<tr><td>Marking on product</td><td colspan="6">(6.1)</td></tr>
<tr><td>Marking on package</td><td colspan="6">(6.2)</td></tr>
<tr><td>Deep-well submersible water pump cable – specific requirements and permitted constructions</td><td colspan="6">(7)</td></tr>
<tr><td>Multiple-conductor cable for use in Mexico</td><td colspan="6">Annex B</td></tr>
</table>

# Annex D (normative)
# Chemical Composition of Recognized ACM or AA 8000 Series Aluminum Alloy Conductor Materials

## Table D1
## Chemical Composition of Recognized ACM or AA 8000 Series Aluminum Alloy Conductor Materials

| Alloys | | Composition, Percent Mass | | | | | | | Others | |
|---|---|---|---|---|---|---|---|---|---|---|
| ANSI | UNS | Aluminum | Silicon | Iron | Copper | Magnesium | Zinc | Boron | Each | Total |
| 8017 | A98017 | Remainder | 0.10 | 0.55 – 0.8 | 0.10 – 0.20 | 0.01 – 0.05 | 0.05 | 0.04 | 0.03[a] | 0.10 |
| 8030 | A98030 | Remainder | 0.10 | 0.30 – 0.8 | 0.15 – 0.30 | 0.05 | 0.05 | 0.001 – 0.04 | 0.03 | 0.10 |
| 8076 | A98076 | Remainder | 0.10 | 0.6 – 0.9 | 0.04 | 0.05 | 0.5 | 0.04 | 0.03 | 0.10 |
| 8130 | A98130 | Remainder | 0.15[b] | 0.40 – 1.0[b] | 0.05 – 0.15 | – | 0.10 | – | 0.03 | 0.10 |
| 8176 | A98176 | Remainder | 0.03 – 0.15 | 0.40 – 1.0 | – | – | 0.10 | – | 0.05[c] | 0.15 |
| 8177 | A98177 | Remainder | 0.10 | 0.25 – 0.45 | 0.04 | | 0.05 | 0.04 | 0.03 | 0.10 |

[a] *0.003 max lithium.*

[b] *1.0 max silicon and iron.*

[c] *0.03 max gallium.*

## Annex E (normative)
## Copper-Clad Aluminum Conductors

(See Clause 4.1.3.)

### E1 General

The copper cladding shall be metallurgically bonded to the aluminum core; shall occupy 10 percent or more of the cross-section of a solid conductor, and of each wire (strand) of a stranded conductor; and shall be concentric with the aluminum. The thickness of the copper shall not be less than 2.56 percent of the diameter of the solid conductor or wire (strand) as determined by microscopic examination of a polished right cross-section of the round strand or round solid conductor.

### E2 Sizes and stranding

Conductors shall be of the same size and assembly indicated for solid or concentric stranded aluminum wire in Table 1. The number of wires in the conductors shall be in accordance with Table 2.

### E3 Conductor resistance

The direct-current resistance of the copper-clad aluminum conductor shall not be greater than specified for aluminum conductors in Tables 14 and 15, as appropriate.

### E4 Physical properties

The tensile strength of a finished copper-clad aluminum conductor tested as a unit or of the wires (strands) from a finished stranded copper-clad aluminum conductor and of a solid copper-clad aluminum conductor shall not exceed 138 MN/$m^2$ (20,000 lbf/$in^2$) when specimens are tested at a maximum separation speed of 300 mm/min (12 in/min). The elongation of the same specimens shall not be less than 15 percent. The bench marks for the tensile and elongation test shall be placed 250 mm (10 inches) apart.

### E5 Marking requirements

E5.1 In addition to the marking required in Clause 6.1 and 6.2, copper-clad aluminum conductors shall be marked ″AL (CU-CLAD)″, ″ALUM (COPPER-CLAD″, ″CU-CLAD AL″, or ″COPPER-CLAD ALUM″ wherever the size of the conductor appears on the wire, cable, or package marking.

E5.2 The following statements shall also appear on the package:

a) ″Copper-clad aluminum shall be used only with equipment marked to indicate that it is for use with aluminum conductors. Terminate copper-clad aluminum with pressure wire connectors marked for use with copper and aluminum conductors.″

b) For 3.31 – 5.26 $mm^2$ (12 – 10 AWG) solid copper-clad aluminum: ″May be used with wire-binding screws and in pressure-plate and push-in spring-type connecting mechanisms that are acceptable for use with copper conductors″.

c) ″Where physical contact between any combination of copper-clad aluminum, copper, and aluminum conductors occurs in a wire connector, the connector shall be of a type marked for such intermixed use and the connection shall be limited to dry locations only.″

## Annex F (informative)
## Metric Sizes

(See Clause 4.1.5.1.)

**Note:** *This annex is not a mandatory part of this Standard but is written in mandatory language to accommodate its adoption by anyone wishing to do so.*

F1 Metric sizes for wire and cable products are not recognized in the *Canadian Electrical Code, Part I*, the *National Electrical Code*, or for Mexico, NOM-001-SEDE, but are employed in some jurisdictions requiring metric-sized conductors. Tables F1 and F2 are based on IEC Publication 60228.

F2 The direct-current resistance values of conductors shall not be greater than given in Table F3, except that a plus tolerance of 2 percent is optional in the case of a conductor in a twisted multiple-conductor cable assembly.

F3 Direct-current resistance shall be determined with the test, DC resistance, in UL 2556, CSA C22.2 No. 2556, or NMX-J-212-ANCE.

F4 The thickness of insulation and jackets, and other related requirements, shall be the same as those that correspond to the AWG or kcmil closest to the metric conductor size ($mm^2$) as shown in Table F5.

**Table F1**
**Solid Class 1 Aluminum and Copper Conductors**
**(See Clause F1.)**

| Conductor area | | Maximum diameter, mm |
|---|---|---|
| Square millimeters | Circular mils | |
| 0.50 | 992 | 0.9 |
| 0.75 | 1 458 | 1.0 |
| 1 | 1 980 | 1.2 |
| 1.5 | 2 952 | 1.5 |
| 2.5 | 4 856 | 1.9 |
| 4 | 7 777 | 2.4 |
| 6 | 11 637 | 2.9 |
| 10 | 19 644 | 3.7 |
| 16 | 31 109 | 4.6 |
| 25 | 49 305 | 5.7 |
| 35 | 68 339 | 6.7 |
| 50 | 92 378 | 7.8 |
| 70 | 133 484 | 9.4 |
| 95 | 185 171 | 11.0 |
| 120 | 234 119 | 12.4 |
| 150 | 287 532 | 13.8 |

## Table F2
## Concentric Stranded Class 2 Aluminum and Copper Conductors
## (See Clause F1.)

| Conductor area | | Number of strands | | | | Maximum diameter, mm |
|---|---|---|---|---|---|---|
| | | Non-compact | | Compact | | |
| Square millimeters | Circular mils | Cu | Al | Cu | Al | |
| 0.50 | 1 043 | 7 | | | | 1.1 |
| 0.75 | 1 485 | 7 | | | | 1.2 |
| 1 | 2 101 | 7 | | | | 1.4 |
| 1.5 | 3 048 | 7 | | 6 | | 1.7 |
| 2.5 | 4 871 | 7 | | 6 | | 2.2 |
| 4 | 7 839 | 7 | 7 | 6 | | 2.7 |
| 6 | 11 735 | 7 | 7 | 6 | | 3.3 |
| 10 | 19 774 | 7 | 7 | 6 | 6 | 4.2 |
| 16 | 31 357 | 7 | 7 | 6 | 6 | 5.3 |
| 25 | 49 689 | 7 | 7 | 6 | 6 | 6.6 |
| 35 | 68 902 | 7 | 7 | 6 | 6 | 7.9 |
| 50 | 93 310 | 19 | 19 | 6 | 12 | 9.1 |
| 70 | 134 869 | 19 | 19 | 12 | 15 | 11 |
| 95 | 187 020 | 19 | 19 | 15 | 18 | 12.9 |
| 120 | 236 334 | 37 | 37 | 18 | 18 | 14.5 |
| 150 | 290 335 | 37 | 37 | 18 | 30 | 16.2 |
| 185 | 364 196 | 37 | 37 | 30 | 34 | 18 |
| 240 | 478 660 | 61 | 61 | 34 | 34 | 20.6 |
| 300 | 600 431 | 61 | 61 | 34 | 53 | 23.1 |
| 400 | 767 984 | 61 | 61 | 53 | 53 | 26.1 |
| 500 | 968 194 | 61 | 61 | 53 | 53 | 29.2 |
| 630 | 1 250 079 | 61 | 91 | 53 | 53 | 33.2 |
| 800 | 1 598 917 | 61 | 91 | 53 | 53 | 37.6 |
| 1 000 | 2 015 748 | 61 | 91 | 53 | 53 | 42.2 |

## Table F3
## Maximum D-C Resistance in Ohms per Kilometer at 20°C
## (See Clause F2.)

| Conductor size $mm^2$ | Solid (Class 1) | | | Stranded (Class 2) | | |
|---|---|---|---|---|---|---|
| | Aluminum | Copper | | Aluminum | Copper | |
| | | Uncoated | Coated | | Uncoated | Coated |
| 0.50 | – | 36.0 | 36.7 | – | 36.0 | 36.7 |
| 0.75 | – | 24.5 | 24.8 | – | 24.5 | 24.8 |
| 1 | – | 18.1 | 18.2 | – | 18.1 | 18.2 |
| 1.5 | 18.1 | 12.1 | 12.2 | – | 12.1 | 12.2 |
| 2.5 | 12.1 | 7.41 | 7.56 | – | 7.41 | 7.56 |
| 4 | 7.41 | 4.61 | 4.70 | 7.41 | 4.61 | 4.70 |
| 6 | 4.61 | 3.08 | 3.11 | 4.61 | 3.08 | 3.11 |
| 10 | 3.08 | 1.83 | 1.84 | 3.08 | 1.83 | 1.84 |
| 16 | 1.91 | 1.15 | 1.16 | 1.91 | 1.15 | 1.16 |
| 25 | 1.20 | 0.727 | – | 1.20 | 0.727 | 0.734 |
| 35 | 0.868 | 0.524 | – | 0.868 | 0.524 | 0.529 |
| 50 | 0.641 | 0.387 | – | 0.641 | 0.387 | 0.391 |

Table F3 Continued on Next Page

## Table F3 Continued

| Conductor size $mm^2$ | Solid (Class 1) | | | Stranded (Class 2) | | |
|---|---|---|---|---|---|---|
| | Aluminum | Copper | | Aluminum | Copper | |
| | | Uncoated | Coated | | Uncoated | Coated |
| 70 | 0.443 | 0.268 | – | 0.443 | 0.268 | 0.270 |
| 95 | 0.320 | 0.193 | – | 0.320 | 0.193 | 0.195 |
| 120 | 0.253 | 0.153 | – | 0.253 | 0.153 | 0.154 |
| 150 | 0.206 | 0.124 | – | 0.206 | 0.124 | 0.126 |
| 185 | 0.164 | – | – | 0.164 | 0.0991 | 0.100 |
| 240 | 0.125 | – | – | 0.125 | 0.0754 | 0.0762 |
| 300 | 0.100 | – | – | 0.100 | 0.0601 | 0.0607 |
| 400 | – | – | – | 0.0778 | 0.0470 | 0.0475 |
| 500 | – | – | – | 0.0605 | 0.0366 | 0.0369 |
| 630 | – | – | – | 0.0469 | 0.0283 | 0.0286 |
| 800 | – | – | – | 0.0367 | 0.0221 | 0.0224 |
| 1000 | – | – | – | 0.0291 | 0.0176 | 0.0177 |
| **Note:** *For temperature correction factors see Table F4.* | | | | | | |

## Table F4
## Temperature Correction Factors, $k_t$, for Conductor Resistance to Correct the Measured Resistance at t°C to 20°C
## (See Table F3.)

| Temperature of conductor at time of measurement, t°C | Correction factor, $k_t$ |
|---|---|
| 5 | 1.064 |
| 6 | 1.059 |
| 7 | 1.055 |
| 8 | 1.050 |
| 9 | 1.046 |
| 10 | 1.042 |
| 11 | 1.037 |
| 12 | 1.033 |
| 13 | 1.029 |
| 14 | 1.025 |
| 15 | 1.020 |
| 16 | 1.016 |
| 17 | 1.012 |
| 18 | 1.008 |
| 19 | 1.004 |
| 20 | 1.000 |
| 21 | 0.996 |
| 22 | 0.992 |
| 23 | 0.988 |
| 24 | 0.984 |
| 25 | 0.980 |
| 26 | 0.977 |
| 27 | 0.973 |
| 28 | 0.969 |
| 29 | 0.965 |
| 30 | 0.962 |

Table F4 Continued on Next Page

## Table F4 Continued

| Temperature of conductor at time of measurement, t°C | Correction factor, $k_t$ |
|---|---|
| **Note:** *The values of correction factors $k_t$ in the Table are based on a resistance-temperature coefficient of 0.004 per* °C *at* 20°C. | |

## Table F5
## Closest AWG or kcmil Size(s)
## (See Clause F4.)

| Metric conductor size, mm$^2$ | Closest AWG or kcmil size(s) for selection of insulation and jacket thickness requirement |
|---|---|
| 2.5 | 14 |
| 4 | 12 |
| 6 | 10 |
| 10 | 8 |
| 16 | 6 |
| 25 | 4 |
| 35 | 2 |
| 50 | 1/0 |
| 70 | 2/0 |
| 95 | 3/0 |
| 120 | 250 |
| 150 | 300 |
| 240 | 500 |
| 300 | 600 |
| 400 | 800 |
| 500 | 1000 |
| 630 | 1250 |
| 800 | 1500 |
| 1000 | 2000 |

**Note:** *This table is provided to permit the correct selection of insulation and jacket thickness requirements, which are dependent on conductor size; however, at the time of publication, the* CEC, *NOM-001-SEDE, and* NEC *do not provide ampacity values for the metric conductor sizes shown above.*

## Annex G (informative)
## Evaluation of Materials Having Characteristics Differing from Those in Table 11

(See Clause 4.2.5.3.)

G1 The listing of materials resulting from innovation, based upon the 150-day aging and other tests as described in Clause 4.2.5.3, will normally generate proposals to change, or create additions to, certain requirements of the standard, typified by:

a) Retention of short-term tensile strength and of elongation after accelerated aging in an air oven (see Table 11);

b) Addition to the materials referenced in 4.2.1.

## Annex H (informative)
## French and Spanish Translations and Markings

(See Clauses 6, 7.2.4, 7.3.1, and 7.3.2.)

### H1 General

The following alternative markings to those specified in the Standard are optional for products intended for use in specific national applications.

### H2 Markings on wire

| | English | Spanish | French |
|---|---|---|---|
| GRD | GROUNDING ONLY | SOLO TIERRA | MISE À LA TERRE SEULEMENT |
| – | SUBMERSIBLE PUMP CABLE | CABLE BOMBA SUMERGIBLE | CÂBLE POUR POMPE SUBMERSIBLE |

### H3 Markings on packaging

| English | Spanish | French |
|---|---|---|
| SUBMERSIBLE PUMP CABLE | CABLE BOMBA SUMERGIBLE | CÂBLE POUR POMPE SUBMERSIBLE |
| For Wiring Only Between Equipment Located at Water Well Heads and Motors of Installed Deep-Well Submersible Water Pumps | | Uniquement pour le câblage entre les appareils situés à la tête des puits d’eau et les moteurs des pompes immergées pour puits profonds installées. |

**Superseded requirements for**
**the Standard for**
**Thermoplastic-Insulated Wires and Cables**

**UL 83, Fourteenth Edition**

The requirements shown are the current requirements that have been superseded by requirements in this edition. The numbers in parentheses refer to the new requirements with future effective dates that have superseded these requirements. To retain the current requirements, do not discard the following requirements until the future effective dates are reached.

4.1.4.3 **(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.

**4.4 (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.

7.2.4 **(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.

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