UL 44

ISBN 0-7629-1085-2

Thermoset-Insulated Wires and Cables

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

Sixteenth Edition, Dated July 15, 2005

Summary of Topics

This new edition of UL 44 is issued to harmonize the Canadian, Mexican and UL requirements for thermoset-insulated wires.

The new requirements are substantially in accordance with UL's Bulletin(s) on this subject dated May 6, 2004 and January 21, 2005. The bulletin(s) is now obsolete and may be discarded.

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.

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The requirements in this Standard are now in effect, except for those paragraphs, sections, tables, figures, and/or other elements of the Standard having future effective dates as indicated in the 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that have been revised and that have a future effective date are located after the Standard, and are preceded by a "SUPERSEDED REQUIREMENTS" notice.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
1-186	July 15, 2005

Association of Standardization and Certification
NMX-J-451-ANCE-2005
Third Edition

Canadian Standards Association
CSA C22.2 No. 38-05
Eighth Edition

Underwriters Laboratories Inc.
UL 44
Sixteenth Edition

Thermoset-Insulated Wires and Cables

July 15, 2005

ANSI/UL 44-2005

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.

ISBN 1-55397-413-1

ISBN 0-7629-1085-2

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.

The most recent designation of ANSI/UL 44 as an American National Standard (ANSI) occurred on July 15, 2005.

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

The Department of Defense (DoD) has adopted UL 44 on April 5, 1985. The publication of revised pages or a new edition of this Standard will not invalidate the DoD adoption.

CONTENTS

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Preface

This is the common ANCE, CSA, and UL standard for Thermoset-Insulated Wires and Cables. It is the Third edition of NMX-J-451-ANCE, the Eighth edition of CSA C22.2 No. 38, and the Sixteenth edition of UL 44. This edition of CSA C22.2 No. 38 supersedes the previous edition published in 1995. This edition of UL 44 supersedes the previous edition published in 1999.

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

This standard was reviewed by the CSA Subcommittee on C22.2 No. 38, under the jurisdiction of the CSA Technical Committee on Wiring Products and the CSA Strategic Steering Committee on Requirements for Electrical Safety, and has been formally approved by the CSA Technical Committee. This standard was reviewed and approved by the Committee de Normalizacion of ANCE (CONANCE). This standard was reviewed by UL's Standards Technical Panel (STP) for Power Cables, STP 83.

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

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

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

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

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

Level of harmonization

This standard uses the IEC format but is not based on, nor shall it 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 from IEC

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

Interpretations

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

ANCE effective date

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

CSA effective date

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

UL effective date

As of July 15, 2005 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 as indicated in the list.

July 15, 2006: Clauses 5.13.1, 5.15.1, 6.2(e), 7.3.2(h) and Tables 20, 42, and 47.

January 15, 2007: Clauses 5.14.7, 6.1.9.1(e), 6.1.4, and 6.2(d).

Between July 15, 2005 and the effective dates indicated above, new product submittals to UL may be evaluated under all requirements in this standard or, if requested in writing, evaluated under presently effective requirements only. The presently effective requirements are contained in the fifteenth edition of UL 44.

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

Thermoset-Insulated Wires and Cables

1 Scope

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

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

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

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

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

2 Definitions

2.1 The following definitions apply in this Standard:

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

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

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

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

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

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

Neoprene – a thermoset compound whose characteristic constituent is polychloroprene.

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

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

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

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

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

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

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

3 General

3.1 Units of measure

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

3.2 Reference publications

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

ANCE Standards

NOM-001-SEDE
Standard for Electrical Installations

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

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

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

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

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

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

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

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

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

NMX-J-177-ANCE
Determination of Thickness in 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
Wires and Cables – Accelerated Aging in Forced Air Convection Oven of Semiconducting Shields, Insulations and Jackets of Electrical Conductors – Test Method

NMX-J-190-ANCE
Wires and cables – Thermal Shock Resistance of PVC Insulations and PVC 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-212-ANCE
Electrical Resistance, Resistivity and Conductivity – Test Method

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

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

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

NMX-J-437-ANCE
Wires and Cables – Determination of Light Absorption Coefficient of Polyethylene Pigmented with Carbon Black – Test Method

NMX-J-498-ANCE
Vertical Tray – Flame Test – Test Method

CSA Standards

C22.1-02
Canadian Electrical Code, Part I

CSA C22.2 No. 0.3-01
Test Methods for Electrical Wires and Cables

CSA C22.2 No. 42-99 (R2002)
General Use Receptacles, Attachment Plugs and Similar Wiring Devices

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

UL Standards

UL 498
Standard for Attachment Plugs and Receptacles

UL 1567
Receptacles and Switches Intended for Use with Aluminum Conductors

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

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

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

ASTM (American Society for Testing and Materials)

A 29-03
Steel Bars, Carbon and Alloy, Hot-Wrought and Cold-Finished, General Requirements for

B 3-01
Soft or Annealed Copper Wire

B 8-99
Concentric-Lay-Stranded Copper Conductors, Hard, Medium-Hard, or Soft

B 33-00
Tinned Soft or Annealed Copper Wire for Electrical Purposes

B 172-01
Rope-Lay-Stranded Copper Conductors Having Bunch-Stranded Members, for Electrical Conductors

B 173-01
Rope-Lay-Stranded Copper Conductors Having Concentric-Stranded Members, for Electrical Conductors

B 189-95
Lead-Coated and Lead-Alloy-Coated Soft Copper Wire for Electrical Purposes

B 231-99
Standard Specification for Concentric-Lay-Stranded Aluminum 1350 Conductors

B 298-99
Standard Specification for Silver-Coated Soft or Annealed Copper Wire

B 355-95
Standard Specification for Nickel-Coated Soft or Annealed Copper Wire

B 835-00
Standard Specification for Compact Round Stranded Copper Conductors Using Single Input Wire Construction

B 836-00
Standard Specification for Compact Round Stranded Aluminum Conductors Using Single Input Wire Construction

D 1603-01
Standard Test Method for Carbon Black on Olefin Plastics

D 4218-96 (2001)
Standard Test Method for Determination of Carbon Black Content in Polyethylene Compounds by the Muffle-Furnace Technique

D 6370-99 (2003)
Standard Test Method for Rubber-Compositional Analysis by Thermogravimetry (TGA)

E 1131-03
Standard Test Method for Compositional Analysis by Thermogravimetry

IEC (International Electrotechnical Commission)

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

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

IEEE (Institute of Electrical and Electronic Engineers)

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

NFPA (National Fire Protection Association)

NFPA 70-2002
National Electrical Code

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

All conductors shall be of aluminum conductor material (ACM), AA 8000 series alloy.

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

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

4.1.3 Copper-clad aluminum conductors

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

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

4.1.4 Copper conductors

4.1.4.1 General

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

4.1.4.2 Coated copper conductors

4.1.4.2.1 Each tin-coated conductor shall comply with the requirements of ASTM B 33 or NMX-J-008-ANCE; each wire in a lead-alloy-coated wire shall comply with the requirements of ASTM B 189; a nickel-coated wire shall comply with ASTM B 355 and a silver-coated wire shall comply with ASTM B 298. Conductors coated with other metals or alloys shall be subjected to special investigation.

In Mexico, the use of lead-alloy-coated wires is not permitted.

Note: *In Mexico, the use of ASTM B 355 is recommended for nickel-coated wire, and the use of ASTM B 298 is recommended for silver-coated wire.*

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

4.1.4.3 Uncoated copper conductors

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

4.1.5 Sizes and stranding

4.1.5.1 Sizes

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

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

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

4.1.5.2 Stranding

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

4.1.5.3 Compact

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

4.1.5.4 Compressed

A compressed-stranded conductor shall be a round conductor consisting of a central core surrounded by one or more layers of helically laid wires with either the direction of lay reversed in successive layers or unilay or unidirectional lay. The direction of lay of the outer layer shall be left-hand in all cases. The strands of one or more layers shall be slightly compressed by rolling, drawing, or other means to change the originally round strands to various shapes that achieve filling of some of the spaces originally present between the strands.

4.1.5.5 Assembly of strands

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

4.1.5.6 Length and direction of lay

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

a) The direction of lay of the strands, members, or ropes in a 13.3 – 1010 mm^2 (6 AWG – 2000 kcmil) conductor other than a combination unilay or a compressed unilay or compressed unidirectional lay conductor shall be reversed in successive layers. Rope-lay conductors with bunch-stranded or concentric-stranded members shall be either unidirectional or reversed. All unidirectional lays and the outer layer of reversed lays shall be in the left-hand direction.

b) For a bunch-stranded member of a rope-lay-stranded conductor in which the members are formed into rope-stranded components that are then cabled into the final conductor, the length of lay of the individual members within each component shall not be more than 30 times the outside diameter of one of those members.

c) For a concentric-stranded member of a rope-lay-stranded conductor, the length of lay of the individual strands in a member shall be 8 – 16 times the outside diameter of the member. The direction of lay of the strands in each member shall be reversed in successive layers of the member.

d) The length of lay of the strands in both layers of a 19-wire combination round-wire unilay-stranded copper or aluminum conductor shall be 8 – 16 times the outside diameter of the completed conductor. Otherwise, the length of lay of the strands in every layer of a concentric-lay-stranded conductor consisting of fewer than 37 strands shall be 8 – 16 times the outside diameter of the conductor.

e) The length of lay of the strands in the outer two layers of a concentric-lay-stranded conductor consisting of 37 or more strands shall be 8 – 16 times the outside diameter of the conductor.

f) The length of lay of the members or ropes in the outer layer of a rope-lay-stranded conductor shall be 8 – 16 times the outside diameter of that layer.

4.1.6 Diameter and cross-sectional area

4.1.6.1 The nominal diameters of solid and stranded conductors are shown in Tables 5 – 10. The minimum diameter for a stranded conductor is 98 percent of the nominal. The maximum diameter of any conductor is 101 percent of the nominal. Verification of the diameter shall be determined in accordance with the method described in UL 1581, Section 220, CSA C22.2 No. 0.3, Clause 4.1.1, or NMX-J-066-ANCE.

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

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

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

4.1.7 Joints

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

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

A joint shall be allowed in a Class B stranded 2.08 mm^2 (14 AWG), 3.31 mm^2 (12 AWG), or 5.26 mm^2 (10 AWG) insulated copper conductor intended to be used in a multiple-conductor cable, with an overall covering. The joint (butt splice) shall be made by machine brazing or welding the entire conductor such that the resulting solid section of the stranded conductor is no longer than 13 mm (0.50 inch). In addition, the joint shall not increase the diameter of the conductor, there shall be no sharp points, and the distance between joints in a single conductor shall not average less than 1000 m (3280 ft) in any finished length of that single insulated conductor. A joint (butt splice) shall be made before or after insulating and prior to further processing. Where joints (butt splices) are made after insulating, the insulation applied over the joint shall be of the same insulation material used throughout the length of the conductor, or of another insulating material that meets or exceeds the electrical, physical, and mechanical requirements of this

Standard for the original insulating material. Joints in bare or insulated equipment-grounding conductors shall not be allowed. Insulated conductors with a joint (butt splice) shall not be surface marked with a type designation.

4.1.8 Separator

A separator of suitable material, when present between the conductor and the insulation, shall be of contrasting color to the conductor color, except that clear or green shall not be used. A white colored separator over aluminum complies with this requirement. The separator and the other wire or cable components shall not have any deleterious effect on one another.

4.2 Insulation

4.2.1 General

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

The physical properties of the insulation shall comply with Table 11, when determined in accordance with CSA C22.2 No. 0.3, Clause 4.3.1, UL 1581, Section 400, or NMX-J-178-ANCE and NMX-J-186-ANCE.

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

- a) XL;
- b) EPCV;
- c) Composite Insulation;
  - i) Inner – EP, EPCV, or XL;
  - ii) Outer – EPCV, XL, CP, or CPE;
- d) EP;
- e) SBR/IIR/NR;
- f) Silicone; and
- g) CP, CPE.

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

4.2.2 Repairs

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

4.2.3 Thickness

The average and minimum insulation thicknesses shall be as shown in Tables 12 – 18, when measured in accordance with the methods shown in UL 1581, Section 240, CSA C22.2 No. 0.3, Clause 4.2.1, and NMX-J-177-ANCE.

4.2.4 Centering

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

4.2.5 Insulation strand penetration (fall-in)

The insulation shall not penetrate the stranded conductor in a manner that would hamper the free stripping of the insulation when tested in accordance with Clause 8.7.

4.3 Jackets or fibrous coverings over single conductors

4.3.1 A single-conductor wire and each conductor of any 2-conductor flat parallel cable, and each conductor of any multiple-conductor cable, shall have a protective covering of fibrous material or a jacket applied over the outer surface of the insulation, in accordance with Table 19. The temperature rating of the jacket shall be the same as that of the insulated conductor. Requirements for protective coverings other than jackets are covered in Annex F of this Standard. Physical property requirements for jackets shall comply with Table 20, when tested in accordance with CSA C22.2 No. 0.3, Clause 4.3.1, UL 1581, Section 400, or NMX-J-178-ANCE and NMX-J-186-ANCE. Jacket thickness requirements are shown in Tables 21 – 23.

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

a) Rubber-filled woven cotton tape;

b) Polypropylene tape under a fibrous wrap or braid;

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

d) Fibrous braid;

e) Fibrous wrap;

f) Neoprene jacket;

g) NBR/PVC jacket;

h) CPE jacket;

i) CP jacket;

j) PVC jacket;

k) XL jacket.

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

4.4 Shielding (optional)

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

4.5 Multiple-conductor cables

4.5.1 Lay of cabled conductors

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

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

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

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

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

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

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

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

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

4.5.2 Equipment-grounding conductor

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

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

4.6 Color coding

4.6.1 Color of insulated equipment-grounding conductor

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

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

4.6.2 Identification of ungrounded circuit conductor(s)

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

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

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

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

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

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

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

4.6.3 Identification of grounded circuit conductor(s)

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

See 4.6.1.2 for details on stripes.

4.7 Fillers

When used in a multiple-conductor cable or assembly, fillers shall not have any deleterious effect on other cable components.

4.8 Jacket separators

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

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

4.9 Jackets

4.9.1 General

4.9.1.1 A multiple-conductor cable shall have a protective covering of fibrous material or a jacket applied over the cabled conductors in accordance with Table 19. Requirements for protective coverings, other than jackets, applied over cabled conductors are provided in Annex F of this Standard. Where a thermoplastic or thermoset jacket is required or applied, the jacket shall fit tightly and be applied over cabled conductors or over a jacket separator in compliance with Clause 4.8. The temperature rating of the jacket shall be 75°C. The use of a 90°C rated jacket is optional. The physical properties of the jacket shall comply with Table 20, when determined in accordance with CSA C22.2 No. 0.3, Clause 4.3.1, UL 1581, Section 400; or NMX-J-178-ANCE and NMX-J-186-ANCE. Requirements for jackets over individual conductors are described in Clause 4.3.

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

4.9.2 Jacket thicknesses

The average and minimum thicknesses of a jacket shall not be less than indicated in Table 26 when determined by the method described in CSA C22.2 No. 0.3, Clause 4.2.8, or UL 1581, paragraphs 260.1 – 260.8 or 280.1 – 280.3; or NMX-J-177-ANCE.

4.9.3 Diameter of conductor assembly under jacket

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

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

4.10.1 Materials having characteristics different from those specified in Table 11 or 20 shall be evaluated for the requested temperature rating in accordance with Clause 5.21. To be evaluated, insulations for use without jackets or additional coverings, the outer insulation layer of a composite insulation, and jackets shall have an initial absolute minimum tensile strength of not less than 6.8 MPa (1000 lbf/in^2), and an absolute minimum elongation of 100 percent before aging. Insulations for use with jackets or additional coverings, or the inner layer of composite insulation, shall have an initial absolute minimum tensile strength of not less than 3.4 MPa (500 lbf/in^2) and an absolute minimum elongation of 100 percent before aging.

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

4.11 Assemblies that include single-conductor thermoset-insulated wires

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

Completed assemblies shall meet the requirements of Clause 4.11.2.

4.11.2 Completed assemblies shall meet the following requirements:

a) Assemblies in which an uninsulated copper conductor is included shall be tested in accordance with Clause 5.22.

b) Each assembly in which an uninsulated conductor is not included shall be tested in accordance with Clause 5.21 or Clause 5.22, with each layer in a multiple-layer assembly spark tested separately.

c) Each 2.08 – 8.37 mm^2 (14 – 8 AWG) conductor in an assembly shall be individually tested for continuity in accordance with Clause 5.25 after the assembly is completed.

5 Test requirements

5.1 General

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

5.2 Conductor resistance

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

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

a) Cabled in one layer: 1.02;

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

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

5.2.3 Compliance shall be determined in accordance with Clause 8.2.

5.3 Tests of aluminum conductors

5.3.1 Physical properties

5.3.1.1 All aluminum conductors shall have a minimum elongation of 10 percent. Wires (strands) removed from a finished stranded conductor shall have a tensile strength of 98 – 159 MPa (14,250 – 23,100 lbf/in^2). The tensile strength of all other conductors shall be 103 – 152 MPa (15,000 – 22,000 lbf/in^2). See Clause 8.3.1.

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

5.3.2 High-current heat cycling

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

In Mexico, this requirement does not apply. See Clause 4.1.2.1.

5.4 Long-term insulation resistance in water

5.4.1 Minimum acceptable value

5.4.1.1 The insulation, without the protective covering, of wet-rated single-conductor cable and of the individual single conductors of multiple-conductor cable shall have an insulation resistance at the rated temperature in tap water not less than specified in Tables 33 – 35 at any time during immersion, when tested in accordance with Clause 8.4. 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 Tables 33 – 35. An a-c voltage equal to the voltage rating of the wire (600 V, 1000 V, or 2000 V rms) shall be applied to the insulated conductor at all times other than while measuring the insulation resistance. These tests are accelerated tests.

5.4.1.2 The values in Tables 33 – 35apply only to conductor types with the corresponding insulation thicknesses specified in this Standard. For other parameters of any material, the insulation resistance values shall be calculated by means of the formula in Annex I.

5.4.2 Maximum acceptable rate of decrease

5.4.2.1 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 later half of the specified immersion time, shall not be more than 4 percent if and while the insulation resistance is 3 GΩ·m (10 MΩ·1000 ft) or more; and shall not be more than 2 percent if the insulation resistance is less than 3 GΩ·m (10 MΩ·1000 ft) but more than the value indicated in Tables 33 – 35. Any coil that shows a greater percent decrease in insulation resistance during the extended immersion period shall be allowed to be tested for additional 1-week immersion periods and judged on the basis of the results for every continuous period of 3 weeks during the last 12 weeks of immersion, provided that the final insulation resistance is not less than as specified in Tables 33 – 35.

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

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

5.5.2 Minimum acceptable value

5.5.2.1 The insulation on Type XHH, RHH, and R90 wires shall have an insulation resistance in air at 97 ±1°C that is not less than indicated in Table 36 or 37, whichever is applicable, at any time during an extended period in an acceptable full-draft circulating-air oven, when tested in accordance with Clause 8.5 under the following conditions. The period in the oven shall be 12 weeks or more if the insulation resistance throughout the last 6 weeks of the period is 3 GΩ·m (10 MΩ·1000 ft) or higher. The period in the oven shall be 24 – 36 weeks if the insulation resistance is less than 3 GΩ·m (10 MΩ·1000 ft) but equals or exceeds the values in Table 36 or 37, whichever is applicable. An rms potential equal to the voltage rating of the wire shall be applied at all times other than while reading the insulation resistance.

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

5.5.3 Maximum acceptable rate of decrease

5.5.3.1 The maximum acceptable rate of decrease shall be the same as specified in Clause 5.4.2, except that the final insulation resistance shall not be less than specified in Table 36 or 37.

5.6 Capacitance and relative permittivity

5.6.1 Specimens of finished wire immersed in water at rated temperature, 75°C or 90°C, shall comply with each of the following, when tested in accordance with Clause 8.6:

a) The relative permittivity determined after immersion for 24 h shall not be more than 10 for CP, silicone rubber, and CPE insulation and shall be 6 or less for all other insulations.

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

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

5.7 Conductor corrosion

5.7.1 Bare unprotected copper conductor used without a separator under the insulation or jacket shall not show surface deterioration during visual examination, when tested in accordance with Clause 8.7.

5.8 Insulation fall-in

5.8.1 The stranded conductor shall be free of residual insulation or extruded conductor-shield material when tested in accordance with Clause 8.8.

5.9 Heat shock of thermoplastic jacket

5.9.1 A thermoplastic jacket shall not show any cracks after a specimen of finished wire or cable has been wound or bent around a mandrel having a diameter in accordance with Table 38, and while still on the mandrel, subjected to a temperature of 121 ±1°C for a period of 1 h. For flat cable, the minor cross-sectional dimension of the cable shall be used in determining the mandrel diameter, and the cable shall be wound or bent flatwise around the mandrel. Compliance shall be determined in accordance with Clause 8.9.

5.10 Flexibility of separator under a thermoplastic jacket

5.10.1 A separator under a thermoplastic jacket, as required in Clause 4.8.1, shall not show cracks or open up after a specimen of the finished single-conductor wire or cable, or of the finished multiple-conductor cable, is wound at room temperature around a mandrel, when tested in accordance with Clause 8.10.

5.11 Cold bend and cold impact

5.11.1 Cold bend

5.11.1.1 After conditioning at a temperature of −25 ±1°C for 4 h, the insulation or jacket of a wire, cable, or assembly shall not show any cracks, nor shall any thread or threads of a fibrous covering of a wire, cable, or assembly show any breaks, when tested in accordance with Clause 8.11.1. The mandrel diameter shall be as specified in Table 39 for single conductors, and Table 40 for multiple-conductor cables. When the wire or cable is marked with the optional −40C marking in accordance with Clause 6.1.8, conditioning shall be carried out at a temperature of −40 ±1°C.

5.11.2 Cold impact (optional)

5.11.2.1 Where required, the jacket and/or insulation on at least 8 out of 10 completed cable specimens shall not crack or rupture, nor shall any thread or threads of a fibrous covering break, when tested at −40°C in accordance with Clause 8.11.2.

5.12 Deformation

5.12.1 The thickness of XL insulation shall not decrease more than 30 percent for conductor sizes 2.08 – 107.2 mm^2 (14 – 4/0 AWG) or 15 percent for conductor sizes 127 – 1010 mm^2 (250 – 2000 kcmil) when subjected for 30 min, at a temperature of 131°C ±1°C, to the load specified in Table 41, and tested in accordance with Clause 8.12, except that the test specimens shall be unconditioned.

5.12.2 The thickness of a jacket of thermoplastic material shall not decrease more than 50 percent when subjected to a temperature of 121 ±1°C while under a load of 2000 g, when tested in accordance with Clause 8.12.

5.13 Hot-creep elongation and hot-creep set

5.13.1 Hot-creep elongation and hot-creep set of EP and EPCV insulation shall not exceed 50 percent and 5 percent respectively, after conditioning at 150 ±2°C (302.0 ±3.6°F) for 15 min in an air oven, when tested in accordance with Clause 8.13.

5.14 Flame and smoke

5.14.1 Horizontal specimen (XHH, XHHW, XHHW-2, RHH, RHW RHW-2, SA, SF, and SIS)

5.14.1.1 A finished wire or cable of any construction shall not convey flame along its length or to combustible materials in its vicinity when a specimen is subjected to the flame test described in Clause 8.14.1. The total length of char on the specimen shall not exceed 100 mm (4 inches), and the dripping particles emitted by the specimen during or after the application of flame shall not ignite the cotton on the floor of the enclosure, on the base of the burner, or on the wedge. Flameless charring of the cotton shall be ignored.

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

5.14.2 Burning particles (dropping) test (R90, RW75, RW90, RWU75, and RWU 90)

5.14.2.1 XL insulation shall be such that when a specimen of single-conductor wire or cable without a covering or jacket is subjected to the burning particles (dropping) test, Clause 8.14.2, burning particles from the specimen shall not cause the newsprint to ignite (flame). The specimen shall be tested after allowing at least 3 weeks after manufacture. Earlier testing by the manufacturer is optional.

5.14.3 FT1 (optional)

5.14.3.1 A finished conductor, when tested in accordance with Clause 8.14.3, shall be considered to have met the requirements for this marking if:

a) It does not convey flame.

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

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

5.14.4 VW-1 (vertical-specimen) flame test (optional)

5.14.4.1 For a given size of a finished wire or cable to be marked VW-1, that size and 2.08 mm^2 (14 AWG) copper or 3.31 mm^2 (12 AWG) aluminum shall comply with the requirements of the horizontal flame test described in Clause 5.14.1, and shall be judged capable of not conveying flame along its length or in its vicinity when tested in accordance with Clause 8.14.4. 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.

5.14.5 Vertical-tray (optional)

Finished single conductors shall not exhibit damage that reaches the upper end of any of two sets of specimens when subjected to the flame test indicated in Clause 8.14.5 for the specified period.

5.14.6 FT4 vertical-tray (optional)

Finished single conductors shall not exhibit charred material beyond a length exceeding 1.5 m (5 ft) from the flame impingement when tested in accordance with Clause 8.14.6 for the specified period.

Conductors meeting this requirement need not be subjected to the test described in Clause 5.14.5.

5.14.7 ST1 limited smoke (optional)

5.14.7.1 General

When tested in accordance with Clause 8.14.7, each finished insulated single conductor shall meet the test criteria in Clauses 5.14.5 or 5.14.6. Limits are specified for each fire test to make the following tests equally acceptable for the purpose of quantifying the smoke. The cable manufacturer shall specify, for testing each ″ST1″ (limited smoke) cable construction, either the vertical flame exposure described in Clause 8.14.7.1 or the vertical flame exposure described in Clause 8.14.7.2.

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

5.14.7.2 Vertical-tray flame exposure

Finished insulated single conductors shall exhibit the following properties when tested in accordance with Clause 8.14.7.1:

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

5.14.7.3 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 8.14.7.2:

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 minutes for each set of specimens shall not exceed 150 m^2.

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

d) The values of cable damage height, total smoke released, and peak smoke release rate obtained from one set of specimens shall not differ by more than 15 percent from the values obtained from the second set of specimens. If any of the values differ by more than 15 percent between the two sets of specimens, a third set of specimens shall be tested as described in Clause 8.14.7.2. The values obtained from the third set of specimens shall be within the limits in items a), b), and c).

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

5.14.8.1 General

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

5.14.8.2 Smoke emission

The components of cables shall be tested in accordance with the method described in Clause 8.14.8.1 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 min (VOF_4) shall not be more than 400. For cables with an external diameter larger than 10 mm (0.40 inch), the maximum specific optical density (DM) shall not be more than 500, and the value of smoke obscuration in the first four minutes (VOF_4) shall not be more than 800. Tests shall be performed on die-cut specimens 2 mm (0.08 inch) in thickness.

5.14.8.3 Fire propagation (RPI)

Finished cable samples shall be subjected to the test method described in Clause 8.14.8.2 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).

5.14.8.4 Halogen acid gas emission

Samples of nonmetallic components of cables shall have a maximum loss of mass in the form of acid gas emission not greater than 20 percent (by weight) of halogen acid gas (except hydrogen fluoride), produced by pyrolysis, when tested in accordance with the method described in Clause 8.14.8.3. Acid gas is expressed as percentage of the hydrogen chloride evolved during the test.

5.15 Weather resistance (optional)

5.15.1 For unfilled XL material to be marked SR, the insulation shall contain a minimum of 2.5 percent carbon black content, determined in accordance with Clause 8.15.3. To be marked SR, materials other than unfilled XL shall retain 80 percent of their initial tensile strength and elongation values after being subjected to 720 h xenon or carbon arc exposure in accordance with Clause 8.15.2.

5.16 Oil resistance (optional)

5.16.1 Oil resistance at 60°C

To be marked PR I, the retention of tensile strength and elongation of the insulation, or jacket where used, shall not be less than 50 percent of the unconditioned value after immersion of the finished wire in IRM 902 oil for 96 h at 100°C as described in Clause 8.16.1.

5.16.2 Oil Resistance at 75°C

To be marked PR II, the retention of tensile strength and elongation of the insulation, or jacket where used, shall not be less than 65 percent of the unconditioned value after immersion of the finished wire in IRM 902 oil for 60 d at 75°C, as described in Clause 8.16.2.

5.17 Gasoline and oil resistance (optional)

5.17.1 To be marked GR I or GR II, insulation, or jackets where used, shall comply with the requirements of Clause 5.16.1 for GR I, or 5.16.2 for GR II, and the retention of tensile strength and elongation shall not be less than 65 percent after 30 d immersion in water saturated with equal volumes of iso-octane and toluene (ASTM Reference Fuel C) maintained at 23 ±1°C, in accordance with Clause 8.17.

5.18 Crushing resistance

5.18.1 An average of not less than 5338 N (1200 lbf) shall be necessary to crush finished solid 2.08 mm^2 (14 AWG) Type XHH, XHHW, and XHHW-2 wires, or not less than 8007 N (1800 lbf) to crush finished stranded 33.6 mm^2 (2 AWG) Type XHH, XHHW, and XHHW-2 wires, to the point that the conductor contacts the earth-grounded metal of the testing machine used in the test described in Clause 8.18.

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

5.19 Dielectric breakdown after glancing impact

5.19.1 The average breakdown potential for six specimens of finished solid 2.08 mm^2 (14 AWG) Type XHH, XHHW, and XHHW-2 wires that have separately been subjected to a glancing impact of 2 J (18 in-lbf) shall not be less than 20 percent of the average breakdown potential of six adjacent specimens of the same wire not subjected to the impact. Testing shall be performed in accordance with Clause 8.19.

5.20 Durability of ink printing

5.20.1 Printing on the finished wire shall remain legible after being subjected to the test specified in Clause 8.20.

5.21 Shrinkback

5.21.1 This requirement applies to solid 2.08 – 5.26 mm^2 (14 – 10 AWG) XL insulated conductors only. No exposed end of the conductor shall exceed 3 mm (0.12 inch) in length after 24 h when evaluated in accordance with Clause 8.21. As an option, if the exposed conductor length exceeds 3 mm (0.12 inch), it shall not exceed 4 mm (0.16 inch) in length after 7d.

5.22 Evaluation of new materials – establishment of dry temperature rating

For the insulation and jacketing materials identified in Clause 4.10, the projected elongation of the insulation shall not be less than 50 percent, and the projected tensile strength calculated for 300 d shall not be less than 2 MPa (300 lbf/in^2) for jacketed insulation, and 4 MPa (600 lbf/in^2) for unjacketed insulation and jackets, after being subjected to long-term aging in an air oven for a minimum of 150 d, in accordance with Clause 8.22.

5.23 A-C spark test

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

a) To the a-c spark test in accordance with this clause; or

b) To the dielectric voltage-withstand in water test described in Clause 5.24, and the insulation resistance in water test at 15°C described in Clause 8.24.

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

5.23.2 The test shall be performed in accordance with Clause 8.23. The test potential shall be as shown in Table 42.

5.24 Dielectric voltage-withstand in water

5.24.1 Finished wires and cables, when tested in accordance with Clause 8.24, shall withstand, without breakdown of the insulation, 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) Wires or cables shall be subjected to the a-c test voltage of Table 43 for 60 s;

b) Alternatively, wires and cables shall be subjected to a d-c test voltage of 3 times the a-c voltage specified in item a) for the same period.

5.25 Insulation resistance in water at 15°C

5.25.1 The insulation of single conductors shall have an insulation resistance not less than the values specified in Tables 44 – 46 inclusive. The apparatus and test method shall be in accordance with Clause 8.25. When the water temperature is other than 15°C, the correction factor determined by the method described in Clause 8.25.2 or Table 54 shall be used. The test shall be carried out following the test in Clause 5.24, while still immersed.

5.26 Electrical continuity

Each conductor shall be continuous. Test methods for electrical continuity are specified in Clause 8.26.

6 Marking

6.1 Marking on product

6.1.1 General

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

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

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

6.1.1.4 Clauses 6.1.2 – 6.1.7 describe required markings. Clauses 6.1.8 – 6.1.13 describe additional markings.

6.1.1.5 Markings on a product shall be optional when the product is intended for further processing into another cable product.

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 In the United States, multiple-conductor cables with Type RHH, RHW, RHW-2, SA, XHH, XHHW, or XHHW-2 conductors and an outer covering shall have a suffix after the type letters as follows:

a) D – Cable in which two conductors are laid parallel; or

b) M – Cable in which two or more conductors are cabled together.

In Canada and Mexico, this requirement does not apply.

6.1.3.3 A wire or cable that complies with all of the requirements applicable to two or more types shall be allowed to be marked to so indicate – e.g., ″R90 or XHHW″.

6.1.4 Conductor size

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

a) ″mm^2 (AWG)″ or ″AWG (mm^2)″;

or

b) ″mm^2 (kcmil)″ or ″kcmil (mm^2)″.

Either a comma or a period shall signify a decimal. For printing on products, the use of ″mm^2″ in place of ″mm^2″ shall be allowed.

6.1.5 Aluminum conductors

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

6.1.6 Compact copper conductors

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

In Canada and Mexico, this requirement does not apply.

6.1.7 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 meeting the requirements for −40°C cold bend and cold impact specified in Clause 5.11 may be marked ″(−40C)″.

6.1.9 Flame test marking (optional)

6.1.9.1 General

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

a) ″FT1″: Clause 5.14.3;

b) ″VW-1″: Clause 5.14.4;

c) ″CT″: Clause 5.14.5 or 5.14.6 (see 6.1.9.2 for applicability);

d) ″FT4″: Clause 5.14.6 or 5.14.7 using flame exposure in accordance with Clause 8.14.7.2;

e) ″ST1″: Clause 5.14.7;

f) ″LS″: Clause 5.14.8;

g) ″RPI″: Clause 5.14.8.3; and

h) ″FT2″: Clause 5.14.1.

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

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 5.14.5 or Clause 5.14.6.

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 on equipment-grounding conductors of size 21.2 mm^2 (4 AWG) and larger.

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

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

6.1.10 Weather resistance

Wires or cables meeting the requirements of Clause 5.15 may be marked ″SR″.

6.1.11 Oil resistance

Wires or cables meeting the requirements of Clause 5.16.1 may be marked ″PR I″. Wires or cables meeting the requirements of Clause 5.16.2 may be marked ″PR II″.

6.1.12 Gasoline and oil resistance

Wires or cables meeting the requirements of Clauses 5.16.1 and 5.17 may be marked ″GR I″. Wires or cables meeting the requirements of Clauses 5.16.2 and 5.17 may be marked ″GR II″.

6.1.13 Shielded products

Products meeting the requirements of Clause 4.4 shall be marked ″SHIELDED″.

6.2 Marking on package

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

a) Manufacturer's identification;

b) Date of manufacture, by month and year (a code is acceptable);

c) Type designation;

d) Conductor size in accordance with Clause 6.1.4;

e) ″ALUM″ or ″AL″ after the conductor size [item (d) above], when an aluminum conductor is used. The additional marking ″ACM″ shall be optional. If compact stranding is used, ″ CMPCT ″ or the word ″COMPACT″ shall accompany ″ALUM″ or ″AL″ or ″ACM″;

f) Voltage rating;

g) In the United States, if stranded copper conductors are compact, the words ″Compact Copper″ or ″Compact Cu″ or ″Cmpct Cu″ shall appear after the conductor size [item (d) above]. The following statement shall also appear on the package: ″Terminate with connectors identified for use with compact-stranded copper conductors″;

h) ″SHIELDED″ when applicable; and

i) Optionally, the maximum operating dry and wet temperature rating of insulation.

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. The assemblies shall be with or without an overall jacket. A low-temperature rating of −40°C shall be optional. Either twisted or parallel configurations shall be permitted.

7.2 Construction

7.2.1 General

Except as indicated, the components of deep-well submersible water-pump cable shall comply with the requirements of Clauses 7.2 – 7.4 of this Standard.

7.2.2 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, or stranded 42.4 – 253 mm^2 (1 AWG – 500 kcmil) copper or aluminum. The optional insulated equipment-grounding conductor shall be of the same construction as the circuit conductors, except that a copper equipment-grounding conductor shall be allowed with aluminum circuit conductors, or an aluminum equipment-grounding conductor shall be allowed with copper circuit conductors. The minimum sizes of equipment-grounding conductors shall be as specified in Table 25. All conductors shall comply with Clause 4.1 of this Standard.

7.2.3 Insulation

Insulated conductors shall be of the types provided in Clause 7.2.4.

7.2.4 Assembly

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

a) CABLED WITH AN OVERALL JACKET – This cable assembly shall have two or more insulated circuit conductors of one of the following types: RHW-2, XHHW-2, RHW, XHHW, RWU75, or RWU90. The insulated circuit conductors 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 47 and the physical properties requirements in Table 20.

b) CABLED WITHOUT AN OVERALL JACKET – This cable assembly shall have 2 – 6 insulated circuit conductors of one of the following types: RHW-2, XHHW-2, RHW, XHHW, RWU75, or RWU90. The insulated conductors 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 AN OVERALL JACKET – This cable assembly shall have two, three, or four circuit conductors of one of the following types: RHW-2, XHHW-2, RHW, XHHW, RWU75, or RWU90. The circuit conductors shall be laid flat and parallel together with any optional equipment-grounding conductor laid parallel on the same axis. The conductors shall be joined to one another with an interconnecting web. The conductor insulation 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 AN OVERALL JACKET AND INTEGRAL FILLERS OR WEBS – This cable assembly shall have two, three, or four insulated circuit conductors of the following types: RHW-2, XHHW-2, RHW, XHHW, RWU75, or RWU90. The circuit conductors shall be laid parallel on the same axis, together with an optional insulated equipment-grounding conductor, and having an overall jacket that 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.

7.2.5 Polarity identification of conductors

7.2.5.1 Polarity identification of conductors other than the grounding or grounded conductor shall be provided by means of contrasting colors or stripes 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 or gray stripes.

In Canada, the color of the conductors shall also be in accordance with Annex G.

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

7.2.5.2 The equipment-grounding conductor shall be colored green or green with yellow stripes.

7.2.5.3 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 Clause 7.2.5.1 or by means of legible, durable ink printing of ″GROUNDING ONLY″ or equivalent on the outer surface of the finished conductor.

7.2.6 Jackets

7.2.6.1 Jackets shall comply with the requirements of Clause 4.9.1.

7.2.6.2 The average and minimum thicknesses of a jacket shall not be less than indicated in Table 47 when determined by the method described in CSA C22.2 No. 0.3, Clause 4.2.8, or UL 1581, paragraphs 260.1 – 260.8 or 280.1 – 280.3, or NMX-J-177-ANCE. The diameter over the assemblies described in Clause 7.2.3, for the purpose of determining jacket thickness, shall be obtained as specified in Clause 4.9.3.

7.3 Markings

7.3.1 Markings on product

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

a) The manufacturer's identification in accordance with Clause 6.1.2;

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

c) The conductor size in accordance with Clause 6.1.4;

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

e) The designation ″SUBMERSIBLE PUMP CABLE″ (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 marking in accordance with Clause 6.1.8 for cables complying with Clause 7.4.3;

h) The type designation of individual conductors, either on the conductor insulation surface or the outer jacket; and

i) Optional markings specified in Clause 6.1 as applicable.

7.3.1.2 The markings in Clause 7.3.1.1 shall be surface ink-printed, indented, or embossed at intervals not exceeding 0.6 m (24 inches). Indent markings shall be such that the minimum specified thickness of the jacket or insulation is maintained.

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

7.3.2 Markings on package

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

a) The manufacturer’s identification in accordance with Clause 6.1.2;

b) The month and year of manufacture;

c) The designation ″SUBMERSIBLE PUMP CABLE″;

d) The conductor size in accordance with Clause 6.1.4;

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

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

g) The low-temperature rating marking in accordance with Clause 6.1.8 for cables in compliance with Clause 7.4.3;

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

In Mexico, this requirement does not apply; and

i) The type designation of the individual conductors.

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

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, and the spark test specified in Table 42, the completed cable shall be subjected to the tests in Clauses 7.4.2 – 7.4.4.

7.4.2 Dielectric withstand

The finished assembly or cable shall withstand the a-c voltage as specified in Clause 5.23. 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.

7.4.3 Cold impact

A cabled assembly with Type RWU75 or RWU90 conductors shall comply with the requirements in Clause 5.11.2. This test is optional for cabled assemblies with other conductor types.

7.4.4 Electrical Continuity

Each conductor shall be continuous when tested in accordance with Clause 8.26.

8 Test methods

8.1 General

The test methods are presented in Clauses 8.2 – 8.25.

8.2 Conductor resistance

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

8.3 Test methods for aluminum conductors

8.3.1 Physical properties

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

8.3.2 High-current heat cycling

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

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

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

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

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

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

Screws shall be free-running when finger torque is applied until the head of the screw engages with the wire.

The wire shall be connected to form a 3/4 loop under the head of the screw as specified in CAN/CSA-C22.2 No. 48 or UL 1567. Terminal screws shall be torqued to 0.68 N and held for 30 s. Jigs shall be connected together at terminal screws A and B by means of a 610 – 685 mm (24 – 27 inch) piece of aluminum conductor material (ACM) wire. Terminal screws C and D of each jig shall be connected by a 610 – 685 mm (24 – 27 inch) piece of the ACM wire. One thermocouple (Type J No. 30 AWG iron constantan) shall be cemented or soldered as per Figure 2, attached at the midpoint (on the breakoff tab) of each terminal baseplate between the screws. These jigs shall then be connected to a 40 A, 60 Hz constant-current supply and subjected to 500 cycles of operation, with each cycle consisting of 3.5 h ON and 0.5 h OFF. Care shall be taken not to disturb the connecting wires after applying the torque.

*American Iron and Steel Institute.

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

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

8.4 Long-term insulation resistance in water

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

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

Compliance shall be determined with the apparatus and method specified in UL 1581, paragraphs 920.1 – 920.6, CSA C22.2 No. 0.3, Clause 4.28.2, or NMX-J-294-ANCE, modified as described in Clauses 5.4 and 5.5, using 3 or more 15 m (50 ft) coils.

8.6 Capacitance and relative permittivity

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

8.7 Conductor corrosion

A copper conductor removed from unaged specimens of the finished wire or cable and from specimens aged at elevated temperature, as described in Table 11, for the particular insulation being employed shall not show any evidence of corrosion (normal oxidation or discoloration of the copper not caused by the insulation or by any separator shall be disregarded) when subjected to a visual examination. The examination shall be made with normal or corrected vision without magnification.

8.8 Insulation fall-in

A 75 mm (3 inch) length of the insulation shall be stripped from a sample length of the finished stranded conductor, and the outer surface of the conductor shall be cleaned with a wire brush to remove the visible insulation. The outermost strands shall then be peeled back and examined for the presence of residual insulation or extruded conductor-shield material on the portions of these strands that were not accessible to the wire brush or on the remainder of the conductor beneath these strands.

8.9 Heat shock of thermoplastic jacket

Compliance with Clause 5.9.1 shall be determined with the apparatus and according to the method described in CSA C22.2 No. 0.3, Clause 4.23.1, UL 1581, Section 540, or NMX-J-190-ANCE.

8.10 Flexibility of separator under thermoplastic jacket

8.10.1 Compliance with Clause 5.10 shall be determined using a mandrel having a diameter 2.5 times the diameter of the wire or cable under test, except for 2-conductor parallel constructions, where the mandrel diameter shall be 2.5 times the minor dimension of the cable. Specimens having a diameter or minor dimension of 19 mm (3/4 inch) or less shall be wound for three turns around the mandrel. Specimens having a diameter or minor dimension greater than 19 mm (3/4 inch) shall be bent 180° around the mandrel. The winding shall be done at a uniform rate so that the time taken for winding three turns does not exceed 1 min.

8.10.2 The condition of the separator shall be determined by opening the jacket sufficiently to view the overlap of the tape separator, and examining the tape while the wire or cable is still around the mandrel.

8.11 Cold bend and cold impact

8.11.1 Cold bend

8.11.1.1 Compliance shall be determined with the apparatus and method specified in UL 1581, Section 580, CSA C22.2 No. 0.3, Clause 4.12.1, or NMX-J-193-ANCE.

8.11.1.2 In the case of 85.0 mm^2 (3/0 AWG) or smaller single conductors, 6 adjacent turns shall be tightly wound around the mandrel, and the winding shall be done at a uniform rate of approximately 3 s per turn. For sizes 107 mm^2 (4/0 AWG) and larger single conductors, and all multiple conductors, a 180° U-bend shall be performed. Mandrel diameters shall be in accordance with Tables 39 and 40.

8.11.2 Cold impact

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

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

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

8.11.2.3 Test specimens shall consist of ten separate 125 mm (5 inch) sections cut from a straight sample length of the finished wire or cable.

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

8.11.2.5 At the conclusion of at least 4 h of cooling, one of the wood anvils shall be removed from the cold chamber and shall be secured to a concrete floor, the building framework, or another solid support that does not absorb the impact. The impact weight shall be supported with its lower face horizontal. A vertical line through the centers of gravity of the impact weight and the stationary anvil shall be coincident with a vertical line through the dimensional center of the lower face of the impact weight and the dimensional center of the upper face of the stationary anvil. A set of rails or other vertical guide(s) shall constrain the impact weight and keep its lower face horizontal while the weight is falling and after it has struck the wire or cable. The rails or other guide(s) shall not interfere with the free fall of the impact weight. A means shall be provided at the top of the guide(s) for releasing the impact weight to fall freely from any chosen height and strike the wire or cable. A means shall also be provided to keep the weight from striking the wire or cable more than once during each drop.

8.11.2.6 One of the test specimens of the wire or cable shall be removed from the cold chamber and shall be tested as follows without delay and within 15 s of being removed from the chamber. Insulating gloves shall be worn while conducting the test. The time in seconds between removal of the specimen from the chamber and the impact shall be noted and recorded. The impact weight shall be secured several specimen diameters (several times the length of the minor axis in the case of a flat cable) above the anvil and the specimen shall be placed and held on the cold anvil with the longitudinal axis of the specimen horizontal, perpendicular to the longitudinal axis of the anvil, and in the vertical plane containing the coincident vertical lines mentioned in Clause 8.11.2.5. In the case of a flat cable, the specimen shall be flatwise on the anvil. The position of the impact weight shall be adjusted to place the lower face of the weight 900 mm (36 inches) above the upper surface of the specimen. The impact weight shall be released from this height, shall fall freely in the guides, shall strike the specimen once, and then shall immediately be raised up to and secured at the 900 mm (36 inch) height. After warming in still air at a temperature of 24.0 ±8.0°C (75.2 ±14.4°F) for 24 h, the specimen shall be examined for compliance with Clause 5.11.2 in each of its nonmetallic components, insulation, jacket, other covering, etc. The examinations shall be made without any aid other than the examiner’s normal corrective lenses, if any. Each of the remaining nine specimens shall be tested in succession.

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

8.12 Deformation

Compliance shall be determined with the apparatus and method specified in UL 1581, Section 560, CSA C22.2 No. 0.3, Clause 4.3.6.1, or NMX-J-191-ANCE. A specimen in a smoothed strip form shall have a maximum width of 14 mm (0.56 inch).

8.13 Hot creep

8.13.1 General

8.13.1.1 The hot-creep elongation and set shall be determined on specimens prepared from the finished wire and tested as described in Clauses 8.13.2 – 8.13.7.

8.13.2 Circulating-air oven

8.13.2.1 The oven shall have an interior size that is not smaller than 305 mm (12 inches) in both width and depth and or 508 mm (20 inches) in height. The oven shall be equipped with an observation window. The heating medium shall be air that is circulated at atmospheric pressure and maintains a uniform temperature throughout the test chamber. The temperature shall be kept within ±2.0 °C (±3.6°F) of the point at which it is set by means of a thermostat.

8.13.3 Specimen Support

8.13.3.1 A specimen shall be suspended vertically by means of a battery clip or other fixed upper jaw, and an unrestrained lower jaw assembly shall be clamped to the lower end of the specimen. The lower jaw assembly shall consist of a battery clip or another clip that supports a pan or other receptacle in which pellets or other pieces of metal can be placed to add weight in small increments to stress the specimen. See Figure 5 for a typical apparatus, noting that the construction and dimensions are not critical and therefore are not specified. A specimen shall not touch any part of the oven or the support apparatus.

8.13.4 Specimens

8.13.4.1 At least three specimens shall be prepared from a sample of the insulation taken from the finished product. Any jacket or covering shall be removed before the specimens are prepared.

8.13.4.2 For an insulated conductor up to 8.37 mm^2 (8 AWG), the specimen shall be the entire cross-section of the insulation (tubular specimen). Such a specimen shall not be cut longitudinally.

8.13.4.3 For an insulated conductor larger than 33.6 mm^2 (2 AWG), a die-cut specimen with a uniform cross-sectional area not greater than 16 mm^2 (0.025 in^2) throughout the specimen length shall be prepared from the insulation. A die-cut specimen shall be prepared using:

a) A dumbbell-shaped die 125 – 140 mm (5 – 5.5 inches) long with a constricted portion 59 ±2 mm (2.32 ±0.08 inches) long and 3 – 6 mm (0.125 – 0.250 inch) wide with a specimen length of not less than 150 mm (6 inches); or

b) A dumbbell-shaped die 100 – 115 mm (4 – 4.5 inches) long with a constricted portion 33 ±2 mm (1.31 ±0.08 inches) long and 3 – 6 mm (0.125 – 0.250 inch) wide with a specimen length of not less than 115 mm (4.5 inches).

A die-cut specimen shall not have any surface incisions or other imperfections.

8.13.4.4 For conductor sizes 13.3 – 33.6 mm^2 (6 – 2 AWG), a tubular or die-cut specimen shall be allowed.

8.13.4.5 Except for when an entire cross-section is used, all surface irregularities (such as corrugations from stranding) shall be removed to result in a specimen that is smooth and of uniform thickness throughout its length. Specimens of insulation shall be prepared as described in UL 1581, Section 440, CSA C22.2 No. 0.3, Clause 4.3.2, or NMX-J-186-ANCE.

8.13.5 Elongation test

8.13.5.1 One specimen shall be tested and the other two specimens shall be held in reserve.

8.13.5.2 An unstretched specimen shall be marked with benchmarks that are 25 mm (1 inch) apart and shall be placed in the jaws of the support apparatus. The distance between the jaws shall not be greater than 100 mm (4 inches).

8.13.5.3 Weight shall be added to the lower jaw assembly so that the total weight of the lower jaw, weight holder, and added weight provides a stress of 20.4 gf/mm^2 (29.0 lbf/in^2) on the specimen cross-section.

8.13.5.4 The total stress weight shall be calculated as follows:

$$\text{Stress weight (gf)} = \text{cross-sectional area (mm}^2\text{)} \times 20.4 \text{ (gf/mm}^2\text{) stress}$$

$$[\text{Stress weight (lbf)} = \text{cross-sectional area (in}^2\text{)} \times 29.0 \text{ (lbf/in}^2\text{) stress}]$$

8.13.5.5 The support apparatus with the attached specimen shall be placed in the circulating-air oven, which shall have been preheated to 150.0 ±2.0 °C (302.0 ±3.6°F).

8.13.5.6 After 15 min, the distance between the benchmarks shall be measured while in the oven and with the weight attached, using a scale calibrated with divisions of 1 mm or 0.1 inch. This distance De shall be recorded to the nearest millimeter (0.1 inch).

8.13.5.7 The hot-creep elongation shall be calculated as follows:

$$C = \frac{100 \times (D_e - G)}{G}$$

Where:

C is the hot creep in percent

D_e is distance between the benchmarks obtained in Clause 8.13.5.6

G is the original distance between the benchmarks

8.13.6 Set test

8.13.6.1 The set test shall be performed on the same specimen as the elongation test in Clauses 8.13.5.2 – 8.13.5.7. The set test shall be made immediately following the elongation test without removing the specimen from the oven.

8.13.6.2 The lower jaw assembly shall be removed from the specimen immediately after the measurement of D_e as described in Clause 8.13.5.6. The oven door shall be closed as quickly as possible to reduce the heat loss and cooling of the specimen.

8.13.6.3 The specimen shall remain in the oven for 5 min and then shall be removed from the oven and kept in still air at room temperature to cool for at least 1 h.

8.13.6.4 The distance D_s between bench marks shall then be measured to the millimeter or 0.1 inch and recorded using the scale mentioned in Clause 8.13.5.6.

8.13.6.5 The hot-creep set shall be calculated as follows (the result can be positive or negative):

$$S = \frac{100 \times (D_s - G)}{G}$$

Where:

S is the hot-creep set in percent

D_s is the distance between the benchmarks obtained in Clause 8.13.6.4

G is the original distance between the benchmarks

8.13.7 Results

If the specimen does not comply with either the hot-creep elongation or set requirement in Clause 5.13.1, each test shall be repeated on the two remaining reserved specimens and, for each property, the average value of the three readings shall comply.

8.14 Flame

8.14.1 Horizontal-specimen flame test

Compliance shall be determined in accordance with UL 1581, Section 1100, CSA C22.2 No. 0.3, Clause 4.11.2 modified by Appendix D, Clause D1 b), or NMX-J-192-ANCE.

8.14.2 Burning particles (dropping) test

8.14.2.1 Test

The specimen shall be subjected to a vertical flame test using the apparatus and in accordance with the method in Clause 8.14.3 except that

a) The flame indicator shall not be applied to the specimen.

b) A steel plate having a thickness of not less than 3 mm (0.12 inch), and approximately 0.2 × 0.3 m (8 x 12 inches) in size shall be placed on the floor of the flame-test apparatus.

c) A sheet of newsprint 215 × 280 mm (8.5 x 11 inches) shall be laid flat on the steel plate. The newsprint shall be standard white, having a mass/unit area of 46.4 – 57 g/m^2 (0.086 – 0.105 lb/yd^2), a thickness of not more than 0.11 mm (4 mils), and an ash content of not more than 6.5 percent.

8.14.2.2 Arrangement of components

For arrangement of the components for the test, see Figure 6. The distance between the newsprint and the point on the specimen where the blue inner cone of the test flame contacts the specimen shall be not greater than 235 mm (9.25 inches).

8.14.2.3 Examination

During the test and up to 60 s following the fifth application, the newsprint shall be continually watched to see if burning particles falling from the specimen cause the newsprint to ignite (flame).

8.14.3 FT1

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

8.14.4 VW-1 (vertical-specimen) flame test

Compliance shall be determined in accordance with UL 1581, Section 1080, or CSA C22.2 No. 0.3, Clause 4.11.7, or NMX-J-192-ANCE, Clause 3.2.

8.14.5 Vertical tray

Compliance shall be determined with the apparatus and method specified in Clause 8.14.7.1. Smoke measurements are not applicable.

8.14.6 FT4 vertical tray

Compliance shall be determined with the apparatus and method specified in UL 1685, Sections 12 – 19, FT4/IEEE 1202 Protocol (smoke measurements not applicable), CSA C22.2 No. 0.3, Clause 4.11.4, or NMX-J-498-ANCE.

8.14.7 ST1 Limited smoke

8.14.7.1 Vertical-tray fire propagation and smoke release

8.14.7.1.1 Apparatus

8.14.7.1.1.1 The test apparatus shall include the following main components:

a) Test enclosure and exhaust duct;

b) Velocity-measuring instrumentation;

c) Ignition source;

d) Smoke-measuring instruments; and

e) Data-acquisition system.

8.14.7.1.1.2 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.

8.14.7.1.2 Test enclosure and exhaust duct

The enclosure in which the cables are tested shall be as shown in Figure 7. Other enclosures shall be allowed if they are shown to provide equivalent results and are of a size [such as a 2.4-m (8-ft) cube] 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 8.14.7.1.3.

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 7 for observation of the fire test. Alternative construction materials 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), shall be 0.072 ±0.043 W/(m·°K) (0.50 ±0.30 Btu thermochemical)·in/(hr·ft^2·°F)).

b) The construction materials shall 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 7. The door shall have an overall thermal conductivity equal to that of the walls. Alternative construction materials meet the intent of these requirements if equivalent thermal conductivity is obtained. The hood shall have an overall thermal conductivity equal to that of the walls.

A truncated-pyramid steel hood and a collection box, each formed as shown in Figure 7, 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 having an inside diameter of 406 mm (16 inches), installed horizontally as shown in Figure 7.

The baffle shown in Figure 7 shall be constructed of a steel plate 3.2 mm (0.125 inch) thick, 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.

8.14.7.1.3 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 8. 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 inch H_2O).

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; and

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

8.14.7.1.4 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.

8.14.7.1.5 Ignition source (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, as shown in Figure 9.

NOTE: *As an example, a burner (catalog no. 10L 11-55) and venturi mixer (catalog no. 14-18) that are known to comply with the requirements in Clauses 8.14.7.1.5 and 8.14.7.2.5 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 inch) 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.

8.14.7.1.6 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 x 10^{-4} m^3/s (29 ft^3/hr), and the air flowmeter 13.3 x 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.

8.14.7.1.7 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.

8.14.7.1.8 Propane

The propane gas supplied to the burner shall be CP-grade propane (99 percent pure) having a nominal heating value of 93.0 MJ/m^3 (22,200 kilocalories (thermochemical)/m^3 [2500 Btu (thermochemical)/ft^3]).

8.14.7.1.9 Gas flows

The propane gas 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.

8.14.7.1.10 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. 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 photo-cell 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 inch) 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.

8.14.7.1.11 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.

8.14.7.1.12 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.

8.14.7.1.13 Test specimens

8.14.7.1.13.1 Cable mounting

Two sets of specimens of each cable construction shall be tested [see item d) of Clause 5.14.7.2, concerning the testing of a third set]. Each set shall consist of multiple 2.44 m (96 inch) 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 2.1 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 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 shall be determined as:

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

or

$$[(4/D_{inches}) + 0.33]$$

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

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

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

8.14.7.1.13.2 Conditioning

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

8.14.7.1.14 Test procedure

8.14.7.1.14.1 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 8.14.7.1.12 shall be performed.

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.

8.14.7.1.14.2 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 8.14.7.1.9. 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.

8.14.7.1.14.3 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).

8.14.7.1.15 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 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 adjusted to a temperature of 298K

0.4064 is the path length in the duct in meters

8.14.7.1.16 Report

The test report shall contain the following summary information:

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

b) The number of burns; and

c) The date on which the test was conducted.

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

8.14.7.2.1 Apparatus

The test apparatus shall be as described in Clause 8.14.7.1.1.

8.14.7.2.2 Cable test enclosure and exhaust duct

The enclosure in which the cables are tested shall be as described in Clause 8.14.7.1.2.

8.14.7.2.3 Velocity-measuring instruments

The velocity in the exhaust duct shall be determined as described in Clause 8.14.7.1.3.

8.14.7.2.4 Cable tray

A steel ladder type of cable tray that is as shown in Figure 10 and is 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.

8.14.7.2.5 Ignition source (burner)

The test flame shall be supplied as described in Clause 8.14.7.1.5, except that the burner shall be mounted on a stand and angled 20° ±2° from the horizontal (see Figure 10) with the burner ports up. 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.

8.14.7.2.6 Flowmeters

Flowmeters shall be as described in Clause 8.14.7.1.6.

8.14.7.2.7 Air

The air supplied to the burner shall be as described in Clause 8.14.7.1.7.

8.14.7.2.8 Propane

The gas supplied to the burner shall be as described in Clause 8.14.7.1.8.

8.14.7.2.9 Gas flows

The gas flow shall be as described in Clause 8.14.7.1.9.

8.14.7.2.10 Smoke-measuring instruments

The photometer system shall be as described in Clause 8.14.7.1.10.

8.14.7.2.11 Data acquisition

A digital data-acquisition system used shall be as described in Clause 8.14.7.1.11.

8.14.7.2.12 Pretest calibration of equipment

Calibration of equipment shall be as described in Clause 8.14.7.1.12.

8.14.7.2.13 Test specimens

8.14.7.2.13.1 Cable mounting

Two sets of specimens of each cable construction shall be tested [see Clause 5.14.7.2 item d)], concerning the testing of a third set). Each set shall consist of multiple 244 cm (96 inch) 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 2.1 mm^2 (14 AWG).

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 48. 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.

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 49.

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

8.14.7.2.13.2 Conditioning

Before the test is started, the test specimens shall be conditioned as described in Clause 8.14.7.1.13.2.

8.14.7.2.14 Test procedure

8.14.7.2.14.1 Initial preparation

See Clause 8.14.7.1.14.1.

8.14.7.2.14.2 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 8.14.7.2.9. 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 10 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 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.

8.14.7.2.14.3 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).

8.14.7.2.15 Calculation of smoke release rate

The smoke release rate (SRR) shall be calculated in accordance with Clause 8.14.7.1.15.

8.13.7.2.16 Report

The test report shall be as summarized in Clause 8.14.7.1.16.

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

8.14.8.1 Smoke emission

8.14.8.1.1 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).

8.14.8.1.2 Apparatus and equipment

The following apparatus shall be required:

a) Smoke density chamber, with integral or separate graphing capability. See Figure 11;

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; and

h) Ethyl alcohol.

8.14.8.1.3 Preparation of sample

8.14.8.1.3.1 Number of sets of samples

A minimum of three sets of samples shall be required.

8.14.8.1.3.2 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; or

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

8.14.8.1.3.3 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.

8.14.8.1.3.4 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 that will leave free the surface that shall 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.

8.14.8.1.4 Procedures

8.14.8.1.4.1 Preparation and start-up of equipment

The following requirements shall apply:

a) Cleaning: The smoke chamber shall be free of contaminants, in particular, the viewing area of the optical system, which shall be cleaned using ethyl alcohol or another adequate cleaner.

b) Characteristics of gas: The gas provided to the chamber shall be a mixture of compressed air and propane with 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 shall be 95 percent pure, maintaining its flow at 50 cm^3/min (3 in^3/min) inside the chamber over the course of the test.

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 11); and taking the measurement with a pressure gauge. Cut off the entrance of air and take 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 11).

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: To reach the test temperature in the chamber, perform the following procedure:

i) Connect the equipment.

ii) Close the smoke extraction system (see [7] of Figure 11).

iii) Open the ventilation window (see [8] of Figure 11).

iv) Close the equipment switch (see [9] of Figure 11).

v) Close the lamp switch (see [5] of Figure 11).

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, adjust it again to 100 percent.

vii) Close the heating switch (see [10] of Figure 11) and gradually heat using the electrical voltage adjustment knob (see [11] of Figure 11) until reaching the necessary corresponding voltage at the previous oven calibration, to obtain a radiation potency of 2.5 ±0.05 W/cm^2 (16.1 ±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 11) reaches 35 ±2°C (95 ±4°F), which is the test temperature.

8.14.8.1.4.2 Calibration of optical system

To calibrate the optical system, perform the following procedure:

a) Verify that the choke of the photomultiplier tube (see [3] of Figure 11) is closed, that the ND-2 filter (see [4] of Figure 11) is in position of the light trajectory, and that the lamp switch is closed (see [5] of Figure 11).

b) Verify that the positions of the photomultiplier switches (see [6] of Figure 11) are as follows:

i) Starter switch on;

ii) Multiplier switch set to 100; and

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 in the rear of the photomultiplier so that the reading of 100 is placed in the desired position on the plotter.

8.14.8.1.4.3 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 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 11).

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 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. Verify that this value is equal to the value specified in the inspection report, provided by the radiometer supplier or with 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 the previous point. After each adjustment, allow the desired reading 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), verify 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. Keep the voltage applied to the oven constant during the entire test, until it is re-calibrated.

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.

8.14.8.1.4.4 Installation and lighting of the gas burner

Perform the following procedure:

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 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 11).

e) Ignite the gas 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).

8.14.8.1.5 Test procedure

8.14.8.1.5.1 Before initiating the evaluation of each sample, verify:

a) That the conditions of the smoke chamber are stable.

b) The calibration of the oven and the burner or pilot, making certain that the air/gas flows are in accordance with the values obtained during the calibration; and

c) That the preparation and mounting of the samples in the trays result in the samples being completely vertical to avoid erroneous results.

8.14.8.1.5.2 Initiate the test using the following procedure:

a) Turn the handle from the smoke extraction system to the closed position (see [16] of Figure 11).

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 11).

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 any effect on the measurement from the outside.

h) To record sensitivity under the 0.1 scale, the following shall be taken into account:

i) Change the photomultiplier to the 1 scale.

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

iii) If the 10 percent scale is reached, change the photomultiplier to the 0.1 scale.

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

8.14.8.1.5.3 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 certain that maximum transmittance has been achieved.

g) Clean the optical system windows with ethyl alcohol.

8.14.8.1.5.4 To test the remaining samples, repeat the procedure described in Clauses 8.14.8.1.5.1 – 8.14.8.1.5.3.

When the results of 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 shows 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.

8.14.8.1.6 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 50.

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) shall be calculated using the following formula:

$$VOF_4 = d_1 + d_2 + d_3 + (d_4/2)$$

Where:

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

8.14.8.2 Fire propagation

8.14.8.2.1 Equipment and instruments

8.14.8.2.1.1 Chamber

The dimensions of the chamber shall be in accordance with Figure 12, and shall contain the following:

a) Three hermetically sealed doors with windows;

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

c) 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 Figures 13 and 14;

d) An extractor mounted in the upper end of the chamber, whose intake shall be located along the chamber axis;

e) An electrical oven comprising essentially a tube of aluminum silicate having an inside diameter of 100 ±3 mm (4 inches), an outside diameter of 115 mm ±3.5 mm (4-1/2 inches), and a length of 203 ±6 mm (8 inches). A 1.307 mm^2 (16 AWG) ceramic insulated nickel-chromium resistance wire is wound on the tube;

f) Power supply that delivers required current;

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

h) A 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 16;

i) A stainless steel tube with the dimensions indicated in Figure 17;

j) A thermometer to measure the temperature; a pyrometer with a range of 0 – 1200°C (32 – 1292°F) that includes an adequate thermocouple attached to the stainless steel tube shall be used;

k) A copper bar with 99 percent or greater purity and with dimensions in accordance with Figure 18;

l) An insulation millboard cover for the upper end of the oven.

8.14.8.2.1.2 Anemometer

An anemometer shall be used to measure the velocity of air that passes through the chimney.

8.14.8.2.1.3 Gas line

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

8.14.8.2.1.4 Chronometer

A chronometer shall be used to measure time intervals.

8.14.8.2.2 Calibration of electrical oven

8.14.8.2.2.1 General

Note: *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 the temperature shall be greater than 15°C (60°F). In order to calibrate the oven, the copper bar referred to in Clause 8.14.8.2.1.1 shall be used. The bar shall be suspended from the metallic structure in such a way that, when the oven is at its high position, the bar is centered with the axis of the oven and has a temperature between 35 and 55°C (95 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 shall be 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 within 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 = rate of temperature rise, in °C/s

T35 = recorded temperature after 35 s, in °C

T5 = recorded temperature after 5 seconds, in °C

K = interval between the two measurements, in seconds = 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 and is generally greater than 780°C (1436°F).

8.14.8.2.2.2 Reference bar

The bar shall be darkened on its surface by means of either coats of colloidal graphite paint having a coefficient of emissivity greater than 0.80, or layers of black smoke applied 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 18.

8.14.8.2.2.3 Adjusting the air velocity

In order to measure the air velocity, an anemometer with an accuracy of ±3 percent and fins having a diameter of 95 ±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 the oven is turned off). The extractor shall be turned on and the lower vents are 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.

8.14.8.2.3 Preparation of specimens

Two specimens, each 1600 mm (63 inches) in length, shall be prepared from the same cable sample. The specimens shall be prepared in accordance with items a), b), or c) as appropriate:

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

b) If the diameter of the conductor sample is larger 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.

Note: *The specimen shall be arranged such that one of the conductors is placed toward in the back end of the chamber, according to Figure 19.*

c) If the diameter of the conductor sample is less than or equal to 15 mm (0.6 inch), the specimen shall be made up of a 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).

8.14.8.2.4 Test procedure

Perform the following procedure:

a) Take care that the air circulating surrounding the chamber is 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 8.14.8.2.2.1 is reached;

c) Once having stabilized the oven, tighten the test specimen in a vertical position using the suspension hooks; and

d) Close the chimney, ignite the burners, and adjust the flame and distance, E, to the surface of the specimen, which shall be 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, turn off the extractor for 60 s and then restart the extractor.

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 flaming of the specimen ceases.

8.14.8.2.5 Results

The specimens shall be inspected visually to determine the height of degradation from the bottom end of the chimney. The specimen shall be marked 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. Deposits produced by combustion, and melting, softening, and blistering of the insulation caused by the flames, and heating of the conductor, shall be excluded.

If there is doubt as to whether a particular portion should be taken into account, the specimen should be cleaned; then that portion shall be cut with a knife. If that portion of the insulation is broken or cracked, this is true damage and shall be taken into account as degraded.

8.14.8.3 Halogen acid gas emission

8.14.8.3.2 Apparatus and equipment

8.14.8.3.2.1 General

The apparatus and components are shown in Figure 20. A detailed illustration of the quartz combustion tube with means for entrance and exit of gases is shown in Figure 21.

8.14.8.3.2.2 Apparatus

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

a) 600 ml and 250 ml beakers;

b) Pipette;

c) Volumetric flask of 500 ml;

d) 5 ml or 10 ml pipettes;

e) 100 ml volumetric pipettes;

f) 300 ml Berzelius 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; and

n) Magnetic bar.

8.14.8.3.2.3 Reactants

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); and

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).

8.14.8.3.3 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.

8.14.8.3.4 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 20.

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 20) 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 by no bubbles forming in the packaging of the system when soapy water is applied 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 20) in the part of the system located between the combustion oven and the first trap of NaOH. Ensure that the heating element maintains a temperature of at least 150°C on the surface of the glass ducting during the test.

g) Set the temperature of the oven to 800 ±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 100 ml of the solution obtained, placing it in a 300 ml Berzelius 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.

8.14.8.3.5 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.

8.14.8.3.6 Description of titration

Figure 22 illustrates the typical titration curve. In Figure 23, achievement of the point of equivalency is observed (volume of silver nitrate solution assigned in the calculation).

The achievement of a curve similar to the one shown in Figure 24 (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 Figure 23.

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 sinterized glass diffusers using chromic solution is optional.

8.15 Weather resistance

8.15.1 General

Insulation materials other than unfilled XL shall be tested in accordance with Clause 8.15.2. Unfilled XL insulation material shall be tested in accordance with Clause 8.15.3.

Specimens shall be conditioned by

a) Xenon-arc radiation and water spray, in accordance with Clause 8.15.2.1; or

b) Carbon-arc radiation and water spray, in accordance with Clause 8.15.2.2.

Following conditioning, specimens shall be prepared and tested for retention of tensile strength and ultimate elongation. Compliance shall be determined using the apparatus and method in CSA C22.2 No. 0.3, Clause 4.3.1, UL 1581, Section 470, or NMX-J-178-ANCE. The specimen rack or drum shall revolve at the rate of 1.00 ±0.01 r/min. Means shall be provided for automatic programming of the temperature and the cycling.

8.15.2 Materials other than unfilled XL

8.15.2.1 By xenon-arc

8.15.2.1.1 The specimens shall be mounted vertically in the specimen rack for xenon-arc-radiation and water-spray exposure. The radiation shall be produced by a lamp assembly of the long-arc water-cooled type. The lamp assembly shall be vertical and located on the rotation axis of the specimen rack. The lamp assembly shall consist of a quartz xenon burner tube that is centered inside concentric inner and outer cylindrical optical filter tubes of soda borosilicate glass (7740 Pyrex glass or its equivalent). Operation of the lamp assembly shall maintain a level of spectral irradiance at the specimens of at least 0.35 W/m^2, monitored at a wavelength of 340 nm.

8.15.2.1.2 Radiation from the xenon arc shall be kept by positive, permanent means from reaching persons within sight of the apparatus. The inner and outer optical filters shall be replaced at intervals that minimize the risk of spontaneous breakage of the filters because of stresses that develop in the glass from exposure to the arc. For this safety reason, the inner filter shall be replaced after no more than 400 h of use, and the outer filter after no more than 2000 h of use.

8.15.2.1.3 Means shall be provided to enable all points of each specimen to pass through a fine spray of water once during each revolution of the specimen rack in the 18 min portion of the 2 h cycle described in Clause 8.15.2.1.4. The water used in the spray shall be clean (it shall not leave any deposit on the specimens and shall not stain the specimens), its pH shall be 6.0 – 8.0, and its temperature shall be 16.0 ±5.0°C (60.0 ±9.0°F). The water used in the spray shall not be re-circulated unless these conditions are maintained. While the xenon arc is in operation, but the spray is off, the equilibrium black-panel temperature at the specimens shall be 63.0 ±3.0°C (145.0 ±5.4°F).

8.15.2.1.4 With the specimen rack revolving continuously, with the xenon arc operating continuously, and with prudent attention to the risk to eyesight and to other health risks presented by the xenon arc, the water spray shall be operated for 18 min on and 102 min off. This 2 h cycle shall be repeated for the total elapsed operating time specified in Clause 5.15. The apparatus shall be turned off after the specified total operating time. The specimens shall be removed from the test apparatus and retained in still air under conditions of ambient room temperature and atmospheric pressure for not less than 16 and not more than 96 h before being subjected to physical tests.

8.15.2.2 By twin carbon-arcs

8.15.2.2.1 The specimens shall be mounted vertically in the specimen drum for carbon-arc-radiation and water-spray exposure equipment. The specimen drum of the apparatus used shall be 787 mm (31 inches) in diameter (the diameter from the face of a specimen on one side of the drum to the face of a specimen on the opposite side of the drum shall be about 762 mm (30 inches) and 451 mm (17-3/4 inches) high. The apparatus shall include twin arcs struck between two sets of vertical carbon electrodes that are 13 mm (1/2 inch) in diameter and are individually enclosed in clear globes of heat-resistant optical glass (9200-PX Pyrex glass or its equivalent) that is opaque at wavelengths shorter than 275 nm (1 percent transmission at 275 nm as the nominal cutoff point) and whose transmission improves to 91 percent at 370 nm. The globes shall be replaced after whichever of the following occurs first: either 2000 h of use or the appearance in the globes of pronounced discoloration, milkiness, or both. The globes shall be washed with detergent and water, rinsed thoroughly, and air-dried at room temperature immediately before each day’s operation.

8.15.2.2.2 Radiation from the carbon arcs shall be kept by positive, permanent means from reaching persons within sight of the apparatus. Ventilation shall be provided to keep the products of combustion in the carbon arcs from contaminating the specimens, and these products and the ozone generated shall be kept from being in any significant concentration in air breathed by persons.

8.15.2.2.3 Means shall be provided to enable all points of each specimen to pass through a fine spray of water once during each revolution of the specimen drum in the 3 min portion of the 20 min cycle described in Clause 8.15.2.2.4. The water shall be clean (it shall not leave any deposit on the specimens and shall not stain the specimens), its pH shall be 6.0 – 8.0, its temperature shall be 16.0 ±5.0°C (60.0 ±9.0°F), and the water shall not be re-circulated unless these conditions are maintained. While the carbon arcs are in operation, but the spray is off, the equilibrium black-panel temperature at the specimens shall be 63.0 ±2.5°C (145.0 ±4.5°F).

8.15.2.2.4 With the specimen drum revolving continuously, with the carbon arcs operating continuously and carrying a current of 15 – 17 A apiece at a drop in rms potential of 120 – 145 V, and with prudent attention to the risk to eyesight and to other health risks presented by the carbon arcs, the spray shall be operated for 3 min on and 17 min off. This 20 min cycle shall be repeated six times, resulting in each specimen being subjected to radiation from the arcs for a total of 102 min and to the water spray with radiation from the arcs for a total of 18 min. This sequence shall be repeated, resulting in the total elapsed operating time specified in Clause 5.15. The apparatus shall be turned off after the total specified operating time. The specimens shall be removed from the test apparatus and retained in still air under conditions of ambient room temperature and atmospheric pressure for not less than 16 and not more than 96 hours before being subjected to physical tests.

8.15.2.2.5 The core (the conductors, insulation, any fillers, and the like) of a multiple-conductor cable having a separable overall jacket shall be removed from five conditioned specimens and from five identical unconditioned specimens. Die-cut specimens shall be prepared from the jacket conditioned in the apparatus and shall include the portions of the jacket closest to the arcs. The surfaces facing the arcs shall not be buffed, skived, or planed away.

8.15.2.2.6 The conductor (conductor plus insulation in the case of a single-conductor cable with a separable jacket) shall be removed from each of five conditioned and from five identical unconditioned specimens. Die-cut specimens shall be prepared from the single-conductor insulation conditioned in the apparatus and shall include the portions of the insulation or jacket closest to the arcs. The surfaces facing the arcs shall not be buffed or planed away.

8.15.2.3 Testing and calculations

The five conditioned specimens and five unconditioned specimens shall be tested separately and in close succession for tensile strength and ultimate elongation. The respective averages shall be calculated from the five tensile-strength and ultimate-elongation values obtained for the conditioned specimens and shall be divided by the averages of the five tensile-strength and ultimate-elongation values obtained for the unconditioned specimens.

8.15.3 Carbon black content of unfilled XL material

8.15.3.1 Compliance with the requirements specified in Clause 5.15.1 shall be determined by testing in accordance with NMX-E-034-SCFI or NMX-J-437-ANCE, or ASTM D 1603 or ASTM D 4218 pyrolytic furnace tests, for insulation that does not generate corrosive fumes on pyrolysis.

8.15.3.2 In Canada and the United States, wire or cable that does not comply with Clause 5.15.1, when tested in accordance with 8.15.3.1, or for insulation that generates corrosive fumes on pyrolysis, compliance shall be determined by testing in accordance with ASTM D 6370 or ASTM E 1131.

In Mexico, this requirement does not apply.

8.16 Oil resistance

8.16.1 Oil resistance at 60°C

The immersion vessel shall be a test tube having an overall diameter of at least 25 mm (1 inch) and a length of at least 150 mm (6 inches). The tube shall be filled with oil and then placed in a bath having an automatic temperature control that maintains the specimens at the specified temperature. Specimens of finished 2.08 – 8.37 mm^2 (14 – 8 AWG) wires, with or without the conductor removed, shall be bent at the center to form a narrow U and shall then be suspended vertically in the oil with the ends of each specimen projecting above the oil. 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. A larger vessel shall be used for die-cut specimens that are to be suspended vertically in the oil.

8.16.2 Oil resistance at 75°C

The test method shall be the same as in Clause 8.16.1, except that the oil temperature shall be 75°C.

8.17 Gasoline resistance

The immersion vessel shall have 25 mm (1 inch) of tap water at the bottom; the remainder of the vessel shall be filled with equal volumes of iso-octane and toluene (ASTM Reference Fuel C).

The following precautionary statements apply:

a) Iso-octane:

i) Danger, extremely flammable; harmful if inhaled; vapor may cause flash fire.

ii) Do not smoke.

iii) Eliminate all sources of ignition, especially electrical equipment that is not explosion-proof.

iv) Use and store in closed containers.

v) Use forced ventilation.

vi) Avoid buildup of vapor.

vii) Do not breathe vapor.

viii) Protect eyes and skin from contact.

b) Toluene:

i) Danger, flammable; vapor harmful if inhaled; central nervous system depressant; vapor and liquid irritate eyes, mucous membranes, and skin.

ii) Do not smoke.

iii) Eliminate all sources of ignition.

iv) Use and store in closed containers.

v) Use forced ventilation.

vi) Do not breathe vapor.

vii) Protect eyes and skin from contact.

8.18 Crushing resistance

8.18.1 Preparation of specimens

The test specimen shall consist of a minimum 2.54 m (100 inch) straight length of the finished wire without any conditioning. The specimen shall be tested at each of ten points evenly spaced along its length. These points shall not be closer together than 254 mm (10 inches), and no point shall be closer than 127 mm (5 inches) to an end of the specimen.

8.18.2 Test apparatus

At each test point, the specimen shall be crushed between a flat, horizontal steel plate and a solid steel rod in a compression machine whose jaws shall be closed at a rate of 10 ±1 mm/min (0.50 ±0.05 in/min). Each plate shall be 50 mm (2 in) wide. A solid steel rod 19 mm (3/4 inch) in diameter and of the same length as the plates shall be bolted or otherwise secured to the upper face of the lower plate. The longitudinal axis of the plates and the rod shall be in the same vertical plane.

The specimen shall be connected in series with a buzzer or other low-voltage indicator and a supply circuit, one leg of which is to be earth-grounded. All metal parts of the crushing apparatus are to be connected to the earth ground.

8.18.3 Test procedure

The upper steel plate in the compression machine shall be raised several specimen diameters above the steel rod and the first test point on the specimen shall be placed and held on the steel rod with the longitudinal axis of the specimen horizontal, perpendicular to the longitudinal axis of the rod, and in the vertical plane that laterally bisects the plates and the rod. The upper steel plate shall be moved down until it is snug against the specimen. The downward motion of the plate shall then be continued at the rate of 12 ±1 mm/min (0.50 ±0.05 in/min), increasing the force on the specimen until the indicator signals that contact has occurred between the specimen conductor and the plate or rod. The force indicated by the dial on the compression machine at the moment of contact shall be recorded. The crushing procedure shall be repeated at each of the remaining nine test points.

The specimen, the apparatus, and the surrounding air shall be in thermal equilibrium with one another at a temperature of 25.0 ±5.0°C (77.0 ±9.0°F) throughout the test. Each specimen shall be tested separately and shall be subjected to an increasing force until a short circuit occurs (as indicated by a low-voltage buzzer circuit or the equivalent) between the conductor in the wire and one or both of the earth-grounded plates. The force at which a short circuit occurs shall be recorded in each case.

8.19 Dielectric breakdown after glancing impact

8.19.1 Preparation of specimens

Both ends of each of six 380 mm (15 inches) specimens of the finished solid 2.08 mm^2 (14 AWG) insulated conductor shall be secured to one of the broad faces of a hard oak board measuring 50 x 100 mm (2 x 4 inches) in cross-section without damage to the insulation, and in a manner that results in the wires being straight and parallel to the longitudinal axis of the board. The board shall be rigidly supported, with the plane formed by the wires inclined 45° from the horizontal and each wire in a vertical plane.

8.19.2 Impacting means

A weight of 0.454 kg (1 lb) consisting of a solid circular steel cylinder that is 20 mm (3/4 inch) in diameter, has all surfaces smooth, and has one end rounded to a hemisphere, shall be supported with its longitudinal axis vertical and in a vertical plane containing one of the wires. The hemispherical end shall be down and centered 460 mm (18 inches) above the midpoint of the length of the wire. A straight vertical tube having a 22 mm (13/16 inch) inside diameter shall surround the cylinder and serve as a guide to keep the cylinder vertical while the cylinder is falling and after it has struck the wire. The inside surface of the guide tube shall be smooth and the tube shall be of a length that keeps the cylinder from coming out of the guide tube. See Figure 25.

8.19.3 Test procedure

8.19.3.1 While the wire specimens, the apparatus, and the surrounding air are in thermal equilibrium with one another at a temperature of 25.0 ±5.0°C (77 ±9°F), the cylinder shall be released, falling freely in the guide tube and striking the wire once, and shall then immediately be raised back up to and be secured at the 460 mm (18 inch) height. This process shall be repeated for each of the five remaining specimens.

8.19.3.2 Each of the impacted specimens shall have its impacted area immersed in tap water that is at a temperature of 25.0 ±5.0°C (77 ±9°F). The water shall be in an earth-grounded metal container whose inside metal surface is directly and entirely in contact with the water (not painted, enameled, or otherwise insulated). The insulation in the impacted area of each specimen shall be stressed electrically to breakdown by means of a 48 – 62 Hz sinusoidal or nearly sinusoidal rms potential applied between the conductor in the specimen and the earth-grounded water container. An isolation transformer in compliance with Clause 8.19.3.3 shall supply the test potential.

8.19.3.3 The isolation transformer shall operate at 48 – 62 Hz, with an output potential that is continuously variable from near zero to at least the specified rms test potential at a rate not exceeding 500 V/s. With a specimen in the earth-grounded water container, the output potential shall have a crest factor (peak voltage divided by rms voltage) equal to 95 – 105 percent of the crest factor of a pure sine wave over the upper half of the output range. The output voltage shall be monitored continuously by an analog or digital-type voltmeter having a response time that does not introduce a lagging error greater than 1 percent of full scale at the specified rate of increase in voltage, and that has an overall accuracy that does not introduce an error exceeding 5 percent. The maximum current output of which the transformer is capable shall enable routine testing of the wire specimens without tripping of the circuit breaker by the charging current.

8.19.3.4 The applied potential shall be increased from near zero at a uniform or nearly uniform rate that is not less than 100 percent of the voltage rating for the product in 60 s, and is not more than 100 percent in 10 s (the rate of increase shall not exceed 500 V/s in any case). The increase shall continue in this manner until breakdown occurs. The breakdown potential for each of the six impacted specimens shall be recorded, and the average of these potentials shall be calculated and recorded. One individual breakdown value that differs widely from most of the other individual values shall be allowed to be discarded. Where one value is discarded, none of the remaining values shall be less than 10 percent of the breakdown voltage of the un-impacted wire.

8.19.3.5 Each of six 380 mm (15 inch) or longer wire specimens not subjected to the impact shall be subjected to the dielectric-breakdown procedures with the center portion of its length immersed in water as described in Clauses 8.19.3.2 – 8.19.3.4. The breakdown potential shall be recorded for each of these specimens, and the average of these potentials shall be calculated and recorded.

8.20 Durability of ink printing

8.20.1 Preparation of specimens

Two straight 300 mm (12 inch) specimens of a single conductor shall be cut from a sample length of any convenient size of the finished wire being evaluated. The specimens shall be handled as little as possible and shall not be wiped, scraped, or otherwise cleaned in any way.

One of the specimens shall be aged in a full-draft circulating-air oven with 100 – 200 fresh-air changes per hour, operating for the time and at the temperature specified for the insulation or jacketing material whose outer surface is printed, and shall then be removed from the oven and kept in still air to cool to room temperature for 60 min before being tested. The one remaining specimen shall rest for at least 24 h in still air at 23.0 ±5.0°C (73.4 ±9.0°F) before being tested.

8.20.2 Test apparatus

The test shall be made using a weight whose lower face is machined to a flat, rectangular surface measuring 25 mm by 50 mm (1 inch by 2 inches). The height of the weight shall be uniform to ensure even distribution of the weight throughout the area of the lower face. Clamps or other means shall be provided for securing to the lower face of the weight a layer of craft felt (composition not specified) that is approximately 1.2 mm (0.047 inch) thick.

8.20.3 Test procedure

8.20.3.1 Without the felt in place, the weight and the means for securing the felt to the weight shall exert 450 ±5 g or 4.45 ±0.06 N (1.00 ±0.013 lbf) on a specimen. It shall be allowed to use the felt for several tests, but the felt shall be replaced as soon as the fibers flatten or become soiled. While not in use, the weight shall be stored resting on one of its surfaces that is not covered with felt. The apparatus and the specimens shall be in thermal equilibrium with the surrounding air at a temperature of 23.0 ±5.0°C (73.4 ±9.0°F) throughout the test.

8.20.3.2 Each specimen shall be placed on a solid, flat, horizontal surface with the printing up and at the center of the length of the specimen. The ends of each specimen shall be bent around supports or otherwise secured to keep the printed area of the insulation or jacket from rotating out from under the weight. The weight with the attached felt shall be slid back and forth over the printed portion of the specimen for three cycles. Each cycle shall consist of one complete back-and-forth motion. The time to perform the operation shall be 5 – 10 s.

8.21 Shrinkback

8.21.1 Apparatus

The apparatus shall consist of:

a) A tank filled with tap water, having a temperature controller capable of maintaining the water at the required temperature ±3°C;

b) A temperature measuring device with an accuracy of ±1°C; and

c) A micrometer caliper or optical micrometer microscope capable of measuring to the nearest 0.01 mm (0.001 inch)

8.21.2 Preparation of specimen

A 5 m (16 ft) length of solid conductor shall be formed into a loose coil of approximately 300 mm (12 inches) in diameter. Care shall be taken not to have any kinks or sharp bends throughout the coil.

8.21.3 Procedure

8.21.3.1 The coil shall be immersed in water at 90 ±3°C with 100 – 110 mm (4 – 4.4 inches) of each end of the wire supported out of the water. Care shall be taken to minimize contact with the walls of the tank. The ends shall be trimmed flush within 1 min following immersion.

8.21.3.2 After 24 h of immersion, the length of conductor exposed at each end shall be measured while the coiled insulated conductor is still immersed in the tank. Measurement of exposed conductor length shall be from the start of the cut caused by the cutting tool to the insulation.

8.21.3.3 If after 24 h the exposed conductor length at either end exceeds 3 mm (1/8 inch), the test shall be continued for an additional 6 d, and the exposed conductor length at each end of the specimen measured.

8.22 Evaluation of new materials – establishment of dry temperature rating

8.22.1 Preparation of specimens

Specimens of insulation shall be prepared as described in UL 1581, Section 440, CSA C22.2 No. 0.3, Clause 4.3.2, or NMX-J-186-ANCE.

8.22.2 Test apparatus

Prepared specimens shall be placed in a full-draft circulating-air oven that complies with UL 1581, Paragraph 420.9, CSA C22.2 No. 0.3, Clause 4.3.2, or NMX-J-417-ANCE. The test temperature shall be 82°C for 75°C rated material, and 97°C for 90°C rated material.

8.22.3 Test procedure

8.22.3.1 After each time interval of 90, 120, and 150 days, the ultimate elongation and tensile strength of sets of six specimens shall be determined as described in CSA C22.2 No. 0.3, Clause 4.3.1, UL 1581, Section 470, or NMX-J-178-ANCE, and then measured and recorded as specified in Clause 8.22.3.2. The elongation and tensile values for a set of specimens shall be averaged for each aging time interval. Collection of data based on 180- and 210-day testing shall be allowed for use in the calculation. If the results of one or more of the six specimens differ significantly, the results from only one specimen shall be allowed to be discarded

8.22.3.2 The formula for ultimate elongation or tensile strength (mathematical model) is:

$$EU_{(t)} = E_{90}\, U_{90} \times e^{-R(t\,-\,90)}$$

Where:

$EU_{(t)}$ is the ultimate elongation, percent or tensile strength, MPa (lbf/in^2)

$E_{90}\, U_{90}$ is the regression constant (ultimate elongation or tensile strength computed at 90 d)

R is the decay constant as determined in Clause 8.21.3.2

t is the time, d

8.22.3.2.1 Use the formula of the mathematical model

$$E_{(t)} = E_{90}\, e^{-R(t - 90)}$$

Where:

$E_{(t)}$ is the elongation percent

t is the time (days)

E_{90} is the computed regression constant (computed elongation at 90 days)

R is the decay constant

The variables in the formula transformed as $Y = \ln[EU_{(t)}]$, $B = \ln[E_{90}U_{90}]$, and $T = (t - 90)$ convert the formula into the linear form $Y = B - RT$.

The variables shall be transformed as:

$T = (t - 90)$

$Y = \ln E(t)$

$B = \ln E_{90}$

to yield the linear form

$Y = B - RT$

Using the 90 d and longer-term data, the constants B and R shall be determined by least squares linear regression. The projected ultimate elongation or tensile strength at 300 d shall then be calculated.

8.22.3.3 The projected ultimate elongation and tensile strength for 300 days shall then be calculated, and shall not be less than specified in Clause 5.22.

8.22.4 Following the determination of the temperature rating, the parameters and requirements for the air oven aging test shall be established in accordance with Annex H.

8.23 A-C spark test

8.23.1 Test apparatus

8.23.1.1 The spark tester shall include a voltage source, electrode, voltmeter, fault-signal device or system, and the necessary electrical connections.

8.23.1.2 The voltage source of the spark tester shall maintain the test voltage specified in this Standard under all normal conditions of leakage current. The core of a transformer and one end of its secondary winding shall be solidly connected to earth ground. A voltage source shall not be connected to more than one electrode.

8.23.1.3 The electrode shall be of the link- or bead-chain type and shall make intimate contact throughout its entire length with the surface of the wire being tested.

The bottom of the metal electrode enclosure shall be U- or V-shaped, the chains shall have a length appreciably greater than the depth of the enclosure, and the width of the trough shall be approximately 40 mm (1-1/2 inches) greater than the diameter of the largest size of wire that is tested.

For a bead-chain electrode, the longitudinal and transverse spacing of the chains and the diameter of each bead shall comply with Table 52. The vertical spacing between beads in each chain shall not exceed the diameter of a bead.

The electrode shall be provided with an earth-grounded metal screen or an equivalent guard that prevents persons from touching the electrode.

8.23.1.4 The voltmeter shall be connected in the circuit to indicate the actual test potential at all times.

8.23.1.5 The equipment shall include a light, counter, or other device or system that gives a signal in the event of a fault. When a fault is detected, the signal shall be maintained until the indicator is reset manually.

8.23.2 Test procedure

8.23.2.1 The spark test shall be conducted as the wire is being cut just prior to storage in or shipping from the factory in which the wire is made. The insulation at points of repair shall be re-sparked.

8.23.2.2 Wire that has been spark-tested in compliance with the requirements of Clause 8.23.2.1 need not be re-sparked after any of the following further-processing operations at the wire factory:

a) Cutting into lengths shorter than 60 m (200 ft);

b) Striping that does not require heat curing; and

c) Color coating that does not require heat curing.

8.23.2.3 The length of the electrode is not specified, but the rate of speed at which the wire travels through the electrode shall keep any point on the wire in contact with the electrode for not less than a total of 18 positive and negative crests of the supply voltage (the equivalent of 9 full cycles of the supply voltage). The maximum acceptable speed of the wire shall be determined by means of the following formula:

Meters per minute = (1/150) x frequency in Hz x electrode length (mm)

Feet per minute = (5/9) x frequency in Hz x electrode length (inches)

For convenience, Table 53 shows the formulas for several frequencies.

8.23.2.4 The conductor of the wire shall be earth-grounded during the spark test. If the conductor coming from the pay-off reel is bare, the conductor shall be earth-grounded at the pay-off reel or at another point at which continuous contact with the bare conductor, prior to the insulating process, is maintained, but need not be tested for continuity or earth-grounded at the take-up reel. If the conductor coming from the pay-off reel is insulated, an earth-ground connection shall be made at either the pay-off or take-up reel but, for sizes 5.26 mm^2 (10 AWG) and smaller, an earth-ground connection shall be made at both the pay-off and the take-up reels if sizes 5.26 mm^2 (10 AWG) are not tested for continuity and found to be of one integral length. In any case, each earth-ground connection shall be bonded directly to the earth ground in the spark tester.

8.24 Dielectric voltage-withstand in water

8.24.1 The apparatus shall consist of a tank in which the test coil shall be immersed in water, an earth-grounding electrode or its equivalent (which shall be allowed to be the inside surface of a metal tank if that surface is not painted or otherwise insulated from the water), and a circuit breaker, lamp bank, or other means for indicating the flow of breakdown current in the test circuit. The test potential shall be supplied by a 48 – 62 Hz isolation transformer with an output potential that is continuously variable from near zero to at least the specified rms test potential at a rate not exceeding 500 V/s. With a specimen in the circuit, the output potential shall have a crest factor (peak voltage divided by rms voltage) equal to 95 – 105 percent of the crest factor of a pure sine wave over the upper half of the output range. The output voltage shall be monitored continuously by a voltmeter that

a) If of the analog rather than digital type, shall have a response time that does not introduce a lagging error greater than 1 percent of full scale at the specified rate of increase in voltage; and

b) Has an overall accuracy that does not introduce an error exceeding 5 percent.

The maximum current output of which the transformer is capable shall enable routine testing of full reels of the wire or cable without tripping of the circuit breaker by the charging current. The water shall be at any convenient temperature, and no correction factor is necessary.

8.24.2 In preparing the coil or reel for the test, each end of the wire or cable shall be brought out well above the water level in the tank. Any fibrous covering and separator shall be removed from the surface of the insulation for about 150 mm (6 inches) at each end, to assist in reducing surface leakage and the likelihood of surface breakdown. It shall be acceptable to dip the insulation at the ends in melted paraffin to keep moisture from forming a conductive path from the conductor metal across the surface of the insulation to the water.

8.24.3 One side of the test circuit shall be connected to the conductor of the wire and the other side to an electrode that is earth-grounded and is in contact with the water in which the coil is immersed.

The applied potential shall be increased from near zero at an essentially uniform rate that

a) Is not less than 100 percent of the potential rating of the wire or cable in 60 s; and

b) Is not more than 100 percent in 10 s (the rate of increase shall not exceed 500 V/s in any case).

The increase shall continue in this manner until the voltage reaches the level of the rms test potential specified. If this level is reached without breakdown, the voltage shall be held constant at the specified level for 60 s and shall then be reduced to near zero at the rate mentioned in items a) or b). The wire shall not be acceptable if breakdown occurs at less than the potential specified in Clause 5.24 while the applied potential is being increasing or decreased, or in less than 60 s at the specified potential.

8.24.4 The individual conductors of multiple-conductor cable shall comply with Clause 5.24.1. After assembly, the test potential shall be applied between each conductor and all of the other conductors connected together and to all shield and metal coverings as applicable.

8.24.5 Breakdown shall be determined by any of the following:

a) Tripping of a circuit breaker;

b) Illumination of a bank of lamps connected in series with the test coil;

c) Insulation resistance failure at room temperature, as determined in accordance with UL 1581, Paragraphs 920.1-920.6, CSA C22.2 No. 0.3, Clause 4.28.2, or NMX-J-294-ANCE;

d) Visual observation of a flash at the point on the cable at which the breakdown takes place; or

e) Other recognized means.

8.25 Insulation resistance in water at 15°C

8.25.1 General

The test equipment and procedures shall be capable of measuring insulation resistance. A megohm bridge used for this purpose shall be of applicable range and calibration, and shall present readings that are accurate to 10 percent or less of the value indicated by the meter. A dc potential of 100 – 500 V shall be applied to the insulation for 60 s prior to a reading. Each galvanometer indication shall be given 60 s to stabilize before the reading is recorded. The duration of each reading shall be 60 s in the case of range switching or for metering equipment that requires time to achieve a null. Delay is not required for instant-reading equipment that has been demonstrated to produce correct readings without a 60 s delay.

If the temperature at which the readings are taken is other than 15°C, the readings shall be multiplied by the applicable multiplying factors established in accordance with Clause 8.25.2. See Table 54 for correction values for materials applicable to this Standard.

The temperature corrected IR in GΩ·m shall be calculated as follows:

$$IR = LR_3F$$

Where:

L is the length of test specimen, m

R_3 is the measured insulation resistance of the test specimen, GΩ

F is the temperature correction factor (See Clause 8.25.2)

The temperature corrected IR in MΩ·1000 ft shall be calculated as follows:

$$IR = (L/1000)R_3F$$

Where:

L is the length of test specimen, feet

R_3 is the measured insulation resistance of the test specimen, MΩ

F is the temperature correction factor (See Clause 8.25.2)

8.25.2 Temperature-correction factor

8.25.2.1 General

Where required, when the test for IR at 15°C is carried out in water or air having a temperature differing from 15°C, the temperature-correction factor, F, referred to in the formula of Clause 8.25.1, shall be determined using the coefficient for 1°C, as determined in accordance with the method in Clause 8.25.2.2.

8.25.2.2 Determination of coefficient for 1°C

Where required, the coefficient for 1°C for a given insulation shall be determined as follows:

a) Three samples shall be selected as representative of the insulation under consideration. The samples shall be of sufficient length to yield insulation resistance values less than 25 GΩ at the lowest water bath temperature.

b) The three samples shall be immersed in a water bath equipped with heating, cooling, and circulation facilities, with the ends of the samples extended at least 0.6 m (24 inches) above the surface of the water and properly prepared for minimum leakage. The samples shall be left in the water at room temperature for 16 h before adjusting the bath temperature to 10°C or before transferring the samples to a 10°C test temperature bath.

c) The resistance of the conductor shall be measured at suitable intervals until it remains unchanged for at least 5 min. The insulation is then at the temperature of the bath, as read on the bath thermometer. Insulation resistance shall then be measured.

d) Each of the three samples shall be exposed to successive water temperatures of 10°C, 16°C, 22°C, 28°C, and 35°C and, returning, 28°C, 22°C, 16°C, and 10°C. Insulation resistance readings shall be taken at each temperature after equilibrium has been established.

e) The two sets of readings taken at the same temperature shall be averaged, and along with the reading at 35°C, plotted on semi-log paper. If the resultant curve is a straight line, the 1°C coefficient shall be calculated as in item f) and Table 54 shall be used. If the resultant curve is not a straight line, the temperature correction factors for each 0.5°C within the range shall be calculated by dividing the insulation resistance at 15°C by the insulation resistance at the desired temperature. The insulation resistance values shall be obtained from the plotted curve.

f) The 1°C coefficient shall be calculated using the following formula:

$$TCC = \text{Antilog}_{\propto} [(\log_{\propto} [IR_{10}/IR_{35}])/25]$$

Where:

TCC = Temperature correction coefficient for 1°C;

$\propto$ = The base of the logarithm;

IR_x = Insulation resistance at x°C.

8.26 Electrical continuity

8.26.1 General

Each of the conductors of the wire or cable shall be connected in series with an a-c or d-c source of voltage less than 30 V, and a means of indicating an unbroken circuit (e.g., an incandescent lamp, a bell, or a buzzer). Operation of the indicator shall be evidence of continuity of the conductor under test.

Alternatively, the test in Clause 8.26.2 shall serve as a substitute for this test.

8.26.2 Eddy current

8.26.2.1 Apparatus

The eddy-current test arrangement shall include equipment that complies with the following:

a) The equipment shall apply current at one or several frequencies in the range of 1 – 125 kHz to a test coil for the purpose of inducing eddy currents in the conductor moving through the coil at production speed.

b) The equipment shall detect the variation in impedance of the test coil caused by each break in the conductor.

c) The equipment shall provide a visual indication to the operator.

8.26.2.2 Procedure

The longitudinal axis of the conductor shall be coincident with the electrical center of the test coil. The wire shall have little or no vibration as it passes through the test coil and shall clear the coil by a distance that is not greater than 13 mm (1/2 inch). Variations in the speed of the wire through the test coil shall be limited to plus 50 percent and minus whatever percentage (50 percent maximum) keeps the signal amplitude from falling below the level at which a break can be detected. Separate calibration, balance, and adjustments for sensitivity, maximum signal-to-noise ratio, and maximum rejection of signals indicating gradual variations in diameter and other slow changes shall be made for each size, type of stranding, and conductor material. Calibration without any wire in the test coil shall be made at least daily to check whether the equipment is functioning.

Note: *The temperature along the length of the wire being tested may vary from the temperature at which the equipment was calibrated, balanced, and so forth for the size, type of stranding, and conductor material, provided that the variations are gradual and are without hot or cold spots that cause false signals.*

Tables

Table 1 – Summary of the Types, Maximum Conductor Temperature, Voltage Ratings, and Number of Insulated Conductors

(See Clauses 1.2, 6.1.3.1, and Annexes B and K)

Type letter designation	Voltage rating, V	Temperature rating	Number of conductors[a]
XHHW-2	600	90°C wet or dry	1, 2 parallel, 2 or more cabled
XHHW	600	75°C wet and 90°C dry	1, 2 parallel, 2 or more cabled
XHH	600	90°C dry	1, 2 parallel, 2 or more cabled
RHH	600 or 2000	90°C dry	1, 2 parallel, 2 or more cabled
RHW-2	600 or 2000	90°C wet or dry	1, 2 parallel, 2 or more cabled
RHW	600 or 2000	75°C wet or dry	1, 2 parallel, 2 or more cabled
SA, SF	600	90°C dry 200°C for special applications	1, 2 parallel, 2 or more cabled
SIS	600	90°C dry	1
R 90	600, 1000, 2000, or 5000[b]	90°C dry	1, 2 parallel, 2 or more cabled
RW 75	600, 1000, 2000, or 5000[b]	75°C wet or dry	1, 2 parallel, 2 or more cabled
RW 90	600, 1000, 2000, or 5000[b]	90°C wet or dry	1, 2 parallel, 2 or more cabled
RWU 75	1000	75°C wet or dry	1
RWU 90	1000	90°C wet or dry	1

[a] See Clause 7 for deep-well submersible pump cable constructions.

[b] In Canada, requirements for 5000 V rated types are obtained from Annex K.

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

Table 2 – Conductors

(See Clauses 4.1.5.1 and D.2 and Annex B)

Wire type	Metal	Conductor size range		Assembly
		mm^2	AWG or kcmil	
XHHW-2, XHHW, XHH, RHH, RHW, RHW-2, R90, RW75, RW90, RWU75, RWU90, SIS[a], SA, or SF	Copper	2.08 – 1010	14 – 2000	Concentric, compressed rope lay, and bunched
		8.37 – 507	8 – 1000	Compact
		2.08 – 107	14 – 4/0	Solid, and combination unilay
XHHW-2, XHHW, XHH, RHH, RHW, RHW-2, R90, RW75, RW90, RWU75, RWU90, SIS[a]	Aluminum	3.31 – 1010	12 – 2000	Concentric, and compressed
		8.37 – 507	8 – 1000	Compact
		3.31 – 107	12 – 4/0	Solid
		13.3 – 107	6 – 4/0	Combination unilay

[a] Type SIS is limited to 2.08 – 107 mm^2 (14 – 4/0 AWG) copper and 3.31 – 107 mm^2 (12 – 4/0 AWG) aluminum. Conductor sizes 42.4 mm^2 (1 AWG) and larger shall be stranded.

Table 3 – Conductor Stranding

(See Clauses 4.1.5.2 and D.2 and Annex B)

Conductor size		Number of strands in combination unilay	Minimum number of strands	
mm^2	AWG or kcmil		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 4 – Length of Lay of Strands in a Bunch-Stranded Conductor Twisted as a Single Bunch[a]

(See Clause 4.1.5.5)

Size of conductor	Maximum acceptable length of lay	
mm^2 (AWG)	mm	inches
2.08 (14)	41	1-5/8
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 (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		
mm^2	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 5 – Conductor Diameter and Cross-Sectional Area

(See Clause 4.1.6.1 and Annex B)

Size of conductor		Nominal diameter of solid conductor		Nominal cross-sectional area of conductor	
mm²	AWG or kcmil	mm	mils	mm²	kcmil
2.08	14 AWG	1.63	64.1	2.08	4110
3.31	12	2.05	80.8	3.31	6530
5.26	10	2.588	101.9	5.26	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	26.7	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
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
602	1200	–	–	608	1200
633	1250	–	–	633	1250
659	1300	–	–	659	1300
709	1400	–	–	709	1400
760	1500	–	–	760	1500
811	1600	–	–	811	1600

Table 5 – Conductor Diameter and Cross-Sectional Area Continued on Next Page

Table 5 – Conductor Diameter and Cross-Sectional Area Continued

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

Table 6 – Diameters of Round Compact-Stranded Conductors

(See Clause 4.1.6.1 and Annex B)

Conductor size		Nominal diameter	
mm^2	AWG or kcmil	mm	inch
8.37	8 AWG	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
458	900	25.37	0.999
507	1000	26.92	1.060

Table 7 – Diameters of Round Compressed Concentric-Lay-Stranded Classes B, C, and D Aluminum, Uncoated Copper and Coated Copper Conductors

(See Clause 4.1.6.1 and Annex B)

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	0.3	0.405
85.0	3/0	1.6	0.456
107	4/0	3.0	0.512
127	250 kcmil	4.2	0.558
152	300	5.5	0.611
177	350	6.8	0.661
203	400	7.9	0.706
226	450	9.0	0.749
253	500	0.0	0.789
279	550	1.1	0.829
304	600	2.0	0.866
329	650	2.9	0.901
355	700	3.7	0.935
380	750	4.6	0.968
405	800	5.4	1.000
456	900	6.9	1.060
507	1000	8.4	1.117
557	1100	9.8	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

Table 7 – Diameters of Round Compressed Concentric-Lay-Stranded Classes B, C, and D Aluminum, Uncoated Copper and Coated Copper Conductors Continued on Next Page

Table 7 – Diameters of Round Compressed Concentric-Lay-Stranded Classes B, C, and D Aluminum, Uncoated Copper and Coated Copper Conductors Continued

Conductor size		Nominal diameter	
mm^2	AWG or kcmil	mm	inches
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
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 8 – Diameters of Round Compressed Unidirectional or Unilay Stranded Class B Aluminum, Uncoated Copper, and Coated Copper Conductors

(See Clauses 4.1.6.1 and 4.1.6.2 and Annex B)

Conductor size		Nominal diameter	
mm^2	AWG or kcmil	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

Table 8 – Diameters of Round Compressed Unidirectional or Unilay Stranded Class B Aluminum, Uncoated Copper, and Coated Copper Conductors Continued on Next Page

Table 8 – Diameters of Round Compressed Unidirectional or Unilay Stranded Class B Aluminum, Uncoated Copper, and Coated Copper Conductors Continued

Conductor size		Nominal diameter	
mm²	AWG or kcmil	mm	inches
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

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 9 – Diameter of Class B, C, and D Round Concentric-Lay-Stranded Copper and Aluminum Conductors

(See Clause 4.1.6.1 and Annex B)

Conductor size		Nominal diameter					
mm²	AWG or kcmil	Class B		Class C		Class D	
		mm	inch	mm	inch	mm	inch
2.08	14 AWG	1.85	0.0727	9.15	2.78	9.25	2.82
3.31	12	2.32	0.0915	5.75	1.75	5.75	1.75
5.26	10	2.95	0.116	3.55	1.08	3.62	1.10
8.37	8	3.71	0.146	2.23	0.679	2.23	0.679
13.3	6	4.67	0.184	1.41	0.427	1.41	0.427
21.2	4	5.89	0.232	0.882	0.269	0.882	0.269
26.7	3	6.60	0.260	0.700	0.213	0.700	0.213
33.6	2	7.42	0.292	0.555	0.169	0.555	0.169
42.4	1	8.43	0.332	0.440	0.134	0.440	0.134
53.5	1/0	9.45	0.372	0.349	0.106	0.349	0.106
67.4	2/0	10.62	0.418	0.276	0.0844	0.276	0.0844
85.0	3/0	11.94	0.470	0.219	0. 0669	0.219	0.0669
107	4/0	13.41	0.528	0.174	0.0530	0.174	0.0530
127	250 kcmil	14.6	0.575	0.147	0.0449	0.147	0.0449
152	300	16.00	0.630	0.122	0.0374	0.122	0.0374
177	350	17.30	0.681	0.105	0.0320	0.105	0.0320
203	400	18.49	0.728	0.0920	0.0280	0.0920	0.0280
228	450	19.61	0.772	0.0818	0.0249	0.0818	0.0249
253	500	20.65	0.813	0.0736	0.0224	0.0736	0.0224
279	550	21.72	0.855	0.0669	0.0204	0.0669	0.0204
304	600	22.68	0.893	0.0614	0.0187	0.0614	0.0187
329	650	23.60	0.929	0.0566	0.0172	0.0566	0.0172
355	700	24.49	0.964	0.0526	0.0160	0.0526	0.0160
380	750	25.35	0.998	0.0491	0.0150	0.0491	0.0150
405	800	26.16	1.030	0.0460	0.0141	0.0460	0.0141

Table 9 – Diameter of Class B, C, and D Round Concentric-Lay-Stranded Copper and Aluminum Conductors Continued on Next Page

Table 9 – Diameter of Class B, C, and D Round Concentric-Lay-Stranded Copper and Aluminum Conductors Continued

Conductor size		Nominal diameter					
mm^2	AWG or kcmil	Class B		Class C		Class D	
		mm	inch	mm	inch	mm	inch
456	900	27.79	1.094	0.0409	0.0124	0.0409	0.0124
507	1000	29.26	1.152	0.0364	0.0111	0.0368	0.0112
557	1100	30.71	1.209	0.0335	0.0102	0.0335	0.0102
608	1200	32.08	1.263	0.0307	0.00935	0.0307	0.00935
633	1250	32.74	1.289	0.0295	0.00898	0.0295	0.00898
659	1300	33.38	1.314	0.0284	0.00863	0.0284	0.00863
709	1400	34.67	1.365	0.0260	0.00794	0.0263	0.00802
760	1500	35.86	1.412	0.0243	0.00741	0.0246	0.00748
811	1600	37.06	1.459	0.0231	0.00702	0.0231	0.00702
861	1700	38.20	1.504	0.0216	0.00660	0.0216	0.00660
887	1750	38.76	1.526	0.0210	0.00642	0.0210	0.00642
912	1800	39.32	1.548	0.0202	0.00617	0.0205	0.00623
963	1900	40.39	1.590	0.0192	0.00584	0.0194	0.00591
1010	2000	41.45	1.632	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 for copper conductors, and ASTM B 231 or NMX-J-032-ANCE for aluminum conductors.*

Table 10 – Strand and Conductor Dimensions of 19-Wire Combination Round-Wire Unilay-Stranded Copper or Aluminum Conductors

(See Clause 4.1.6.1 and Annex B)

Conductor size		Nominal strand dimensions								Nominal conductor diameter E = 3A + 2C	
		Large strand				Small strand					
		Diameter A		Cross-sectional area		Diameter B		Cross-sectional area			
mm^2	AWG	mm	inch	mm^2	cmil	mm	inch	mm^2	cmil	mm	inch
2.08	14	0.404	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 11 – Physical Properties of Insulation

(See Clauses 4.2.1.1, 4.10.1, 4.10.2, and 8.7, Table 51, and Annexes B and H)

Condition	Test	EP		XL		EPCV	
		RW75, RWU75	R90, RW90, RWU90, RHW-2, RHW, RHH	RW75, RWU75, RHW	R90, RW90, RWU90, RHH, XHHW, XHHW-2, RHW-2, SIS	RW75, RWU75	R90, RW90, RWU90, RHH, RHW, RHW-2, SIS
Before aging	Elongation, minimum	250 percent	250 percent	150 percent	150 percent	225 percent	225 percent
	Tensile strength, minimum, MPa (lbf/in^2)	4.8 MPa (700)	4.8 MPa (700)	10.3 MPa (1500)	10.3 MPa (1500)	8.3 MPa (1200)	8.3 MPa (1200)
After air oven accelerated aging		110 ±1°C for 7 d	121 ±1°C for 7 d	113 ±1°C for 7d	121 ±1°C for 7 d	110 ±1°C for 7 d	121 ±1°C for 7 d
	Tensile strength, minimum	75 percent of unaged value	75 percent of unaged value	70 percent of unaged value	70 percent of unaged value	75 percent of unaged value	75 percent of unaged value
	Elongation, minimum	75 percent of unaged value	75 percent of unaged value	70 percent of unaged value	70 percent of unaged value	75 percent of unaged value	75 percent of unaged value

Condition	Test	CP		CPE		SBR/IIR/NR		Silicone	
		RHW	RHW-2, RHH, SIS	RHW	RHW-2, RHH, SIS	RHW[a]	RHW-2[b] RHH[b]	RHH, RHW, R90	SA, SF
Before aging	Elongation, minimum	200 percent	200 percent	200 percent	250 percent	300 percent	300 percent	250 percent	250 percent
	Tensile strength, Minimum MPa (lbf/in^2)	10.3 (1500)	10.3 (1500)	10.3 (1500)	10.3 (1500)	4.8 (700)	4.8 (700)	5.5 (800)	5.5 (800)

Condition	Test	CP		CPE		SBR/IIR/NR		Silicone	
		RHW	RHW-2, RHH, SIS	RHW	RHW-2, RHH, SIS	RHW[a]	RHW-2[b] RHH[b]	RHH, RHW, R90	SA, SF
After air oven accelerated aging		113 ±1°C for 7 d	121 ±1°C for 7 d	113 ±1°C for 7 d	121 ±1°C for 7 d	100°C for 10 d	121 ±1°C for 7 d	136°C for 60 d	210°C for 60 d
	Tensile strength, Minimum	85 percent of unaged value	85 percent of unaged value	85 percent of unaged value	85 percent of unaged value	50 percent of unaged value	70 percent of unaged value	65 percent of unaged value	60 percent of unaged value
	Elongation, minimum	50 percent of unaged value	50 percent of unaged value	60 percent of unaged value	60 percent of unaged value	60 percent of unaged value	60 percent of unaged value	75 percent of unaged value	75 percent of unaged value

Table 11 – Physical Properties of Insulation Continued on Next Page

Table 11 – Physical Properties of Insulation Continued

After immersion in oil		18 h @ 121 ±1°C	18 h @ 121±1°C	18 h @ 121±1°C	18 h @ 121±1°C	–	–	–	–
	Tensile strength, Minimum	60 percent of unaged value	60 percent of unaged value	60 percent of unaged value	60 percent of unaged value	–	–	–	–
	Elongation, minimum	60 percent of unaged value	60 percent of unaged value	60 percent of unaged value	60 percent of unaged value	–	–	–	–

[a] The maximum set 25 mm (1 inch) benchmarks stretched to 62.5 mm (2.5 inches) is 25 percent.

[b] The maximum set 25 mm (1 inch) benchmarks stretched to 75 mm (3 inches) is 25 percent.

Table 12 – Thicknesses of Insulation on 600 V Types XHHW-2, XHHW, XHH, and Types RW75, R90, and RW90

(See Clause 4.2.3, Tables 35, 36, and 45, and Annex B)

Size of conductor		mm		mils	
mm^2	AWG or kcmil	Minimum average thickness	Minimum thickness at any point	Minimum average thickness	Minimum thickness at any point
2.08 – 5.26	14 – 10 AWG	0.76	0.69	30	27
9.37 – 33.6	8 – 2	1.14	1.02	45	40
42.4 – 107	1 – 4/0	1.40	1.27	55	50
larger than 107 – 253	larger than 4/0 – 500 kcmil	1.65	1.47	65	58
larger than 253 – 507	larger than 500 – 1000	2.03	1.83	80	72
larger than 507 – 1010	larger than 1000 – 2000	2.41	2.18	95	86

Table 13 – Thicknesses of Insulation on Type SA and SF Wires

(See Clause 4.2.3, Table 45, and Annex B)

Conductor size		mm		mils	
mm^2	AWG or kcmil	Minimum average thickness	Minimum thickness at any point	Minimum average thickness	Minimum thickness at any point
2.08 – 5.26	14 – 10	1.14	1.02	45	40
8.37 – 33.6	8 – 2	1.52	1.37	60	54
42.4 – 107	1 – 4/0	2.03	1.83	80	72
larger than 107 – 253	larger than 4/0 – 500 kcmil	2.41	2.18	95	86
larger than 253 – 507	larger than 500 – 1000	2.79	2.51	110	99
larger than 507 – 1010	larger than 1000 – 2000	3.18	2.84	125	112

Table 14 – Thicknesses of Insulation on Type SIS Wire

(See Clause 4.2.3, Table 45, and Annex B)

Conductor size		mm		mils	
mm^2	AWG	Minimum average thickness	Minimum thickness at any point	Minimum average thickness	Minimum thickness at any point
2.08 – 5.26	14 – 10	0.76	0.69	30	27
8.37 – 33.6	8 – 2	1.14	1.02	45	40
42.4 – 107	1 – 4/0	1.40	1.27	55	50

Table 15 – Thicknesses of Insulation on 600 V Type RHW, RHW-2, RHH, and R90 Silicone

(See Clause 4.2.3, Tables 35, 36, and 45, and Annex B)

Size of conductor		Insulation other than composite layers (see Annex F for required or optional overall covering and Table 21 for jacket thickness)		Composite insulation of CP, CPE, EPCV, or XL over EP, XL, or EPCV Types RHH, RHW, RHW-2					
				Inner layer			Outer layer		
		mm							
mm^2	AWG or kcmil	Minimum average thickness	Minimum thickness at any point[a]	Minimum average thickness	Minimum thickness at any point[a]		Minimum average thickness	Minimum thickness at any point[a]	
					A	B		A	B
2.08 – 5.26	14 – 10 AWG	1.14	1.02	0.76	0.69	0.71	0.38	0.36	0.30
8.37	8	1.52	1.37	1.14	1.02	1.07	0.38	0.36	0.30
13.3 – 33.6	6 – 2	1.52	1.37	1.14	1.02	1.12	0.76	0.69	0.61
42.4 – 107	1 – 4/0	2.03	1.83	1.40	1.27	1.37	1.14	1.02	0.91
larger than 107 – 253	larger than 4/0 – 500 kcmil	2.41	2.18	1.65	1.47	1.65	1.65	1.47	1.32
larger than 253 – 507	larger than 500 – 1000	2.79	2.51	2.03	1.83	1.98	1.65	1.47	1.32
					A	B		A	B
larger than 507 – 1010	larger than 1000 – 2000	3.18	2.84	2.54	2.27	2.51	2.41	2.16	1.93
		mils							
					A	B		A	B
2.08 – 5.26	14 – 10 AWG	45	40	30	27	28	15	14	12
8.37	8	60	54	45	40	42	15	14	12
13.3 – 33.6	6 – 2	60	54	45	40	44	30	27	24
42.4 – 107	1 – 4/0	80	72	55	50	54	45	40	36
larger than 107 – 253	larger than 4/0 – 500 kcmil	95	86	65	58	65	65	58	52
larger than 253 – 507	larger than 500 – 1000	110	99	80	72	78	65	58	52
larger than 507 – 1010	larger than 1000 – 2000	125	112	100	90	99	95	85	76

Table 15 – Thicknesses of Insulation on 600 V Type RHW, RHW-2, RHH, and R90 Silicone Continued on Next Page

Table 15 – Thicknesses of Insulation on 600 V Type RHW, RHW-2, RHH, and R90 Silicone Continued

Size of conductor		Insulation other than composite layers (see Annex F for required or optional overall covering and Table 21 for jacket thickness)		Composite insulation of CP, CPE, EPCV, or XL over EP, XL, or EPCV Types RHH, RHW, RHW-2			
				Inner layer		Outer layer	
		mm					
mm^2	AWG or kcmil	Minimum average thickness	Minimum thickness at any point[a]	Minimum average thickness	Minimum thickness at any point[a]	Minimum average thickness	Minimum thickness at any point[a]

[a] The minimum thickness at any point shall not be less than indicated in Column A or B under inner layer with the minimum thickness at any point not less than indicated in the corresponding Column A or B under outer layer. The thickness in Column B under inner layer plus the thickness in Column B under outer layer equals 90 percent of the sum of the average thickness indicated under inner layer and outer layer.

Table 16 – Thicknesses of Insulation on 1000 V Types RW75, R90, and RW90

(See Clause 4.2.3 and Annex B)

Conductor size		mm		mils	
mm^2	AWG or kcmil	Minimum average thickness	Minimum thickness at any point	Minimum average thickness	Minimum thickness at any point
2.08 – 8.37	14 – 8 AWG	1.14	1.01	45	40
13.3 – 33.6	6 – 2	1.52	1.37	60	54
42.4 – 107	1 – 4/0	2.03	1.82	80	72
larger than 107 – 507	larger than 4/0 – 1000 kcmil	2.28	2.05	90	81
larger than 507 – 1010	larger than 1000 – 2000	2.79	2.51	110	99

Table 17 – Thicknesses of Insulation on 2000 V Types R90, RW75, RW90, RHH, RHW, and RHW-2

(See Clause 4.2.3, Tables 35, 36, and 46, and Annex B)

Size of conductor	EP, XL, or EPCV: Types R90, RW75, RW90, RHH, RHW, and RHW-2 and Silicone Rubber for RHH or RHW only		CP, CPE, or SBR/ IIR/NR Types RHH, RHW, RHW-2		Composite insulation of CP, CPE, EPCV, or XL over EP, XL, or EPCV Types RHH, RHW, RHW-2					
					Inner layer			Outer layer		
mm^2	Min. avg. thickness	Min. at any point	Min. avg. thickness	Min. at any point	Min. avg. thickness	Min. thickness at any point[a]		Min. avg. thickness	Min. thickness at any point[a]	
	mm									
						A	B		A	B
2.08 – 5.26	1.52	1.37	2.03	1.83	1.14	1.02	1.07	0.38	0.36	0.30
8.37	1.78	1.60	2.03	1.83	1.40	1.27	1.32	0.76	0.69	0.61
13.3 – 33.6	1.78	1.60	2.41	2.18	1.40	1.27	1.32	0.76	0.69	0.61
42.4 – 107	2.29	2.06	2.79	2.51	1.65	1.47	1.60	1.14	1.02	0.91

Table 17 – Thicknesses of Insulation on 2000 V Types R90, RW75, RW90, RHH, RHW, and RHW-2
Continued on Next Page

Table 17 – Thicknesses of Insulation on 2000 V Types R90, RW75, RW90, RHH, RHW, and RHW-2 Continued

Size of conductor	EP, XL, or EPCV: Types R90, RW75, RW90, RHH, RHW, and RHW-2 and Silicone Rubber for RHH or RHW only		CP, CPE, or SBR/ IIR/NR Types RHH, RHW, RHW-2		Composite insulation of CP, CPE, EPCV, or XL over EP, XL, or EPCV Types RHH, RHW, RHW-2					
					Inner layer			Outer layer		
mm^2	Min. avg. thickness	Min. at any point	Min. avg. thickness	Min. at any point	Min. avg. thickness	Min. thickness at any point[a]		Min. avg. thickness	Min. thickness at any point[a]	
Larger than 107 – 253	2.67	2.39	3.18	2.84	1.90	1.73	1.88	1.65	1.47	1.32
Larger than 253 – 507	3.05	2.74	3.56	3.20	2.29	2.06	2.24	1.65	1.47	1.32
Larger than 507 – 1010	3.56	3.20	3.56	3.20	2.92	2.64	2.87	2.41	2.16	1.93
	mils									
						A	B		A	B
2.08 – 5.26	60	54	80	72	45	40	42	15	14	12
8.37	70	63	80	72	55	50	52	30	27	24
13.3 – 33.6	70	63	95	86	55	50	52	30	27	24
42.4 – 107	90	81	110	99	65	58	63	45	40	36
	mils									
Larger than 107 – 253	105	94	125	112	75	68	74	65	58	52
						A	B		A	B
Larger than 253 – 507	120	108	140	126	90	81	88	65	58	52
Larger than 507 – 1010	140	126	140	126	115	104	113	95	85	76

[a] The minimum thickness at any point shall not be less than indicated in Column A or B under inner layer with the minimum thickness at any point not less than indicated in the corresponding Column A or B under outer layer. The thickness in Column B under inner layer plus the thickness in Column B under outer layer equals 90 percent of the sum of the average thicknesses indicated under inner layer and outer layer.

Table 18 – Insulation Thicknesses on 1000 V Types RWU75 and RWU90

(See Clause 4.2.3 and Annex B)

Conductor size		Insulation thickness			
mm^2	AWG or kcmil	mm		mils	
		Minimum average thickness	Minimum thickness at any point	Minimum average thickness	Minimum thickness at any point
2.08 – 5.26	14 – 10 AWG	1.52	1.37	60	54
8.37	8	2.03	1.83	80	72
13.3 – 33.6	6 – 2	2.03	1.83	80	72
42.4 – 107	1 – 4/0	2.41	2.18	95	86
Larger than 107 – 253	Larger than 4/0 – 500 kcmil	2.79	2.51	110	99
Larger than 253 – 507	Larger than 500 – 1000 kcmil	3.18	2.84	125	112
Larger than 507 – 1010	Larger than 1000 – 2000 kcmil	3.56	3.20	140	126

Table 19 – Insulations and Protective Coverings

(See Clauses 4.2.1.1, 4.3.1, 4.9.1.1, F.1.1 and F.1.3, and Annex B)

Type designation	Insulation	Jacket or fibrous covering	
		Over Single Conductor	Over two or more parallel or twisted conductors
XHH, XHHW, and XHHW-2	XL or EPCV	None	Jacket or fibrous covering[a]
SA or SF 2.08 – 10.6 mm^2 (14 – 8 AWG)	Silicone Rubber	One or more glass or aramid braid fibrous coverings	Fibrous covering
SA or SF 13.3 – 1010 mm^2 (6 AWG – 2000 kcmil)	Silicone Rubber	Two or more glass or aramid braid fibrous coverings	Fibrous covering
SIS	XL, EPCV, CP or CPE	None	Not applicable
RHH, RHW, RHW-2 (600 V, 2.08 – 10.6 mm^2 (14 – 8 AWG))	EP, SBR/IIR, NR	Jacket or one or more fibrous coverings[a]	Jacket or fibrous covering[a]
RHH, RHW, RHW-2 (600 V, 13.3 – 1010 mm^2 (6 AWG – 2000 kcmil)) and all 2 kV	EP, SBR/IIR, NR	Jacket or two or more fibrous coverings[a]	Jacket or fibrous covering[a]
RHH, RHW, and RHW-2	XL, EPCV, CP, CPE, Composite	Jacket or fibrous covering[a] (optional)	Jacket or fibrous covering[a]
R90, RW75, RW90	EP	Jacket	Jacket
RWU75, RWU90	EP or EPCV	Jacket	Not applicable
R90, RW75, RW90	XL or EPCV	Jacket (optional)	Jacket
RWU75, RWU90	XL	Jacket (optional)	Not applicable
R90	Silicone	Jacket	Jacket
RHH or RHW (600 or 2000 V)	Silicone	Jacket or two or more fibrous coverings[a]	Jacket or fibrous covering[a]

[a] In the United States only, for Types other than SA or SF, the use of a fibrous covering(s) in this table is an alternate to a jacket.

In Canada and Mexico, the use of fibrous coverings does not apply.

Table 20 – Physical Properties of Jackets

(See Clauses 4.3.1, 4.9.1.1, 4.10.1, 4.10.2 and 7.2.4, Table 51, and Annexes B and H)

Condition	Test			Material and properties				
				Neoprene, CP, CPE, NBR/PVC		PVC		XL
				75°C	90°C	75°C	90°C	90°C
Before aging	Elongation	Minimum		200 percent	200 percent	100 percent	100 percent	150 percent
	Tensile strength	Minimum		8.3 MPa (1200 lbf/in²)	8.3 MPa (1200 lbf/in²)	10.3 MPa (1500 lbf/in²)	10.3 MPa (1500 lbf/in²)	10.3 MPa (1500 lbf/in²)
After accelerated aging	Air-oven test	Temperature		100 ±1°C	110 ±1°C	100 ±1°C	121 ±1°C	110 ±1°C
		Time		10 d	10 d	10 d	7 d	10 d
		Minimum percent of results obtained on unaged specimens	Elongation	50	50	45	45	75
			Tensile strength	50	50	70	85	75
	Oil-immersion test	Temperature		121 ±1°C	121 ±1°C	70 ±1°C	70 ±1°C	121 ±1°C
		Time		18 h	18 h	4h	4h	18 h
		Minimum percent of results obtained on unaged specimens	Elongation	60	60	75	75	60
			Tensile strength	60	60	75	75	40

Table 21 – Thicknesses of Jacket on 600 V, 1000 V, and 2000 V Single-Conductor Types RW75, RW90, R90, RHW, RHW-2, and RHH

(See Clause 4.3.1, Table 15, and Annex B)

Conductor size		600 V and 1000 V				2000 V			
mm²	AWG or kcmil	Minimum average jacket thickness	Minimum jacket thickness at any point	Minimum average jacket thickness	Minimum jacket thickness at any point	Minimum average jacket thickness	Minimum jacket thickness at any point	Minimum average jacket thickness	Minimum jacket thickness at any point
		mm	mm	mils	mils	mm	mm	mils	mils
2.08 – 3.31	14 – 12 AWG	0.38	0.30	15	12	0.38	0.30	15	12
5.26	10	0.38	0.30	15	12	0.76	0.61	30	24
8.37 – 26.7	8 – 3	0.76	0.61	30	24	0.76	0.61	30	24
33.6	2	0.76	0.61	30	24	1.14	0.91	45	36
42.4 – 85.0	1 – 3/0	1.14	0.91	45	36	1.14	0.91	45	36
107	4/0	1.14	0.91	45	36	1.65	1.32	65	52
127 – 507	250 – 1000 kcmil	1.65	1.32	65	52	1.65	1.32	65	52
Larger than 507 – 1010	Larger than 1000 – 2000	2.41	1.93	95	76	2.41	1.93	95	76

Table 22 – Thicknesses of Jacket on 1000 V Single-Conductor Type RWU75 and RWU90

(See Clause 4.3.1 and Annex B)

Conductor size		Thickness of jacket							
		XL insulated				EP or EPCV insulated			
mm²	AWG or kcmil	Minimum average		Minimum at any point		Minimum average		Minimum at any point	
		mm	mils	mm	mils	mm	mils	mm	mils
2.08 – 5.26	14 – 10 AWG	0.38	0.30	15	12	1.14	0.91	45	36
8.37	8	0.76	0.60	30	24	1.14	0.91	45	36
13.3 – 26.7	6 – 3	0.76	0.60	30	24	1.65	1.32	65	52
33.6 – 85.0	2 – 3/0	1.14	0.91	45	36	1.65	1.32	65	52
107	4/0	1.65	1.32	65	52	1.65	1.32	65	52
127 – 507	250 – 1000 kcmil	1.65	1.32	65	52	2.41	1.93	95	76
633 – 1010	1250 – 2000	2.41	1.93	95	76	3.17	2.54	125	100

Table 23 – Thicknesses of Optional Jacket on Each Insulated Conductor in 2-Conductor Flat Parallel Wire or Cable, and on Each Insulated Conductor in a Multiple-Conductor Cable or Assembly

(See Clause 4.3.1 and Annex B)

Calculated diameter of insulation under jacket		Thicknesses of jacket[a]			
mm	inches	Average		Minimum at any point	
		mm	mils	mm	mils
0 – 6.35	0 – 0.250	0.38	15	0.30	12
6.36 – 10.80	0.251 – 0.425	0.64	25	0.51	20
10.81 – 17.80	0.426 – 0.700	0.76	30	0.61	24
17.81 – 38.10	0.701 – 1.500	1.27	50	1.02	40
38.11 – 63.50	1.501 – 2.500	2.03	80	1.62	64

[a] Not applicable to a colored coating on an insulated conductor.

Table 24 – Maximum Length of Lay of Multiple-Conductor Cables

(See Clause 4.5.1.3)

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 25 – Minimum Size of Equipment-Grounding Conductor in Multiple-Conductor Cable Types XHHW-2, XHHW, XHH, RHH, RHW, RHW-2, R90, RW75, and RW90

(See Clauses 4.5.2 and 7.2.2)

Circuit conductor size		Size of equipment-grounding conductor							
		75°C (RHW, RW75)				90°C (XHHW, XHHW-2, XHH, RHH, RHW-2, R90, RW90)			
mm^2	AWG or kcmil	Copper		Aluminum		Copper		Aluminum	
		mm^2	AWG	mm^2	AWG	mm^2	AWG	mm^2	AWG
Copper									
2.08	14 AWG	2.08	14	–	–	2.08	14	–	–
3.31	12	3.31	12			3.31	12		
5.26	10	5.26	10	–	–	5.26	10	–	–
8.37	8	5.26	10	8.37	8	5.26	10	8.37	8
13.3, 21.2	6, 4	8.37	8	13.3	6	8.37	8	13.3	6
26.7	3	8.37	8	13.3	6	13.3	6	21.2	4
33.6 – 67.4	2 – 2/0	13.3	6	21.2	4	13.3	6	21.2	4
85.0	3/0	13.3	6	21.2	4	21.2	4	33.6	2
107 – 152	4/0 – 300 kcmil	21.2	4	33.6	2	21.2	4	33.6	2
177 – 203	350 – 400	26.7	3	42.4	1	26.7	3	42.4	1
253	500	26.7	3	42.4	1	33.6	2	53.5	1/0
304 – 380	600 – 750	33.6	2	53.5	1/0	33.6	2	53.5	1/0
405	800	33.6	2	53.5	1/0	42.4	1	67.4	2/0
456 – 507	900 – 1000	42.4	1	67.4	2/0	42.4	1	67.4	2/0
633	1250	42.4	1	67.4	2/0	53.5	1/0	85.0	3/0
887 – 1010	1500 – 2000	53.5	1/0	85.0	3/0	53.5	1/0	85.0	3/0
Aluminum									
3.31	12 AWG	2.08	14	3.31	12	2.08	14	3.31	12
5.26	10	3.31	12	5.26	10	3.31	12	5.26	10
8.37	8	5.26	10	8.37	8	5.26	10	8.37	8
13.3	6	5.26	10	8.37	8	5.26	10	8.37	8
221.2 – 33.6	4 – 2	8.37	8	13.3	6	8.37	8	13.3	6
42.4	1	8.37	8	13.3	6	13.3	6	21.2	4
53.5 – 85	1/0 – 3/0	13.3	6	21.2	4	13.3	6	21.2	4
107	4/0	13.3	6	21.2	4	21.2	4	33.5	2
126 – 177	250 – 350 kcmil	21.2	4	33.6	2	21.2	4	33.6	2
202	400	21.2	4	33.6	2	26.7	3	42.4	1
253 – 354	500 – 700	26.7	3	42.4	1	26.7	3	42.4	1
380 – 405	750 – 800	26.7	3	42.4	1	33.6	2	53.5	1/0
456 – 507	900 – 1000	33.6	2	53.5	1/0	33.6	2	53.5	1/0
633	1250	33.6	2	53.5	1/0	42.4	1	67.4	2/0
760	1500	42.4	1	67.4	2/0	42.4	1	67.4	2/0
887 – 1010	1750 – 2000	42.4	1	67.4	2/0	53.5	1/0	85.0	3/0

Table 26 – Thicknesses of Overall Jacket on Multiple-Conductor Cable

(See Clause 4.9.2 and Annex B)

Calculated diameter under jacket of round cable or calculated length of major axis under jacket of 2-conductor flat parallel		Thicknesses 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	3.55	140	2.85	112

Table 27 – Maximum Direct-Current Resistance at 20°C of Solid Aluminum, Bare Copper, and Coated-Copper Conductors

(See Clauses 5.2.1 and 5.2.2 and Annex B)

Size of conductor		Aluminum		Bare copper		Coated copper	
mm^2	AWG	Ohms per km	Ohms per 1000 ft	Ohms per km	Ohms per 1000 ft	Ohms per km	Ohms per 1000 ft
2.08	14	–	–	8.45	2.57	8.78	2.68
3.31	12	8.71	2.65	5.31	1.62	5.53	1.68
5.26	10	5.48	1.67	3.34	1.02	3.48	1.06
8.37	8	3.45	1.05	2.10	0.641	2.16	0.659
13.3	6	2.17	0.661	1.32	0.403	1.36	0.415
21.2	4	1.36	0.416	0.832	0.254	0.856	0.261
26.7	3	1.08	0.330	0.660	0.201	0.679	0.207
33.6	2	0.857	0.261	0.523	0.159	0.538	0.164
42.4	1	0.680	0.207	0.415	0.126	0.427	0.130
53.5	1/0	0.539	0.164	0.329	0.100	0.337	0.103
67.4	2/0	0.428	0.130	0.261	0.0795	0.267	0.0814
85.0	3/0	0.339	0.103	0.207	0.0631	0.212	0.0655
107	4/0	0.269	0.0820	0.164	0.0500	0.168	0.0512

Table 28 – Maximum Direct-Current Resistance at 20°C of Aluminum and Bare Copper Conductors – Concentric-Stranded Classes B, C, and D; Compact-Stranded, Compressed-Stranded, and Combination Unilay[a]

(See Clauses 5.2.1, 5.2.2, and D.3 and Annex B)

Size of conductor		Conductor resistance			
		Aluminum		Bare copper	
mm²	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	0.654
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	0.129
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	0.0708	0.0216
279	550	0.106	0.0322	0.0644	0.0196
304	600	0.0967	0.0295	0.0590	0.0180
329	650	0.0893	0.0272	0.0545	0.0166
355	700	0.0829	0.0253	0.0506	0.0154
380	750	0.0774	0.0236	0.0472	0.0144
405	800	0.0725	0.0221	0.0443	0.0135
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

Table 28 – Maximum Direct-Current Resistance at 20°C of Aluminum and Bare Copper Conductors – Concentric-Stranded Classes B, C, and D; Compact-Stranded, Compressed-Stranded, and Combination Unilay[a] Continued on Next Page

Table 28 – Maximum Direct-Current Resistance at 20°C of Aluminum and Bare Copper Conductors – Concentric-Stranded Classes B, C, and D; Compact-Stranded, Compressed-Stranded, and Combination Unilay[a] Continued

Size of conductor		Conductor resistance			
		Aluminum		Bare copper	
mm^2	AWG or kcmil	Ohms per km	Ohms per 1000 ft	Ohms per km	Ohms per 1000 ft
963	1900	0.0306	0.00931	0.0186	0.00568
1010	2000	0.0290	0.00884	0.0177	0.00540

[a] **Note:** *Combination unilay strand sizes for copper are 2.08 – 107 mm^2 (14 – 4/0 AWG), for aluminum 13.3 – 107 mm^3 (6 – 4/0 AWG).*

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 29 – Maximum Direct-Current Resistance at 20°C of Copper Conductors, Concentric-Stranded and Compressed- Stranded Class B, C, and D with Each Strand Coated, and Combination Unilay[a] with Each Strand Coated

(See Clauses 5.2.1, 5.2.2, and D.3 and Annex B)

Size of conductor		Class B		Class C and Combination Unilay		Class D	
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	8.96	2.73	9.15	2.78	9.25	2.82
3.31	12	5.64	1.72	5.75	1.75	5.75	1.75
5.26	10	3.55	1.08	3.55	1.08	3.62	1.10
8.37	8	2.23	0.679	2.23	0.679	2.23	0.679
13.3	6	1.40	0.427	1.41	0.427	1.41	0.427
21.2	4	0.882	0.269	0.882	0.269	0.882	0.269
26.7	3	0.700	0.213	0.700	0.213	0.700	0.213
33.6	2	0.555	0.169	0.555	0.169	0.555	0.169
42.4	1	0.440	0.134	0.440	0.134	0.440	0.134
53.5	1/0	0.349	0.106	0.349	0.106	0.349	0.106
67.4	2/0	0.276	0.0843	0.276	0.0844	0.276	0.0844
85.0	3/0	0.219	0.0669	0.219	0.0669	0.219	0.0669
107	4/0	0.172	0.0525	0.174	0.0530	0.174	0.0530
127	250 kcmil	0.147	0.0449	0.147	0.0449	0.147	0.0449
152	300	0.122	0.0374	0.122	0.0374	0.122	0.0374
177	350	0.105	0.0320	0.105	0.0320	0.105	0.0320
203	400	0.0911	0.0278	0.0920	0.0280	0.0920	0.0280
228	450	0.0810	0.0247	0.0818	0.0248	0.0818	0.0249
253	500	0.0729	0.0222	0.0736	0.0224	0.0736	0.0224
279	550	0.0669	0.0204	0.0669	0.0204	0.0669	0.0204
304	600	0.0614	0.0187	0.0614	0.0187	0.0614	0.0187
329	650	0.0561	0.0171	0.0566	0.0172	0.0566	0.0172
355	700	0.0520	0.0159	0.0526	0.0160	0.0526	0.0160
380	750	0.0486	0.0148	0.0491	0.0150	0.0491	0.0150

Table 29 – Maximum Direct-Current Resistance at 20°C of Copper Conductors, Concentric-Stranded and Compressed- Stranded Class B, C, and D with Each Strand Coated, and Combination Unilay[a] with Each Strand Coated Continued on Next Page

Table 29 – Maximum Direct-Current Resistance at 20°C of Copper Conductors, Concentric-Stranded and Compressed- Stranded Class B, C, and D with Each Strand Coated, and Combination Unilay[a] with Each Strand Coated Continued

Size of conductor		Class B		Class C and Combination Unilay		Class D	
mm²	AWG or kcmil	Ohms per km	Ohms per 1000 ft	Ohms per km	Ohms per 1000 ft	Ohms per km	Ohms per 1000 ft
405	800	0.0455	0.0139	0.0460	0.0141	0.0460	0.0141
456	900	0.0405	0.0123	0.0409	0.0124	0.0409	0.0124
507	1000	0.0364	0.0111	0.0364	0.0111	0.0368	0.0112
557	1100	0.0331	0.0101	0.0335	0.0102	0.0335	0.0102
608	1200	0.0303	0.00925	0.0307	0.00935	0.0307	0.00935
633	1250	0.0292	0.00888	0.0295	0.00898	0.0295	0.00898
659	1300	0.0280	0.00854	0.0284	0.00863	0.0284	0.00863
709	1400	0.0260	0.00793	0.0260	0.00794	0.0263	0.00802
760	1500	0.0243	0.00740	0.0243	0.00741	0.0246	0.00748
811	1600	0.0228	0.00694	0.0231	0.00702	0.0231	0.00702
861	1700	0.0214	0.00653	0.0216	0.00660	0.0216	0.00660
887	1750	0.0208	0.00635	0.0210	0.00642	0.0210	0.00642
912	1800	0.0202	0.00617	0.0202	0.00617	0.0205	0.00623
963	1900	0.0192	0.00584	0.0192	0.00584	0.0194	0.00591
1010	2000	0.0182	0.00555	0.0183	0.00555	0.0184	0.00561

[a] **Note:** *Combination unilay strand sizes are 2.08 – 107 mm² (14 – 4/0 AWG).*

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

Table 30 – Maximum Direct-Current Resistance at 20°C of Class G and H Stranded Conductors

(See Clauses 5.2.1, 5.2.2, and D.3 and Annex B)

Size of conductor		Bare copper				Coated copper[a]				Aluminum			
		Class G		Class H		Class G		Class H		Class G		Class H	
mm²	AWG or kcmil	Ohms per km	Ohms per 1000 ft	Ohms per km	Ohms per 1000 ft	Ohms per km	Ohms per 1000 ft	Ohms per km	Ohms per 1000 ft	Ohms per km	Ohms per 1000 ft	Ohms per km	Ohms per 1000 ft
	AWG												
2.08	14	8.70	2.65	–	–	9.24	2.82	–	–	–	–	–	–
3.31	12	5.48	1.67	–	–	5.81	1.77	–	–	–	–	–	–
5.26	10	3.45	1.05	–	–	3.66	1.11	–	–	–	–	–	–
8.37	8	2.16	0.660	2.18	0.666	2.30	0.701	–	–	–	–	–	–
13.3	6	1.37	0.415	1.38	0.419	1.42	0.431	–	–	2.23	0.680	–	–
21.2	4	0.857	0.261	0.865	0.263	0.890	0.271	–	–	1.41	0.428	–	–
26.7	3	0.679	0.207	0.6866	0.209	0.707	0.215	–	–	1.11	0.340		
33.6	2	0.539	0.164			0.560	0.170			0.883	0.369	–	–
(No. of wires)		Class H only											
33.6	2 (133)			0.544	0.166			0.566	0.172			0.891	0.271
33.6	2 (259)			0.547	0.166			0.580	0.176			–	–
42.4	1	0.431	0.132	0.434	0.133	0.449	0.137	–	–	0.707	0.215	–	–

Table 30 – Maximum Direct-Current Resistance at 20°C of Class G and H Stranded Conductors
Continued on Next Page

Table 30 – Maximum Direct-Current Resistance at 20°C of Class G and H Stranded Conductors Continued

Size of conductor		Bare copper				Coated copper[a]				Aluminum			
		Class G		Class H		Class G		Class H		Class G		Class H	
mm²	AWG or kcmil	Ohms per km	Ohms per 1000 ft	Ohms per km	Ohms per 1000 ft	Ohms per km	Ohms per 1000 ft	Ohms per km	Ohms per 1000 ft	Ohms per km	Ohms per 1000 ft	Ohms per km	Ohms per 1000 ft
53.5	1/0	0.342	0.104	0.344	0.105	0.355	0.108	–	–	0.560	0.170	–	–
67.4	2/0	0.271	0.0826	0.272	0.0830	0.282	0.0860	–	–	0.445	0.136	–	–
85.0	3/0	0.215	0.0656			0.223	0.0681			0.353	0.107		
(No. of wires)		Class H only											
85.0	3/0 (259)			0.216	0.0659			0.0685	0.224			0.354	0.108
85.0	3/0 (427)			0.217	0.0662			0.0703	0.231			–	–
107	4/0 (259)			0.171	0.0522			0.0544	0.179			0.280	0.0857
107	4/0 (427)			0.172	0.0525			0.0546	0.180			0.283	0.0861
107	4/0	.170	.0520			.177	.0541			.279	.0853		
	kcmil												
127	250	.145	.0443	.146	.0445	.151	.0460	.0462	.152	.238	.0725	.239	.0728
152	300	.121	.0368	.121	.0370	.125	.0384	.0386	.126	.198	.0604	.199	.0607
177	350	.104	.0316	.104	.0317	.108	.0328	.0330	.108	.170	.0518	.170	.0520
203	400	.0917	.0276	.0911	.0277	.0942	.0288	.0289	.0948	.149	.0453	.149	.0455
226	450	.0806	.0246	.0810	.0247	.0838	.0255	.0257	.0843	.132	.0403	.133	.0405
253	500	.0725	.0221	.0729	.0222	.0755	.0230	.0232	.0758	.119	.0362	.119	.0364
279	550	.0663	.0202	.0669	.0204	.0690	.0210	.0212	.0696	.108	.0332	.110	.0335
304	600	.0607	.0186	.0613	.0187	.0631	.0193	.0195	.0638	.0996	.0304	.100	.0306
329	650	.0561	.0171	.0566	.0172	.0583	.0177	.0180	.0589	.0919	.0280	.0928	.0283
355	700	.0520	.0159	.0525	.0160	.0542	.0165	.0166	.0547	.0834	.0260	.0862	.0262
380	750	.0486	.0148	.0491	.0150	.0505	.0154	.0155	.0510	.0797	.0243	.0804	.0245
405	800	.0456	.0139	.0460	.0140	.0473	.0145	.0146	.0478	.0747	.0227	.0754	.0230
456	900	.0405	.0123	.0409	.0124	.0421	.0129	.0130	.0425	.0664	.0202	.0670	.0204
507	1000	.0364	.0111	.0368	.0112	.0379	.0115	.0116	.0382	.0598	.0183	.0603	.0184
608	1200	.0304	.00926	.0307	.00934	.0316	.00963	.00972	.0319	.0498	.0152	.0503	.0153
633	1250	.0292	.00888	.0295	.00897	.0303	.00924	.00933	.0306	.0478	.0146	.0482	.0147
659	1300	.0280	.00855	.0283	.00863	.0292	.00888	.00897	.0295	.0460	.0140	.0464	.0142
709	1400	.0260	.00794	.0263	.00801	.0270	.00825	.00833	.0273	.0426	.0131	.0430	.0132
760	1500	.0243	.00741	.0245	.00748	.0253	.00770	.00777	.0255	.0398	.0121	.0402	.0122
811	1600	.0230	.00701	.0230	.00701	.0239	.00729	.00729	.0239	.0377	.0115	.0377	.0115
861	1700	.0216	.00660	.0216	.00660	.0225	.00686	.00686	.0225	.0355	.0108	.0355	.0108
887	1750	.0210	.00641	.0210	.00641	.0218	.00666	.00666	.0218	.0345	.0105	.0345	.0105
912	1800	.0204	.00623	.0204	.00623	.0212	.00648	.00648	.0212	.0335	.0102	.0335	.0102
963	1900	.0194	.00591	.0194	.00591	.0201	.00614	.00614	.0201	.0317	.00968	.0317	.00968
1010	2000	.0184	.00561	.0184	.00561	.0192	.00583	.00583	.0192	.0302	.00919	.0302	.00919

[a] Each strand coated with tin or a tin/lead alloy.

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

Table 31 – Maximum Direct-Current Resistance at 20°C of Class M Stranded Conductors

(See Clauses 5.2.1 and 5.2.2 and Annex B)

Size of conductor		Bare copper		Coated copper (each strand coated with tin or a tin/lead 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 32 – Maximum Direct-Current Resistance at 20°C of Class I and K Stranded Conductors

(See Clauses 5.2.1, 5.2.2 and Annex B)

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

Table 33 – Minimum Long-Term Insulation Resistance at Rated Temperatures – Types RW75 and RW90

(See Clauses 5.4.1.1, 5.4.1.2, and 5.4.2.1 and Annex B)

Conductor size		Minimum IR at 75°C for RW75						Minimum IR at 90°C for RW90					
		600 V		1000 V		2000 V		600 V		1000 V		2000 V	
mm^2	AWG or kcmil	GΩ·m	MΩ ·1000 ft	GΩ·m	MΩ ·1000 ft	GΩ·m	MΩ ·1000 ft	GΩ·m	MΩ ·1000 ft	GΩ·m	MΩ ·1000 ft	GΩ·m	MΩ ·1000 ft
	AWG												
2.08	14	15.5	50.9	21.0	68.9	25.4	83.3	11.5	37.7	15.5	50.9	19.1	62.5
3.31	12	13.0	42.7	17.5	57.4	21.8	71.6	9.8	32.2	13.0	42.7	16.4	53.7
5.26	10	10.5	34.4	14.5	47.6	18.5	60.7	8.1	26.6	11.0	36.1	13.9	45.5
8.37	8	12.5	41.0	12.0	39.4	17.5	57.5	9.4	30.8	9.3	30.5	13.1	43.1
13.3	6	10.0	32.8	13.0	42.7	14.7	48.4	7.8	25.6	9.7	31.8	11.1	36.3
21.2	4	8.5	27.9	10.5	34.4	12.3	40.4	6.4	21.0	8.1	26.6	9.2	30.3
26.7	3	7.7	25.3	9.8	32.2	11.2	36.8	5.8	19.0	7.4	24.3	8.4	27.6
33.6	2	7.0	23.0	8.9	29.2	10.2	33.5	5.2	17.1	6.7	22.0	7.7	25.1
42.4	1	7.5	24.6	10.0	32.8	11.3	37.0	5.6	18.4	7.6	24.9	8.5	27.8
53.5	1/0	6.8	22.3	9.2	30.2	10.3	33.7	5.1	16.7	6.9	22.6	7.7	25.3
67.4	2/0	8.4	27.6	8.4	27.6	9.3	30.6	4.6	15.1	6.3	20.7	7.0	23.0
85.0	3/0	7.6	24.9	7.6	24.9	8.4	27.7	4.1	13.5	5.7	18.7	6.3	20.8
107	4/0	4.9	16.1	6.8	22.3	7.6	25.1	3.7	12.1	5.1	16.7	5.7	18.8
	kcmil												
127	250	5.3	17.4	7.0	23.0	8.1	26.6	4.0	13.1	5.3	17.4	6.1	20.0
152	300	4.9	16.1	6.5	21.3	7.5	24.6	3.7	12.1	4.9	16.1	5.6	18.4
177	350	4.6	15.1	6.0	19.7	7.0	23.0	3.4	11.2	4.5	14.8	5.3	17.2
203	400	4.3	14.1	5.7	18.7	6.6	21.7	3.2	10.5	4.3	14.1	5.0	16.3
253	500	3.9	12.8	5.1	16.7	6.0	19.6	2.9	9.5	3.8	12.5	4.5	14.7
304	600	4.3	14.1	4.7	15.4	6.2	20.4	3.2	10.5	3.5	11.5	4.7	15.3
355	700	4.0	13.1	4.4	14.4	5.8	19.0	3.0	9.8	3.3	10.8	4.3	14.3
380	750	3.9	12.8	4.3	14.1	5.6	18.4	2.9	9.5	3.2	10.5	4.2	13.8
405	800	3.8	12.5	4.1	13.5	5.5	17.9	2.8	9.2	3.1	10.2	4.1	13.4
456	900	3.6	11.8	3.9	12.8	5.2	17.0	2.7	8.9	2.9	9.5	3.9	12.7
507	1000	3.4	11.2	3.7	12.1	4.9	16.2	2.5	8.2	2.8	9.2	3.7	12.1
608	1250	3.6	11.8	4.1	13.5	5.1	16.8	2.7	8.9	3.0	9.8	3.8	12.6
760	1500	3.3	10.8	3.7	12.1	4.7	15.5	2.5	8.2	2.8	9.2	3.5	11.6
887	1750	3.1	10.2	3.5	11.5	4.4	14.4	2.3	7.5	2.6	8.5	3.3	10.8
1010	2000	2.9	9.5	3.2	10.5	4.1	13.5	2.2	7.2	2.4	7.9	3.1	10.2

Note:

K = 60 at 75°C for GΩ·m and 196 for MΩ·1000 ft.

K = 45 at 90°C for GΩ·m and 148 for MΩ·1000 ft.

Table 34 – Minimum Long-Term Insulation Resistance at Rated Temperatures - 1000 V Types RWU75 and RWU90

(See Clauses 5.4.1.1, 5.4.1.2 and 5.4.2.1 and Annex B)

Conductor size		Minimum IR at 75°C for RWU75		Minimum IR at 90°C for RWU90	
mm^2	AWG or kcmil	GΩ·m	MΩ·1000 ft	GΩ·m	MΩ·1000 ft
2.08	14 AWG	25.0	82.0	19.0	62.3
3.31	12	21.0	68.9	16.0	52.5
5.26	10	18.0	59.1	13.5	44.3
8.37	8	19.0	62.3	14.0	45.9
13.3	6	16.0	52.5	12.0	39.4
21.2	4	13.5	44.3	10.0	32.8
26.7	3	12.0	39.4	9.3	30.5
33.6	2	11.0	36.1	8.5	27.9
42.4	1	11.5	37.7	8.8	28.9
53.5	1/0	10.5	34.4	8.0	26.2
67.4	2/0	9.7	31.8	7.3	24.0
85.0	3/9	8.8	28.9	6.6	21.7
107	4/0	8.0	26.2	6.0	19.7
127	250 kcmil	8.4	27.6	6.3	20.7
152	300	7.7	25.3	5.8	19.0
177	350	7.2	23.6	5.4	17.7
203	400	6.8	22.3	5.1	16.7
253	500	6.2	20.3	4.6	15.1
304	600	6.4	21.0	4.8	15.7
355	700	5.9	19.4	4.4	14.4
380	750	5.8	19.0	4.3	14.1
405	800	5.6	18.4	4.2	13.8
456	900	5.3	17.4	4.0	13.1
507	1000	5.1	16.7	3.8	12.5
608	1250	5.1	16.7	3.8	12.5
760	1500	4.7	15.4	3.5	11.5
887	1750	4.3	14.1	3.2	10.5
1010	2000	4.1	13.5	3.0	9.8

Note:

K = 60 at 75°C for GΩ·m and 196 for MΩ·1000 ft.

K = 45 at 90°C for GΩ·m and 148 for MΩ·1000 ft.

Table 35 – Minimum Long-Term Insulation Resistance at Rated Temperature – Types XHHW-2, RHW-2, XHHW, and RHW

(See Clauses 5.4.1.1, 5.4.1.2, and 5.4.2.1 and Annex B)

Conductor size		Type XHHW-2 and XHHW with insulation as indicated in Table 12	Minimum long-term insulation resistance at rated temperature [a]					
			600 V Types RHW-2 and RHW with insulation as indicated in Table 15			2000 V Types RHW-2 and RHW with insulation as indicated in Table 17		
			CP, CPE, SBR/IIR, and silicone rubber	EP, EPCV, XL	Composite EP, XL, or EPCV inner with EPCV, XL, CPE, or CPE outer	CP, CPE, SBR/IIR, and silicone rubber	EP, EPCV, XL	Composite EP, XL, or EPCV inner with EPCV, XL, CPE, or CPE outer
mm²	AWG	GΩ·m						
2.08	14	.060	.030	.075	.075	.045	.090	.090
3.31	12	.050	.025	.065	.065	.040	.080	.080
5.26	10	.040	.025	.055	.055	.035	.070	.070
8.37	8	.045	.020	055	.055	025	.060	.065
13.3	6	.035	.020	.045	.055	.025	.050	.055
21.2	4	.030	.015	.035	.045	.020	.040	.050
26.7	3	.025	.015	.035	.040	.020	.040	.045
33.6	2	.025	.015	.030	.035	.020	.035	.040
42.4	1	.025	015	.035	.040	.020	.040	.045
53.5	1/0	.025	.015	.030	.040	.020	.035	040
67.4	2/0	.020	.015	.030	.035	.015	.030	.040
85.0	3/0	.020	.010	.025	.030	.015	.030	.035
107	4/0	.020	.010	.025	.030	.015	.025	.030
mm²	**AWG**	**MΩ·1000ft**						
2.08	14	.180	.095	.240	.240	.135	.290	.290
3.31	12	.155	.080	.205	.205	.120	.250	.250
5.26	10	.125	.070	.175	.175	.105	.215	.215
8.37	8	.130	.065	.165	.165	.080	.185	.210
13.3	6	.110	.055	.135	.165	.075	.155	.180
21.2	4	.090	.045	.115	.135	.065	.130	.150
26.7	3	.080	.040	.105	.125	.060	.115	.135
33.6	2	.075	.035	.095	.110	.055	.105	.125
42.4	1	.075	.040	.105	.130	.055	.115	.140
53.5	1/0	.070	.040	.100	.115	.050	.105	.125
67.4	2/0	.060	.035	.085	.105	.045	.095	.115
85.0	3/0	.055	.030	.080	.095	.040	.085	.105
107	4/0	.050	.025	.070	.090	.035	.080	.095

[a] Types XHHW-2 and RHW-2 are tested at 90°C; Types XHHW and RHW are tested at 75°C.

Table 36 – Minimum Long-Term Insulation Resistance at 97°C – Types XHH, RHH, and R90 Silicone

(See Clauses 5.5.2.1 and 5.5.3.1)

Conductor size		Type XHH with insulation as indicated in Table 12	600 V Type RHH or R90 Silicone with insulation as indicated in Table 15			2000 V Type RHH with insulation as indicated in Table 17		
			CP, CPE, SBR/IIR or silicone rubber	EP, EPCV, XL	Composite EP, XL, or EPCV inner with EPCV, XL, CPE, or CPE outer	CP, CPE, SBR/IIR or silicone rubber	EP, EPCV, XL	Composite EP, XL, or EPCV inner with EPCV, XL, CPE, or CPE outer
mm^2	AWG	GΩ·m						
2.08	14	.060	.030	.075	.075	.045	.090	.090
3.31	12	.050	.025	.065	.065	.040	.080	.080
5.26	10	.040	.025	.055	.055	.035	.070	.070
8.37	8	.045	.020	055	.055	025	.060	.065
13.3	6	.035	.020	.045	.055	.025	.050	.055
21.2	4	.030	.015	.035	.045	.020	.040	.050
26.7	3	.025	.015	.035	.040	.020	.040	.045
33.6	2	.025	.015	.030	.035	.020	.035	.040
42.4	1	.025	015	.035	.040	.020	.040	.045
53.5	1/0	.025	.015	.030	.040	.020	.035	040
67.4	2/0	.020	.015	.030	.035	.015	.030	.040
85.0	3/0	.020	.010	.025	.030	.015	.030	.035
107	4/0	.020	.010	.025	.030	.015	.025	.030
mm^2	AWG	MΩ·1000 ft						
2.08	14	.180	.095	.240	.240	.135	.290	.290
3.31	12	.155	.080	.205	.205	.120	.250	.250
5.26	10	.125	.070	.175	.175	.105	.215	.215
8.37	8	.130	.065	.165	.165	.080	.185	.210
13.3	6	.110	.055	.135	.165	.075	.155	.180
21.2	4	.090	.045	.115	.135	.065	.130	.150
26.7	3	.080	.040	.105	.125	.060	.115	.135
33.6	2	.075	.035	.095	.110	.055	.105	.125
42.4	1	.075	.040	.105	.130	.055	.115	.140
53.5	1/0	.070	.040	.100	.115	.050	.105	.125
67.4	2/0	.060	.035	.085	.105	.045	.095	.115
85.0	3/0	.055	.030	.080	.095	.040	.085	.105
107	4/0	.050	.025	.070	.090	.035	.080	.095

Table 37 – Minimum Long-Term Insulation Resistance at 97°C – Type R90 for All Materials Except R90 Silicone

(See Clauses 5.5.2.1 and 5.5.3.1 and Annex B)

Conductor size		Minimum IR at 97°C					
mm^2	AWG or kcmil	600 V		1000 V		2000 V	
		GΩ·m	MΩ·1000 ft	GΩ·m	MΩ·1000 ft	GΩ·m	MΩ·1000 ft
2.08	14 AWG	3.54	11.61	4.77	15.65	5.72	18.77
3.31	12	2.98	9.78	4.04	13.25	4.93	16.17
5.26	10	2.46	8.07	3.38	11.08	4.18	13.71
8.37	8	2.84	9.32	2.84	9.32	3.96	13.35
13.3	6	2.36	7.74	2.98	9.78	3.35	11.00
21.2	4	1.94	6.36	2.47	8.10	2.79	9.15
26.7	3	1.76	5.77	2.40	7.88	2.55	8.37
33.6	2	1.59	5.21	2.04	6.69	2.32	7.61
42.4	1	1.70	5.58	2.33	7.64	2.56	8.40
53.5	1/0	1.53	5.02	2.11	6.92	2.33	7.64
67.4	2/0	1.39	4.58	1.92	6.30	2.12	6.96
85.0	3/0	1.24	4.07	1.74	5.71	1.92	6.30
107	4/0	1.12	3.67	1.57	5.15	1.74	5.71
127	250 kcmil	1.21	3.97	1.62	5.31	1.85	6.07
152	300	1.11	3.64	1.49	4.89	1.71	5.61
177	350	1.04	3.41	1.39	4.56	1.59	5.21
203	400	0.88	2.89	1.31	4.30	1.50	4.92
253	500	0.91	2.99	1.19	3.90	1.36	4.46
304	600	0.88	2.89	1.09	3.58	1.41	4.62
355	700	0.91	2.99	1.02	3.35	1.32	4.30
380	750	0.88	2.89	0.99	3.25	1.28	4.20
405	800	0.86	2.82	0.97	3.18	1.24	4.07
456	900	0.81	2.66	0.91	2.99	1.18	3.87
507	1000	0.77	2.53	0.86	2.82	1.12	3.67
608	1250	0.82	2.69	0.94	3.08	–	–
760	1500	0.75	2.46	0.86	2.82	–	–
887	1750	0.70	2.30	0.80	2.62	–	–
1010	2000	0.65	2.13	0.75	2.46	–	–

Note: K = 13.3 for GΩ·m and 43.6 for MΩ·1000 ft.

Table 38 – Mandrel Diameters for Heat Shock Test

(See Clause 5.9.1 and Annex B)

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

Table 39 – Mandrel Diameters for Cold Bend Test – Single Conductors

(See Clauses 5.11.1.1, 8.11.1.2, F.8.1.2, and F.8.1.4 and Annex B)

Conductor size		Mandrel diameter	
mm^2	AWG/kcmil	mm	inches
2.08	14 AWG	8	0.313
3.31	12	9	0.375
5.26	10	14	0.563
8.37	8	17	0.688
13.3	6	32	1.250
21.2	4	35	1.375
26.7	3	37	1.458
33.6	2	40	1.563
42.4	1	68	2.688
53.5	1/0	73	2.875
67.4	2/0	76	3.000
85.0	3/0	83	3.250
107	4/0	89	3.500
126	250 kcmil	160	6.304
152	300	171	6.744
177	350	182	7.160
203	400	191	7.536
228	450	201	7.904
253	500	209	8.232
279	550	280	11.030
304	600	290	11.430
329	650	299	11.790
355	700	308	12.140
380	750	317	12.490
405	800	326	12.820
456	900	342	13.450
507	1000	357	14.040
557	1100	379	14.930
602	1200	393	15.490
633	1250	401	15.770
659	1300	408	16.050
709	1400	420	16.540
760	1500	432	17.020
811	1600	444	17.490
861	1700	456	17.940
887	1750	462	18.170

Table 39 – Mandrel Diameters for Cold Bend Test – Single Conductors Continued on Next Page

Table 39 – Mandrel Diameters for Cold Bend Test – Single Conductors Continued

Conductor size		Mandrel diameter	
mm²	AWG/kcmil	mm	inches
912	1800	467	18.380
963	1900	478	18.800
1010	2000	488	19.220

Table 40 – Mandrel Diameters for Cold Bend Test – Multiple-Conductor Cables

(See Clauses 5.11.1.1 and 8.11.1.2 and Annex B)

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

Table 41 – Deformation Load Requirements

(See Clause 5.12.1 and Annex B)

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 AWG	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 kcmil	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 42 – Test Potential for Spark Test

(See Clauses 5.23.2 and 7.4.1)

Conductor size		RMS test potential in kV	
mm²	AWG or kcmil	600 V	1000 V or 2000 V
2.08 – 5.26	14 – 10 AWG	7.5	10.0
8.37 – 33.6	8 – 2	10.0	12.5
42.4 – 107	1 – 4/0	12.5	15.0
Larger than 107 – 253	Larger than 4/0 – 500 kcmil	15.0	17.5
Larger than 253 – 507	Larger than 500 – 1000	17.5	20.0
Larger than 507 – 1010	Larger than 1000 – 2000	20.0	22.5

Table 43 – A-C Test Voltages for Dielectric Strength Test

(See Clause 5.24.1)

Conductor size		1 min test voltage, kV	
mm²	AWG or kcmil	600 V	1000 V or 2000 V
2.08 – 5.26	14 – 10 AWG	3.0	6.0
8.37 – 33.6	8 – 2	3.5	7.5
42.4 – 107	1 – 4/0	4.0	9.0
Larger than 107 – 253	Larger than 4/0 – 500 kcmil	5.0	10.0
Larger than 253 – 507	Larger than 500 – 1000	6.0	11.0
Larger than 507 – 1010	Larger than 1000 – 2000	7.0	13.5

Table 44 – Minimum Insulation Resistance at 15°C – R90, RW75, RW90, RWU75, and RWU90 – for All Materials Except R90 Silicone

(See Clause 5.25.1 and Annex B)

Conductor size		RWU90, RWU75 with XL insulation		RWU75 and RWU90 (1000 V only) with EP insulation, and RW75, RW90, and R90 of all materials				R90, RW75 and RW90 of all materials	
		1000 V		600 V		1000 V		2000 V	
mm²	AWG or kcmil	GΩ·m	MΩ·1000 ft	GΩ·m	MΩ·1000 ft	GΩ·m	MΩ·1000 ft	GΩ·m	MΩ·1000 ft
	AWG								
2.08	14	2500	8200	1550	5090	2100	6890	2540	8330
3.31	12	2100	6890	1300	4270	1750	5740	2180	7150
5.26	10	1800	5910	1050	3440	1450	4760	1850	6070
8.37	8	1900	6230	1200	3940	1200	3940	1750	5740
13.3	6	1600	5250	1000	3280	1300	4270	1470	4820
21.2	4	1350	4430	850	2790	1050	3440	1230	4040
26.7	3	1200	3940	770	2530	980	3220	1120	3670
33.6	2	1100	3610	690	2260	890	2920	1020	3350
42.4	1	1150	3770	740	2430	1000	3280	1130	3710
53.5	1/0	1050	3440	670	2200	920	3020	1030	3380
67.4	2/0	970	3180	600	1970	840	2760	930	3050
85.0	3/9	880	2890	540	1770	760	2490	840	2760
107	4/0	800	2620	490	1610	680	2230	760	2490
	kcmil								
127	250	840	2760	530	1740	700	2300	810	2660
152	300	770	2530	480	1570	650	2130	750	2460
177	350	720	2360	450	1480	600	1970	700	2300
203	400	680	2230	420	1380	570	1870	660	2170
253	500	620	2030	380	1250	510	1670	600	1970
304	600	640	2100	420	1380	470	1540	620	2030
355	700	590	1940	400	1310	440	1440	580	1900
380	750	580	1900	380	1250	430	1410	560	1840
405	800	560	1840	370	1210	410	1350	550	1800
456	900	530	1740	350	1150	390	1280	520	1710
507	1000	510	1670	330	1080	370	1210	490	1610
608	1250	510	1670	350	1150	410	1350	510	1670
760	1500	470	1540	320	1050	370	1210	470	1540

Table 44 – Minimum Insulation Resistance at 15°C – R90, RW75, RW90, RWU75, and RWU90 – for All Materials Except R90 Silicone Continued on Next Page

Table 44 – Minimum Insulation Resistance at 15°C – R90, RW75, RW90, RWU75, and RWU90 – for All Materials Except R90 Silicone Continued

Conductor size		RWU90, RWU75 with XL insulation		RWU75 and RWU90 (1000 V only) with EP insulation, and RW75, RW90, and R90 of all materials				R90, RW75 and RW90 of all materials	
		1000 V		600 V		1000 V		2000 V	
mm^2	AWG or kcmil	GΩ·m	MΩ·1000 ft	GΩ·m	MΩ·1000 ft	GΩ·m	MΩ·1000 ft	GΩ·m	MΩ·1000 ft
887	1750	430	1410	300	980	350	1150	440	1440
1010	2000	410	1350	280	920	320	1050	410	1350

Notes:

1) K = 6000.

2) The insulation resistance of finished wires or cables having a thermoset or thermoplastic covering shall not be less than 60 percent of that specified above.

Table 45 – Minimum Insulation Resistance at 15°C of 600 V Types RWH-2, RHH, R90 Silicone, RHW, XHHW-2, XHHW, XHH, SA, SF, and SIS Wires and Cables

(See Clause 5.25.1 and Annex B)

Conductor size		Type SA and SF wire with insulation as indicated in Table 13		Type XHHW-2, XHHW, and XHH wires with insulation as indicated in Table 12		Type SIS wire EPCV, CP, CPE and XL insulation as indicated in Table 14		Type RHW-2, RHH, R90 silicone, and RHW wires with insulation as indicated in Table 15							
								SBR/IIR, silicone rubber		CP, CPE		EP, EPCV, XL		Composite EP, XL, or EPCV inner with EPCV, XL, CPE, CPE outermost	
mm^2	(AWG or kcmil)	GΩ·m	MΩ ·1000 ft	GΩ·m	MΩ ·1000 ft	GΩ·m	MΩ ·1000 ft	GΩ·m	MΩ ·1000 ft	GΩ·m	MΩ ·1000 ft	GΩ·m	MΩ ·1000 ft	GΩ·m	MΩ ·1000 ft
	AWG														
2.08	14	220	710	810	2660	80	270	430	1420	110	360	1080	3550	1080	3550
3.31	12	180	610	680	2240	70	220	370	1210	90	300	920	3030	920	3030
5.26	10	150	510	560	1850	55	190	310	1020	75	250	770	2540	770	2540
8.36	8	160	530	650	2130	65	210	320	1060	80	270	810	2650	810	2650
13.3	6	140	450	540	1780	55	180	270	900	70	220	680	2240	810	2650
21.2	4	110	370	450	1460	45	150	230	740	55	190	560	1850	680	2220
26.7	3	100	340	400	1330	40	130	210	680	50	170	520	1690	620	2030
33.6	2	95	310	370	1200	35	120	190	610	45	150	470	1530	560	1850
42.4	1	110	350	390	1280	40	130	210	700	55	180	530	1750	640	2100
53.5	1/0	95	320	350	1150	35	120	190	640	50	160	490	1590	580	1910
67.4	2/0	90	290	320	1040	30	100	180	580	45	150	440	1450	530	1740
85.0	3/0	85	260	290	940	30	95	160	520	40	130	400	1300	480	1580
107	4/0	70	240	260	850	25	85	140	470	45	120	460	1180	440	1450
	kcmil														
127	250	80	255	280	910	–	–	160	510	40	130	390	1270	510	1660
152	300	70	240	260	840	–	–	140	470	35	120	360	1170	470	1540
177	350	65	220	240	780	–	–	130	440	35	110	340	1100	440	1440

Table 45 – Minimum Insulation Resistance at 15°C of 600 V Types RWH-2, RHH, R90 Silicone, RHW, XHHW-2, XHHW, XHH, SA, SF, and SIS Wires and Cables Continued on Next Page

Table 45 – Minimum Insulation Resistance at 15°C of 600 V Types RWH-2, RHH, R90 Silicone, RHW, XHHW-2, XHHW, XHH, SA, SF, and SIS Wires and Cables Continued

Conductor size		Type SA and SF wire with insulation as indicated in Table 13		Type XHHW-2, XHHW, and XHH wires with insulation as indicated in Table 12		Type SIS wire EPCV, CP, CPE and XL insulation as indicated in Table 14		Type RHW-2, RHH, R90 silicone, and RHW wires with insulation as indicated in Table 15							
								SBR/IIR, silicone rubber		CP, CPE		EP, EPCV, XL		Composite EP, XL, or EPCV inner with EPCV, XL, CPE, CPE outermost	
mm²	(AWG or kcmil)	GΩ·m	MΩ ·1000 ft	GΩ·m	MΩ ·1000 ft	GΩ·m	MΩ ·1000 ft	GΩ·m	MΩ ·1000 ft	GΩ·m	MΩ ·1000 ft	GΩ·m	MΩ ·1000 ft	GΩ·m	MΩ ·1000 ft
203	400	65	210	220	730	–	–	130	410	30	100	320	1040	420	1360
226	450	60	200	210	700	–	–	120	390	30	100	300	980	400	1290
253	500	55	190	200	660	–	–	110	370	30	95	290	940	380	1240
279	550	60	200	230	770	–	–	120	410	30	100	310	1020	400	1300
304	600	60	200	220	740	–	–	120	390	30	100	300	980	380	1250
329	650	60	190	220	710	–	–	120	380	30	95	290	950	370	1210
355	700	55	180	210	690	–	–	110	370	30	90	280	920	360	1170
380	750	55	180	200	670	–	–	110	360	25	90	270	890	350	1140
405	800	55	170	200	640	–	–	110	350	25	85	260	863	340	1110
456	900	50	160	190	610	–	–	100	330	25	80	250	820	320	1050
507	1000	50	160	180	580	–	–	95	310	25	80	240	780	310	1000
557	1100	50	170	200	650	–	–	100	340	25	80	260	840	–	–
608	1200	50	160	190	630	–	–	100	320	25	80	240	800	–	–
633	1250	50	160	190	610	–	–	95	320	25	80	240	790	–	–
659	1300	50	160	180	600	–	–	95	310	25	80	240	780	–	–
709	1400	45	150	180	580	–	–	90	300	25	75	230	750	–	–
760	1500	45	150	170	560	–	–	90	290	20	75	220	730	–	–
811	1600	45	140	170	550	–	–	85	280	20	70	210	700	–	–
709	1700	40	140	160	530	–	–	85	270	20	70	210	690	–	–
887	1750	40	140	160	520	–	–	85	270	20	70	210	680	–	–
912	1800	40	130	160	520	–	–	80	270	20	65	200	670	–	–
963	1900	40	130	150	500	–	–	80	260	20	65	200	650	–	–
1010	2000	40	130	150	490	–	–	75	260	20	65	190	190	–	–

Table 46 – Minimum Insulation Resistance at 15°C of 2000 V Types RHW-2, RHH, RHW Wires and Cables

(See Clause 5.25.1 and Annex B)

Conductor size		Insulation as indicated in Table 17									
		EP, EPCV, XL		CP, CPE		SBR/IIR		Composite EP, XL, or EPCV inner with EPCV, XL, CP, CPE outermost		RHH or RHW with silicone rubber	
mm^2	AWG or kcmil	GΩ·m	MΩ·1000 ft	GΩ·m	MΩ·1000 ft	GΩ·m	MΩ·1000 ft	GΩ·m	MΩ·1000 ft	GΩ·m	MΩ·1000 ft
	AWG										
2.08	14	1310	4300	160	510	630	2050	1310	4300	520	1720
3.31	12	1130	3710	140	450	550	1790	1130	3710	450	1480
5.26	10	950	3120	120	380	470	1530	950	3120	380	1250
8.37	8	910	2980	100	330	400	1310	1040	3420	360	1190
13.3	6	770	2520	95	320	380	1260	890	2910	310	1010
21.2	4	640	2100	80	270	320	1060	740	2440	250	840
26.7	3	590	1920	75	240	300	980	680	2240	230	770
33.6	2	530	1750	70	220	270	890	620	2040	210	700
42.4	1	590	1930	70	230	280	910	690	2260	230	770
53.5	1/0	530	1750	65	210	250	830	630	2060	210	700
67.4	2/0	490	1600	55	190	230	750	570	1880	190	640
85.0	3/0	440	1450	50	170	210	680	520	1710	170	580
107	4/0	400	1310	45	160	190	620	470	1550	160	520
	kcmil										
127	250	420	1390	50	160	200	640	540	1770	170	550
152	300	390	1280	45	150	180	600	500	1640	150	510
177	350	370	1200	40	140	170	560	470	1530	150	480
203	400	350	1130	40	130	160	530	440	1450	140	450
226	450	330	1070	40	130	150	500	420	1380	130	430
253	500	310	1030	35	120	150	480	400	1320	140	410
279	550	340	1100	40	130	150	510	420	1380	135	440
304	600	320	1060	35	120	150	490	410	1330	130	420
329	650	310	1030	35	120	140	470	390	1280	120	410
355	700	300	990	35	110	140	460	380	1240	120	390
380	750	290	960	35	110	130	440	370	1210	110	380
405	800	290	930	35	110	130	430	360	1170	110	370
456	900	270	890	30	100	120	410	340	1110	110	350
507	1000	260	850	30	95	120	390	320	1060	100	340
557	1100	275	905	30	90	110	360	390	1295	110	370
608	1200	265	865	25	85	105	345	380	1250	110	360
633	1250	260	850	25	85	105	340	370	1225	100	350
659	1300	255	840	25	85	100	335	365	1205	100	340
709	1400	245	810	25	80	100	325	355	1165	100	330
760	1500	240	785	25	80	95	315	345	1130	95	320
811	1600	230	760	20	75	90	305	335	1100	95	310
861	1700	225	740	20	74	90	295	325	1070	90	300
887	1750	220	730	20	70	90	290	320	1055	90	300
912	1800	220	720	20	70	90	290	315	1040	90	300
963	1900	215	705	20	70	85	280	310	1020	90	300
1010	2000	210	685	20	70	85	275	300	990	85	290

Table 47 – Thicknesses of Overall Jacket on Down-Well Water Pump Cable

(See Clauses 7.2.4 and 7.2.6.2 and Annex B)

Calculated diameter of cable under jacket		Thickness of jacket			
		Average		Minimum	
mm	inches	mm	mils	mm	mils
Up to 17.8	Up to 0.700	1.14	45	0.91	36
17.9 – 26.7	0.701 – 1.051	1.52	60	1.21	48
26.8 – 38.1	1.052 – 1.500	2.03	80	1.62	64
38.2 – 50.1	1.501 – 1.972	2.41	95	1.93	76
50.2 – 76.2	1.973 – 3.000	2.79	110	2.23	88
76.3 and larger	3.001 and larger	3.18	125	2.54	100
Note: *For flat cable, the calculated major core dimension under the jacket shall be used to determine the jacket thickness required.*					

Table 48 – Tray Loading for Circular Cables Smaller Than 13 mm (0.51 inch) Diameter

(See Clause 8.14.7.2.13.1 and Annex B)

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 49 – Tray Loading for Circular Cables 13 mm (0.51 inch) Diameter and Larger

(See Clause 8.14.7.2.13.1)

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 50 – Conversion of Percent Transmittance to Specific Optical Density

(See Clause 8.14.8.1.6)

Parameters and range of transmittance (T)	Filter position →	0	1	2	3	4	5	6	7	8	9
	Percent T ↓	Specific optical density (D)									
Multiplier 100 with ND-2 filter	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
100 at 10 percent T	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
Multiplier 10 with ND-2 filter	$90x10^{-1}$	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
10 at 1 percent T	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 1 with ND-2 filter	$90x10^{-2}$	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
1 at 0.1 percent T	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	$90x10^{-3}$	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
0.1 at 0.01 percent T	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	$90x10^{-4}$	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
0.01 at 0.001 percent T	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

Table 50 – Conversion of Percent Transmittance to Specific Optical Density Continued on Next Page

Table 50 – Conversion of Percent Transmittance to Specific Optical Density Continued

Parameters and range of transmittance (T)	Filter position →	0	1	2	3	4	5	6	7	8	9
	Percent T ↓	Specific optical density (D)									
	30	597	595	593	592	590	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	90×10^{-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 51 – Worksheet for Determination of Physical Properties of Insulation and Jackets Having Characteristics Different from Those Indicated in Table 11 or 20 [a]

(See Clauses H.2 and H.3)

Condition of specimens at time of measurement	Minimum ultimate elongation (25 mm [1 inch] bench marks)	Minimum tensile strength
Unaged	b	b
Insulation and jacket rated 90°C Aged in a full-draft circulating-air oven for 168 h at 121 ±1°C	b	b
Insulation and jacket rated 75°C Aged in a full-draft circulating-air oven for 10 d at 100 ±1°C	b	b

[a] See Clause 4.10.1, which establishes the initial values of tensile strength and elongation as follows:

i) Insulations without jackets or additional coverings, outer layer of a composite insulation, and jackets: initial absolute minimum tensile strength not less than 6.8 MPa (1000 lbf/in^2); absolute minimum elongation of 100 percent before aging; and

ii) Insulations with jackets or additional coverings, inner layer of composite insulation: initial absolute minimum tensile strength not less than 3.4 MPa (500 lbf/in^2); absolute minimum elongation of 100 percent before aging.

[b] Values as determined in accordance with Clause 8.22.4 for the particular insulation or jacket referenced in Clause 4.10.

Table 52 – Maximum Center-to-Center Spacing of Bead Chains

(See Clause 8.23.1.3)

Diameter of a bead		Longitudinal spacing within each row		Transverse spacing between rows			
				Chains staggered		Chains not staggered	
mm	inch	mm	inch	mm	inch	mm	inch
5.0	3/16	13	1/2	13	1/2	10	3/8
2.5	3/32	The chains shall be staggered and shall touch one another in the longitudinal and transverse directions					
Note: *Diameter and spacings other than indicated are acceptable if investigation shows that the chains contact an equal or greater area of the outer surface of the wire.*							

Table 53 – Formula for Maximum Speed of Wire in Terms of Electrode Length, L

(See Clause 8.23.2.3)

Nominal supply frequency (Hz)	Meters per minute (L in millimeters)	Feet per minute (L in inches)
50	$0.333L_{mm}$	$27.8L_{in}$
60	$0.400L_{mm}$	$33.3L_{in}$
100	$0.667L_{mm}$	$55.6L_{in}$
400	$2.67L_{mm}$	$222L_{in}$
1000	$6.67L_{mm}$	$556L_{in}$
3000	$20.0L_{mm}$	$1667L_{in}$
4000	$26.7L_{mm}$	$2222L_{in}$

Table 54 – Insulation Resistance Temperature-Correction Factor

(See Clauses 5.25.1, 8.25.1, 8.25.2.2, and Annex I)

Temperature	Coefficient for 1°C									
°C	1.04	1.06	1.08	1.10	1.12	1.14	1.16	1.18	1.20	1.22
5.0	0.68	0.56	0.46	0.39	0.32	0.27	0.23	0.19	0.16	0.14
5.5	0.69	0.57	0.48	0.40	0.34	0.29	0.24	0.21	0.18	0.15
6.0	0.70	0.59	0.50	0.42	0.36	0.31	0.26	0.23	0.19	0.17
6.5	0.72	0.61	0.54	0.44	0.38	0.33	0.28	0.24	0.21	0.18
7.0	0.73	0.63	0.56	0.47	0.40	0.35	0.31	0.27	0.23	0.20
7.5	0.75	0.65	0.58	0.49	0.43	0.37	0.33	0.29	0.25	0.23
8.0	0.76	0.67	0.61	0.51	0.45	0.40	0.35	0.31	0.28	0.25
8.5	0.77	0.68	0.62	0.54	0.48	0.43	0.38	0.34	0.31	0.27
9.0	0.79	0.70	0.63	0.56	0.51	0.46	0.41	0.37	0.33	0.30
9.5	0.81	0.73	0.65	0.59	0.54	0.49	0.44	0.40	0.37	0.33
10.0	0.82	0.75	0.68	0.62	0.57	0.52	0.48	0.44	0.40	0.37
10.5	0.84	0.77	0.71	0.65	0.60	0.55	0.51	0.47	0.44	0.41
11.0	0.85	0.79	0.74	0.68	0.64	0.59	0.55	0.52	0.48	0.45
11.5	0.87	0.82	0.76	0.72	0.67	0.63	0.59	0.56	0.53	0.50
12.0	0.89	0.84	0.79	0.75	0.71	0.67	0.64	0.61	0.58	0.55
12.5	0.91	0.86	0.82	0.79	0.75	0.72	0.69	0.66	0.63	0.61
13.0	0.92	0.89	0.86	0.83	0.80	0.77	0.74	0.72	0.69	0.67
13.5	0.94	0.92	0.89	0.87	0.84	0.82	0.80	0.78	0.76	0.74
14.0	0.96	0.94	0.93	0.91	0.89	0.88	0.86	0.85	0.83	0.82
14.5	0.98	0.97	0.96	0.95	0.94	0.94	0.93	0.92	0.91	0.91
15.0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
15.5	1.02	1.03	1.04	1.05	1.06	1.07	1.08	1.09	1.10	1.10

Table 54 – Insulation Resistance Temperature-Correction Factor Continued on Next Page

Table 54 – Insulation Resistance Temperature-Correction Factor Continued

Temperature	Coefficient for 1°C									
°C	1.04	1.06	1.08	1.10	1.12	1.14	1.16	1.18	1.20	1.22
16.0	1.04	1.06	1.08	1.10	1.12	1.14	1.16	1.18	1.20	1.22
16.5	1.06	1.09	1.12	1.15	1.19	1.22	1.25	1.28	1.31	1.35
17.0	1.08	1.12	1.17	1.21	1.25	1.30	1.35	1.39	1.44	1.49
17.5	1.10	1.16	1.21	1.27	1.33	1.39	1.45	1.51	1.58	1.64
18.0	1.12	1.19	1.26	1.33	1.40	1.48	1.56	1.64	2.73	1.82
18.5	1.15	1.23	1.31	1.40	1.49	1.58	1.68	1.78	1.89	2.01
19.0	1.17	1.26	1.36	1.46	1.57	1.69	1.81	1.94	2.07	2.22
19.5	1.19	1.30	1.41	1.54	1.67	1.80	1.95	2.11	2.27	2.45
20.0	1.22	1.34	1.47	1.61	1.76	1.93	2.10	2.29	2.49	2.70
20.5	1.24	1.38	1.53	1.69	1.87	2.96	2.26	2.49	2.73	2.99
21.0	1.27	1.42	1.59	1.77	1.97	2.19	2.44	2.7	2.99	3.30
21.5	1.29	1.46	1.65	1.86	2.09	2.34	2.62	2.93	3.27	3.64
22.0	1.32	1.50	1.71	1.95	2.21	2.50	2.83	3.19	3.58	4.02
22.5	1.34	1.55	1.78	2.04	2.34	2.67	3.04	3.46	3.93	4.44
23.0	1.37	1.59	1.85	2.14	2.48	2.85	3.28	3.76	4.30	4.91
23.5	1.40	1.64	1.92	2.25	1.62	3.05	3.53	4.08	4,71	5.42
24.0	1.42	1.69	2.00	2.36	2.77	3.35	3.80	4.44	5.16	5.99
24.5	1.45	1.74	2.08	2.47	2.93	3.47	4.10	4.82	5.65	6.61
25.0	1.48	1.79	2.16	2.59	3.11	3.71	4.41	5.23	6.19	7.30
25.5	1.51	1.84	2.24	2.72	3.29	3.96	4.75	5.69	6.78	8.07
26.0	1.54	1.90	2.33	2.85	3.48	4.23	5.12	6.18	7.43	8.91
26.5	1.57	1.95	2.2	2.99	3.68	4.51	5.51	6.71	8.14	9.84
27.0	1.60	2.01	2.52	3.14	3.90	4.82	5.94	7.29	8.92	10.87
27.5	1.63	2.07	2.62	3.29	4.12	5.14	6.39	7.92	9.77	12.01
28.0	1.67	2.13	2.72	3.45	4.36	5.49	6.89	8.60	10.70	13.26
28.5	1.70	2.20	2.83	3.62	4.62	5.86	7.42	9.34	11.72	14.65
29.0	1.73	2.26	2.94	3.80	4.89	6.26	7.99	10.15	12.84	16.18
29.5	1.77	2.33	3.05	3.98	5.17	6.69	8.60	11.02	14.06	17.87
30.0	1.80	2.40	3.17	4.18	5.47	7.14	9.27	11.97	15.41	19.74
30.5	1.84	2.47	3.30	4.38	5.79	7.62	9.98	13.01	16.88	21.81
31.0	1.87	2.54	3.43	4.59	6.13	8.14	10.75	14.13	18.49	24.09
31.5	1.91	2.62	3.56	4.82	6.49	8.69	11.58	15.35	20.25	26.60
32.0	1.95	2.69	3.70	5.05	6.87	9.28	12.47	16.67	22.19	29.38
32.5	1.99	2.77	3.85	5.30	7.27	9.90	13.43	18.11	24.30	32.46
33.0	2.03	2.85	4.00	5.56	7.69	10.58	14.46	19.67	26.62	35.85
33.5	2.07	2.94	4.15	5.83	8.14	11.29	15.58	21.37	29.16	39.60
34.0	2.11	3.03	4.32	6.12	8.61	12.06	16.78	23.21	31.95	43.74
34.5	2.15	3.12	4.49	6.41	9.11	12.87	18.07	25.22	35.00	48.31
35.0	2.19	3.21	4.66	6.73	9.65	13.74	19.46	27.39	38.34	53.36

Figures

Figure 1 – Connection of Jigs (Duplex Receptacles)

(See Clause 8.3.2.1)

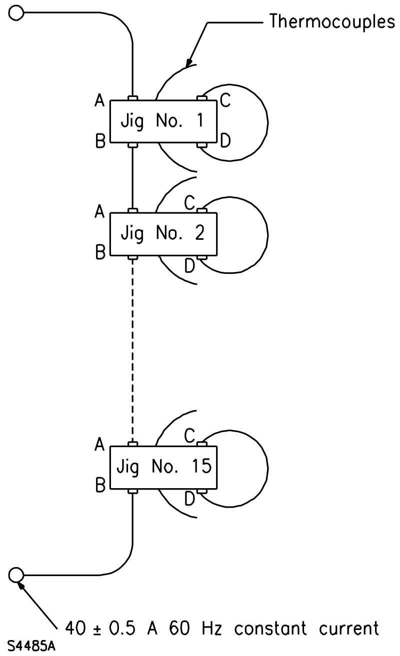
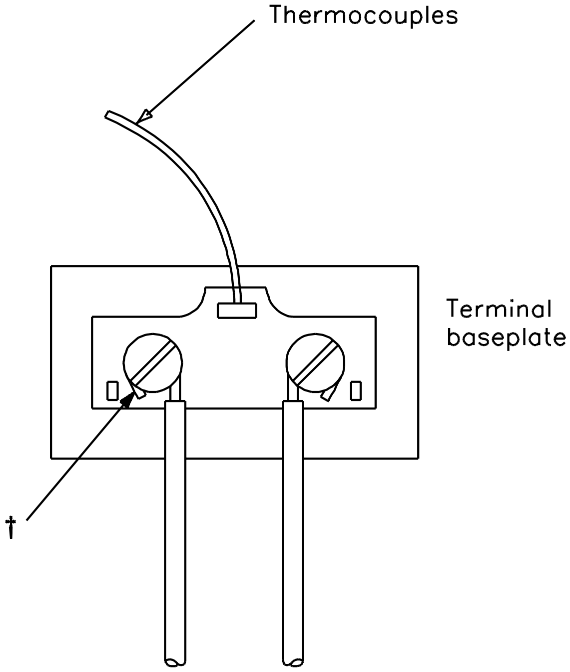


Figure 2 – Detail of the Connection of Jigs (Duplex Receptacles)

(See Clause 8.3.2.1)



The thermocouple is passed through the slot and wound around the break-off tab, and is cemented to the break-off tab with a thermouple cement. [a]

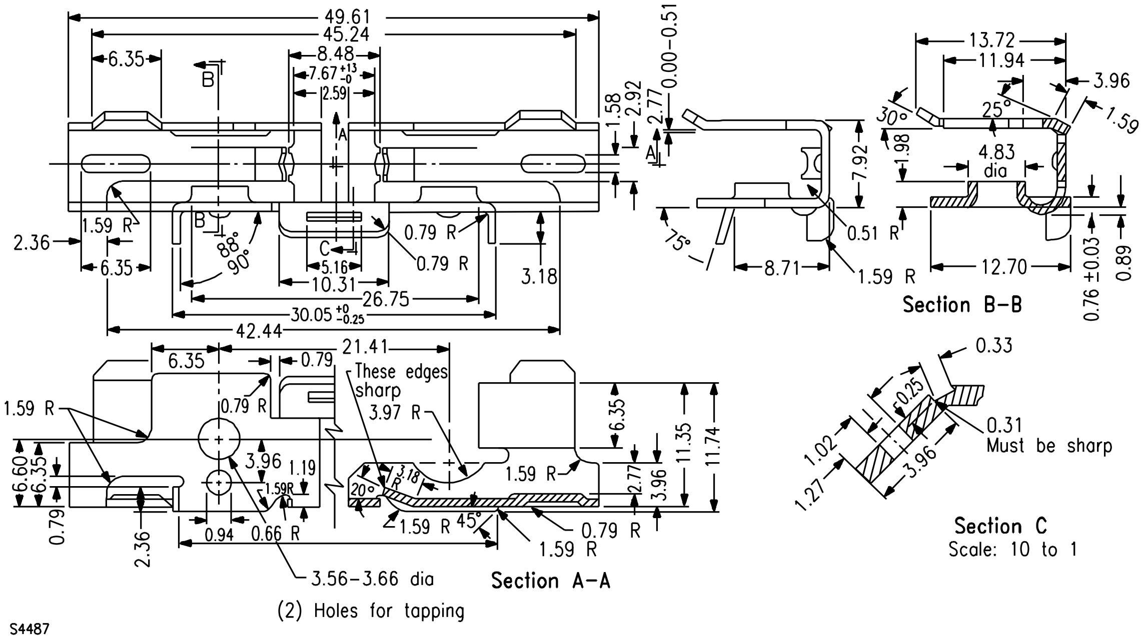
[a] Mixture of kaolin and sodium silicate (water glass) in approximately equal proportions.

† The terminal screws on each terminal baseplate are to be connected by means of ACM conductors that are looped under the screwhead in opposite directions.

S4486A

Figure 3 – Terminal Baseplate (70/30 Brass)

(See Clause 8.3.2.1)



Notes:

1) Dimensions of the contacts used for receiving the blades of a plug have been omitted.

2) Dimensions are given in millimeters.

Figure 4 – Heavy-Duty Special Binding Head No. 8-32 UNC-2A TH'D Material: Steel-AISI 1010

(See Clause 8.3.2.1)

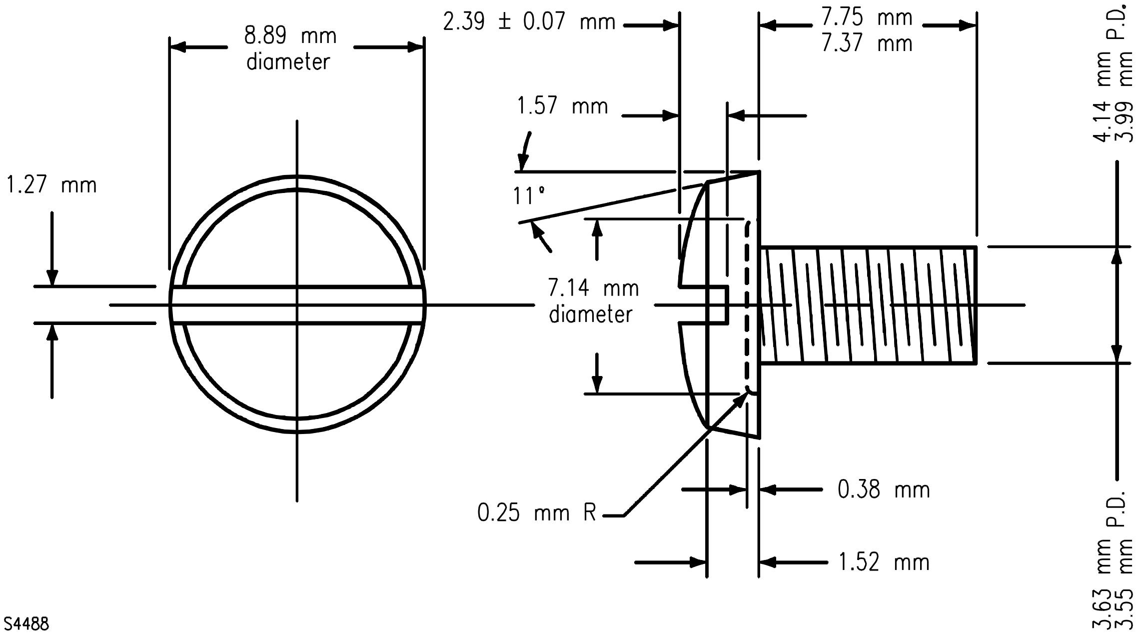
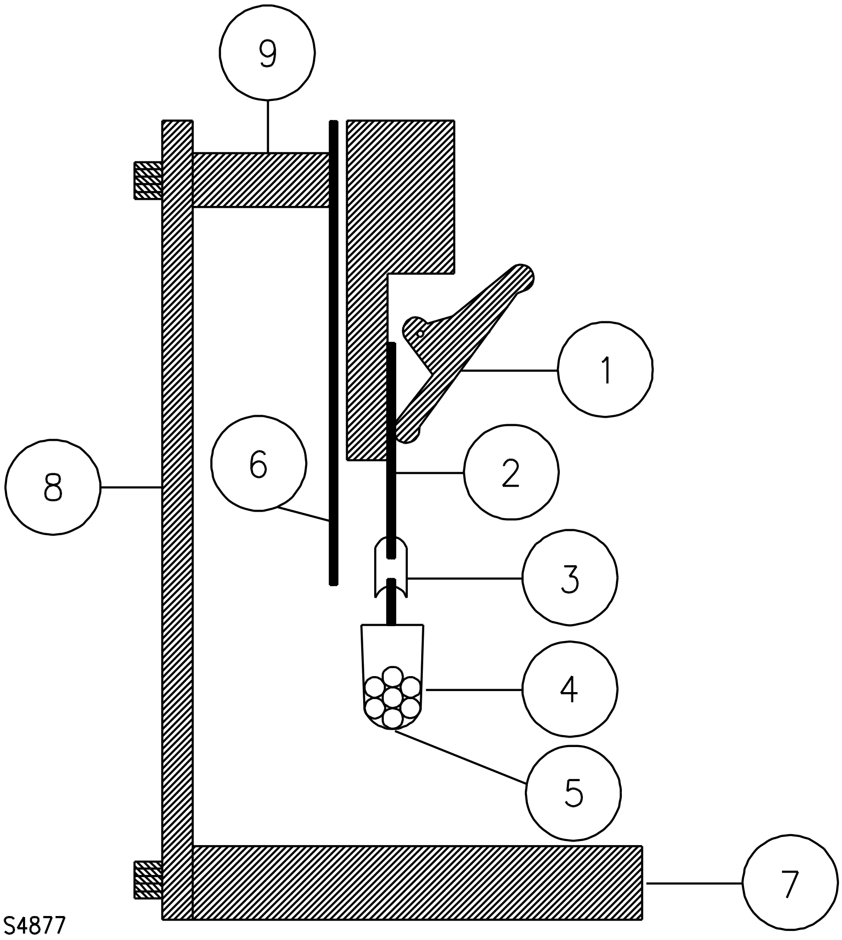


Figure 5 – Hot-Creep Test Specimen Support Apparatus

(See Clause 8.13.3.1)



Legend:

1 – Upper jaw or clamp

2 – Specimen

3 – Lower jaw or clamp

4 – Receptacle for weights

5 – Added weights

6 – Graduated scale

7 – Steel base

8 – Vertical support

9 – Support arm

Figure 6 – Arrangement of Components for Burning Particles (Dropping) Test

(See Clause 8.14.2.2)

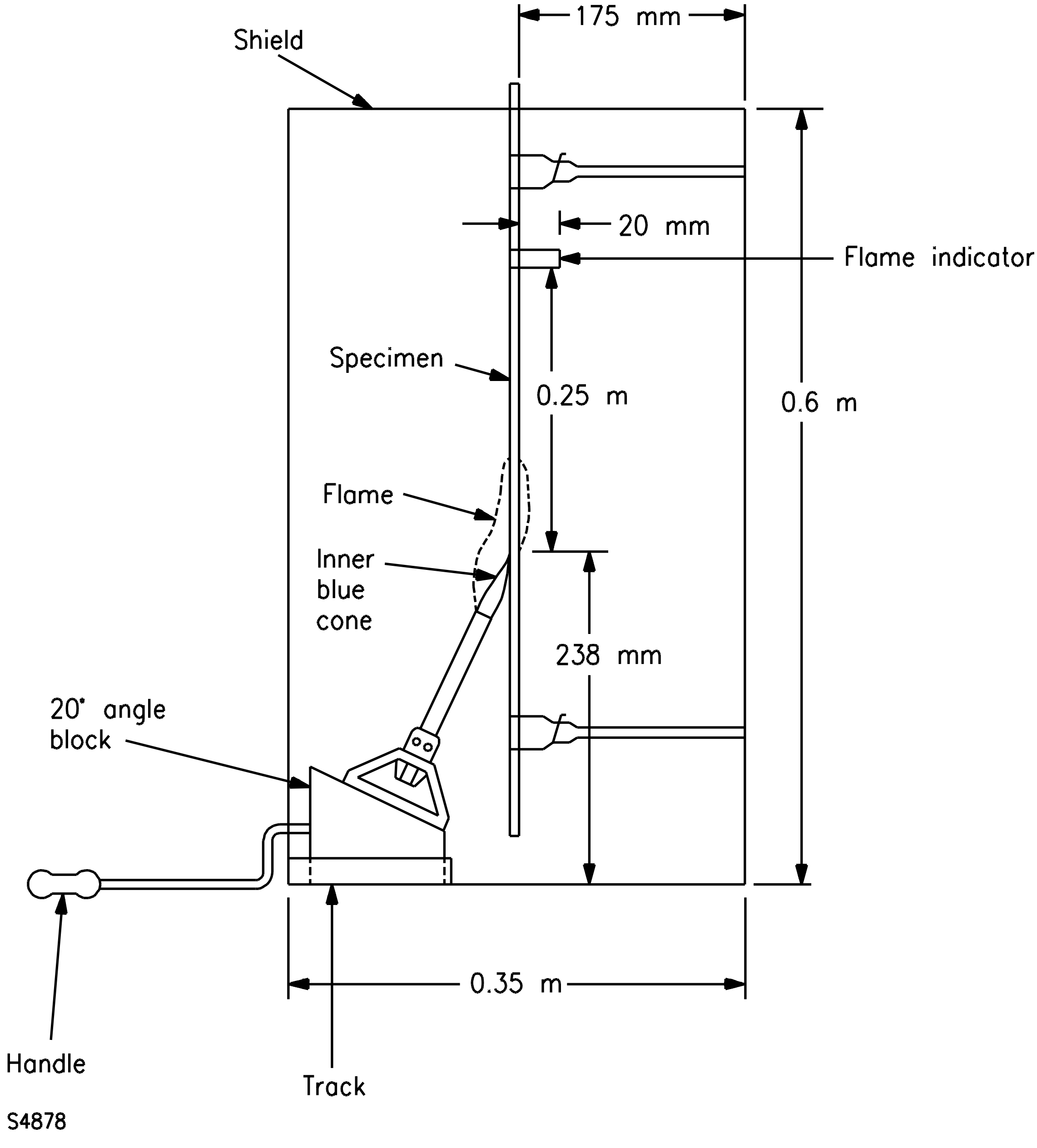
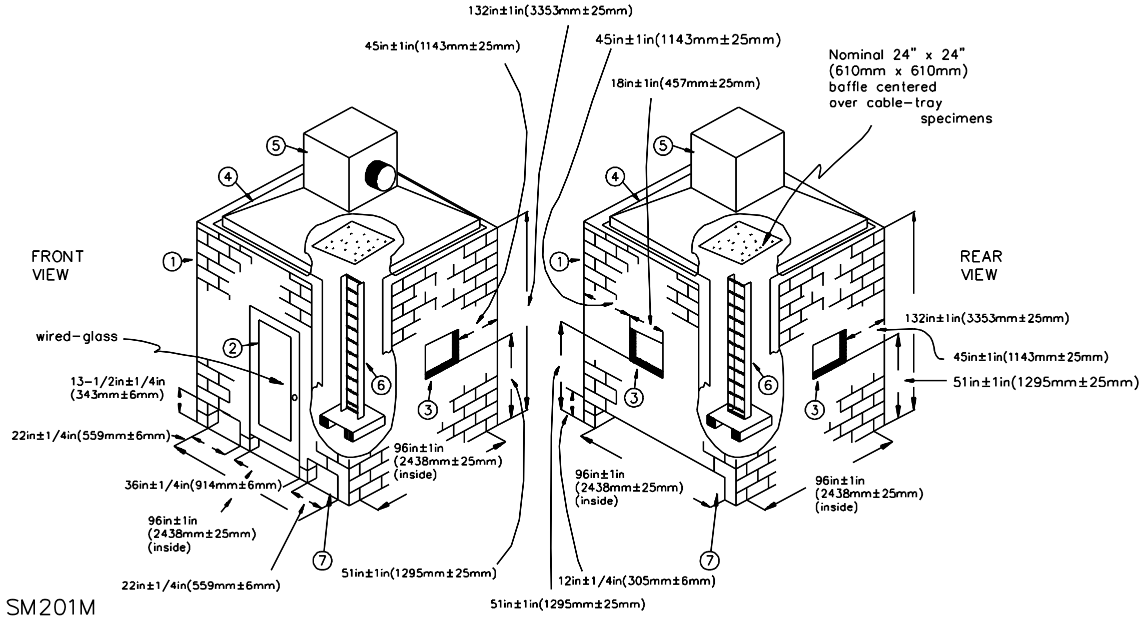


Figure 7 – Test Enclosure and Exhaust Duct

(See Clause 8.14.7.1.2)



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 inches x 16 inches x 6 inches).

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 inches x 84 inches)

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

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

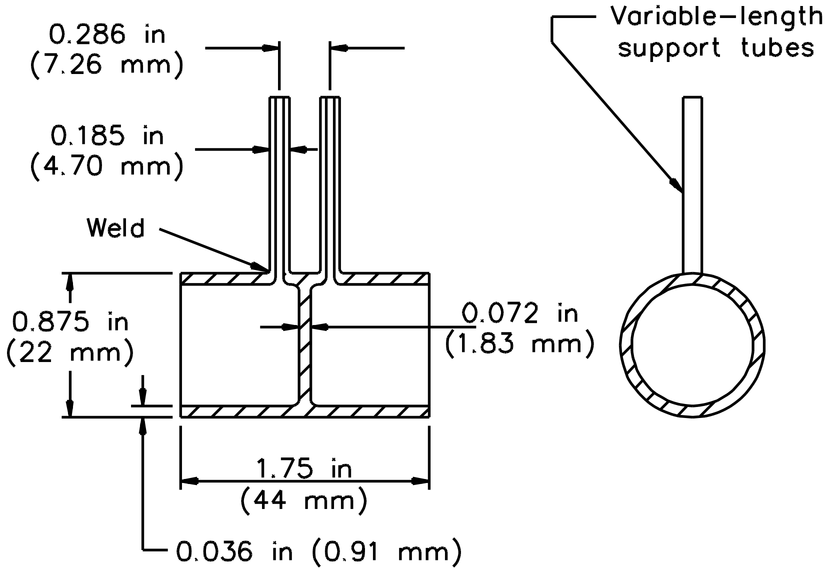
5 – Collection box with exhaust duct centered in one side. The box shall be a cube with each face a 914 mm (36 inch) square.

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

7 – Air-intake openings.

Figure 8 – Bi-directional Probe

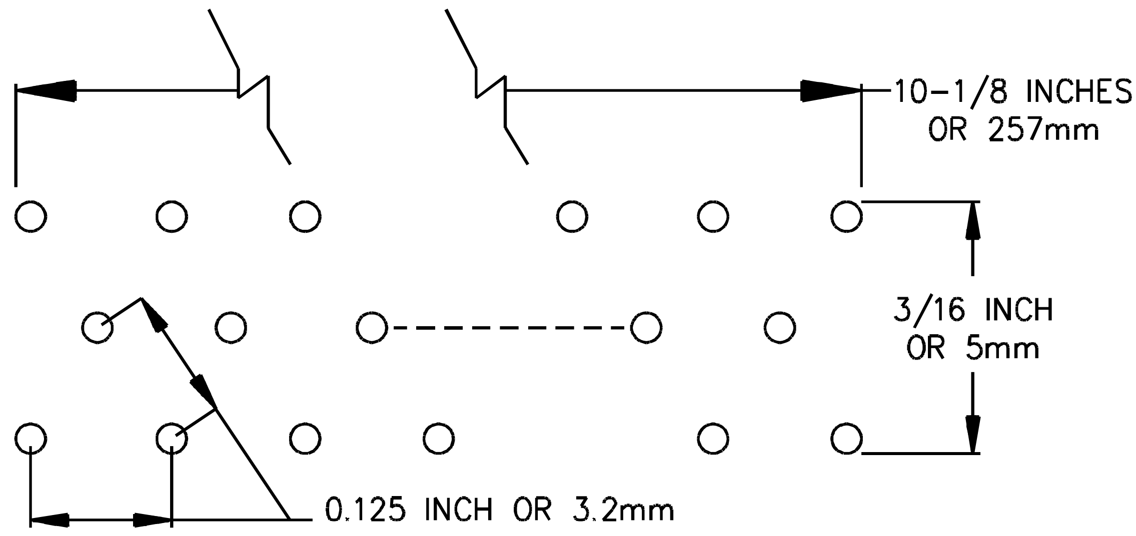
(See Clause 8.14.7.1.3)



S3355A

Figure 9 – Burner Holes

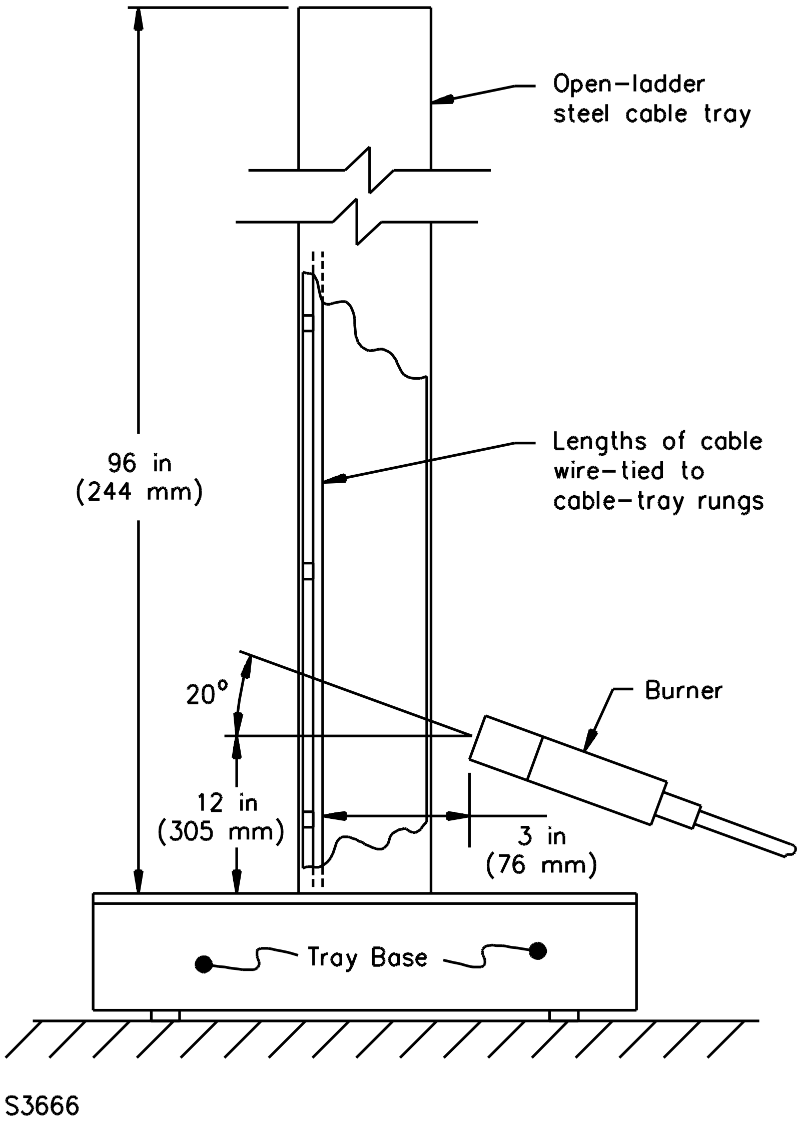
(See Clause 8.14.7.1.5)



SA1738

Figure 10 – Cable Tray, Specimen, and Burner Details

(See Clauses 8.14.7.2.4, 8.14.7.2.5, and 8.14.7.2.14.2)



Notes:

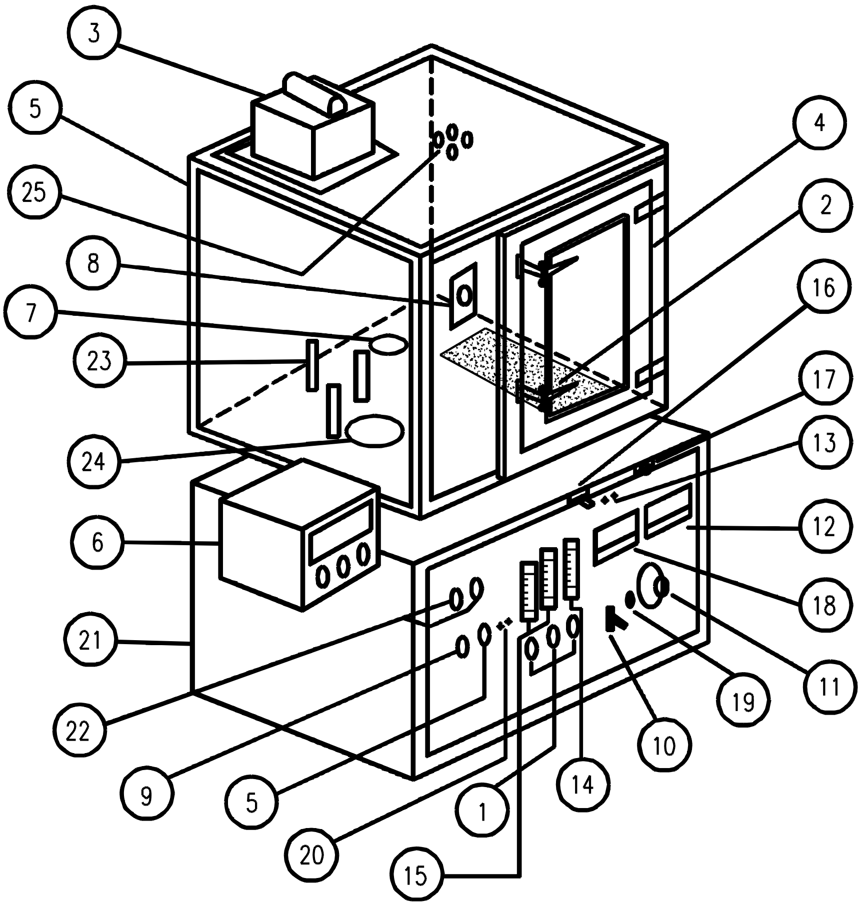
1) Cable tray: Nominally 305 mm wide x 76 mm deep x 2440 mm long (12 inches x 3 inches x 96 inches) with steel rungs nominally 25 ±6 mm (1 ±1/4 inch) wide and spaced 229 mm (9 inches) on centers.

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

3) Tray Base: Optional. 152 mm (6 inches) maximum height.

Figure 11 – Chamber for Smoke Emission Test

(See Clauses 8.14.8.1.2, 8.14.8.1.4, and 8.14.8.1.5.2)



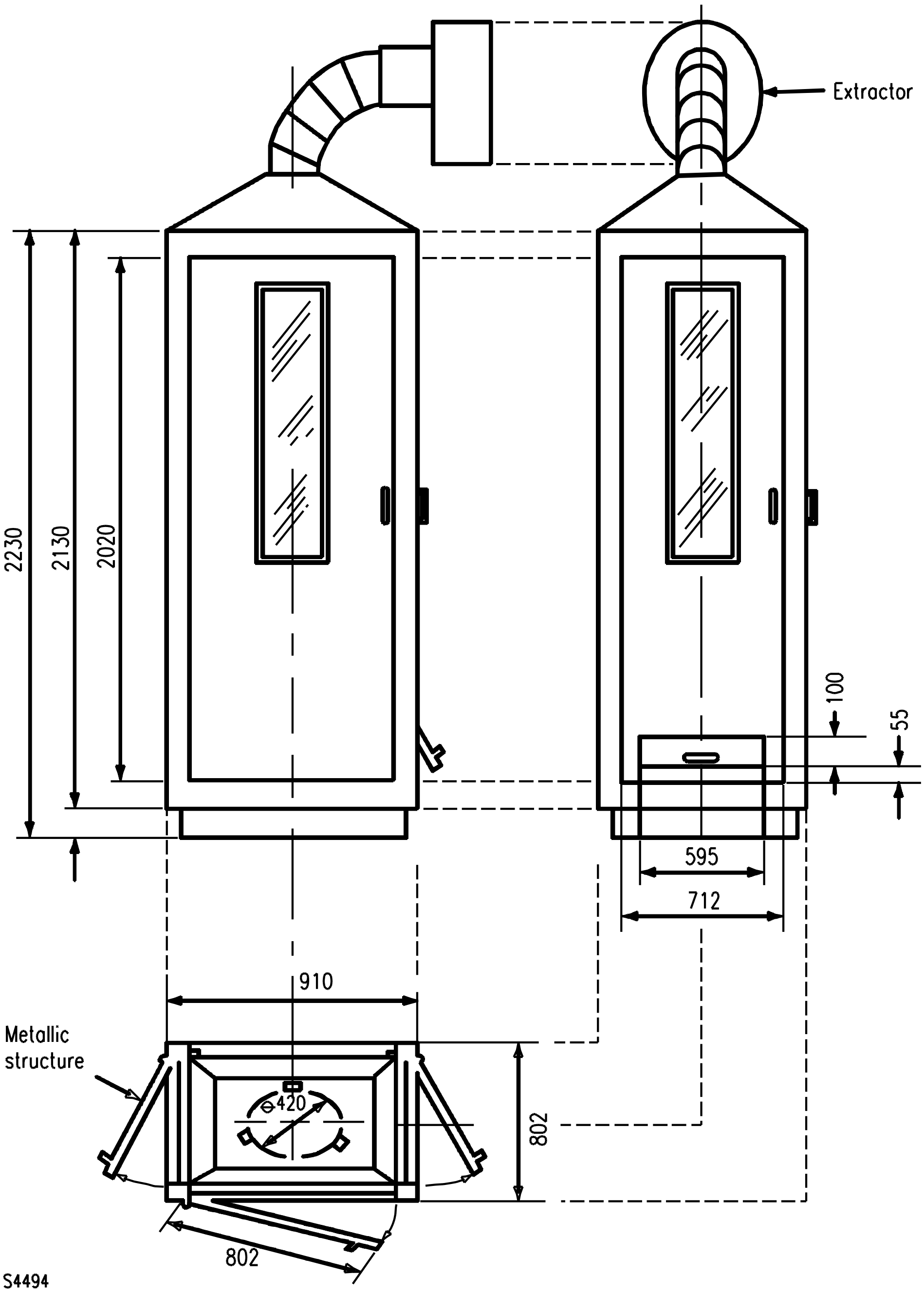
Legend:

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

S4493

Figure 12 – Chamber for Fire Propagation Test

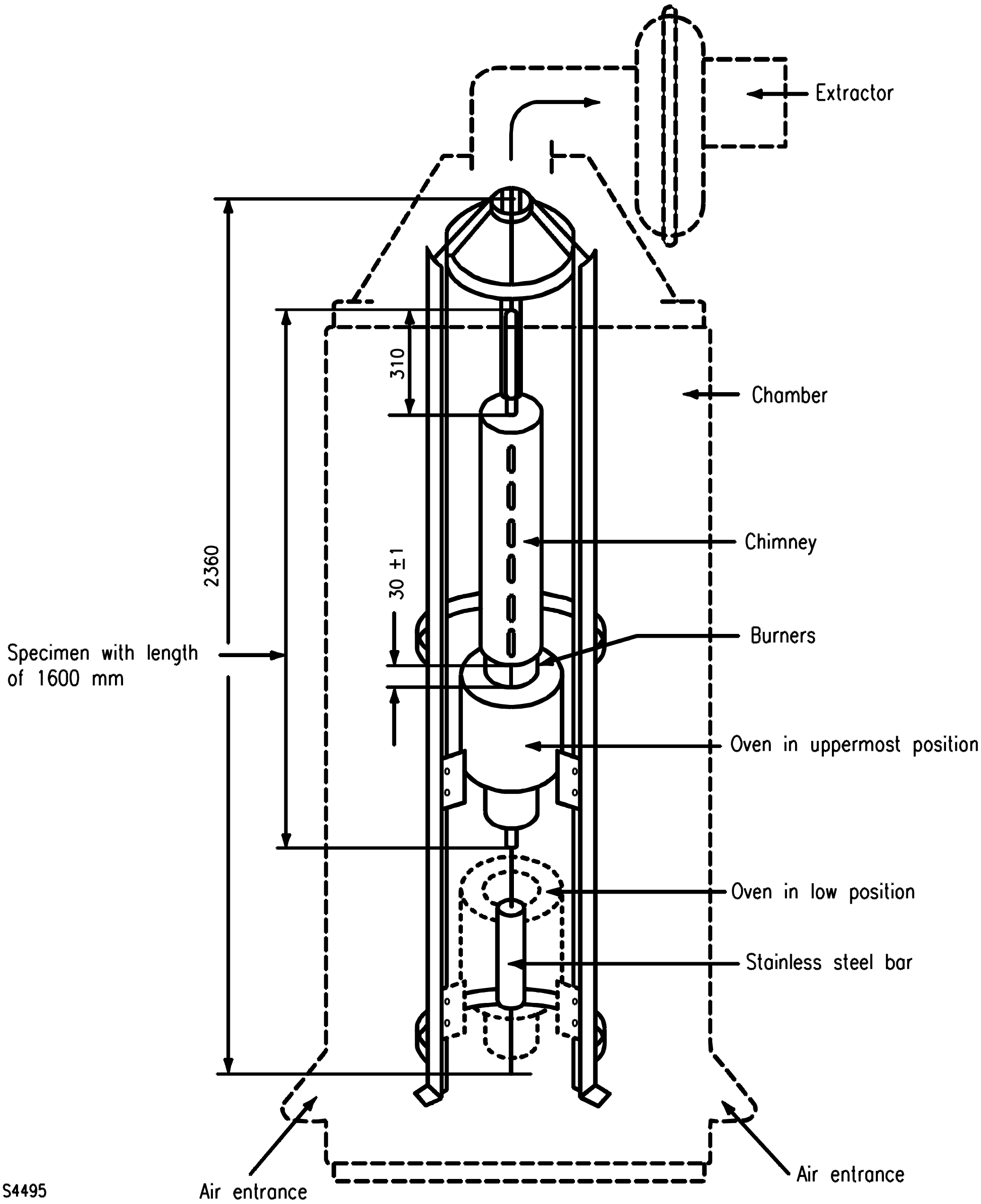
(See Clause 8.14.8.2.1.1)



Note: *Dimensions in millimeters.*

Figure 13 – Detail 1 of Dimensions for Fire Propagation Test Chamber

(See Clause 8.14.8.2.1.1)



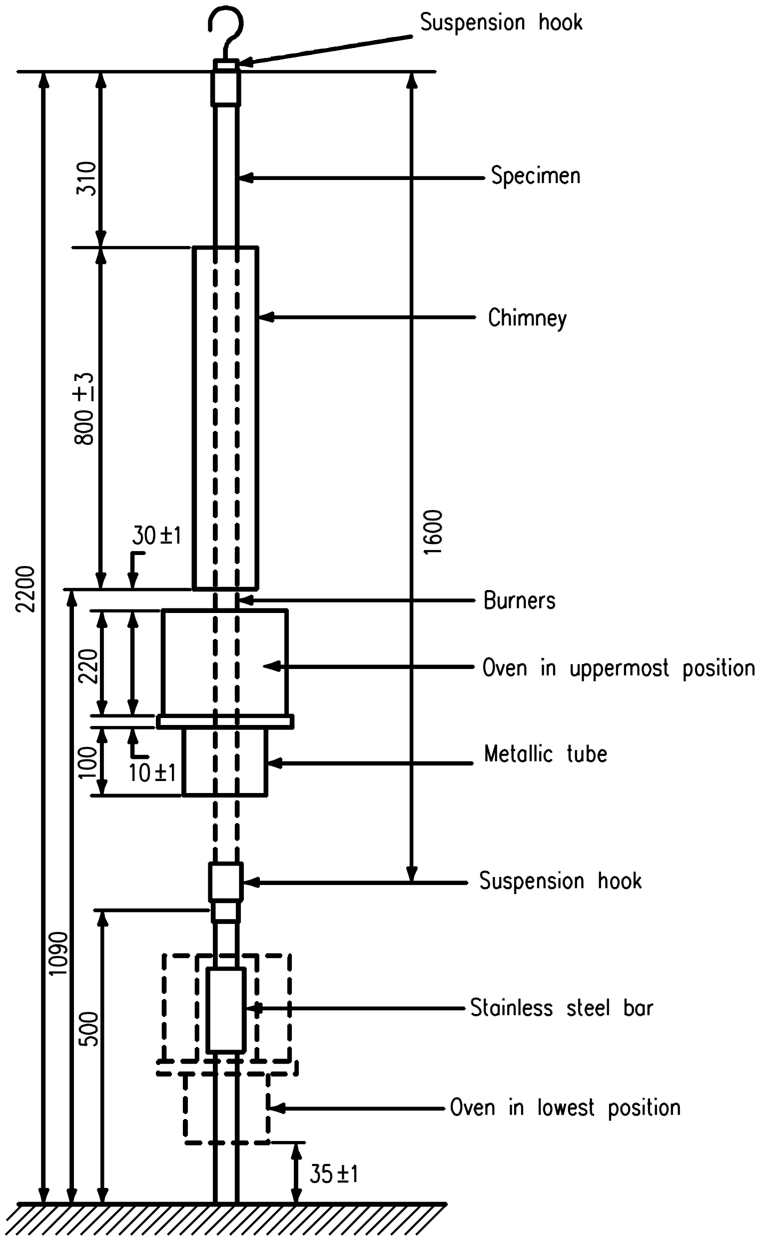
Notes:

1) Dimensions in millimeters.

2) No tolerances shown.

Figure 14 – Detail 2 of Dimensions for Fire Propagation Test Chamber

(See Clause 8.14.8.2.1.1)



S4496

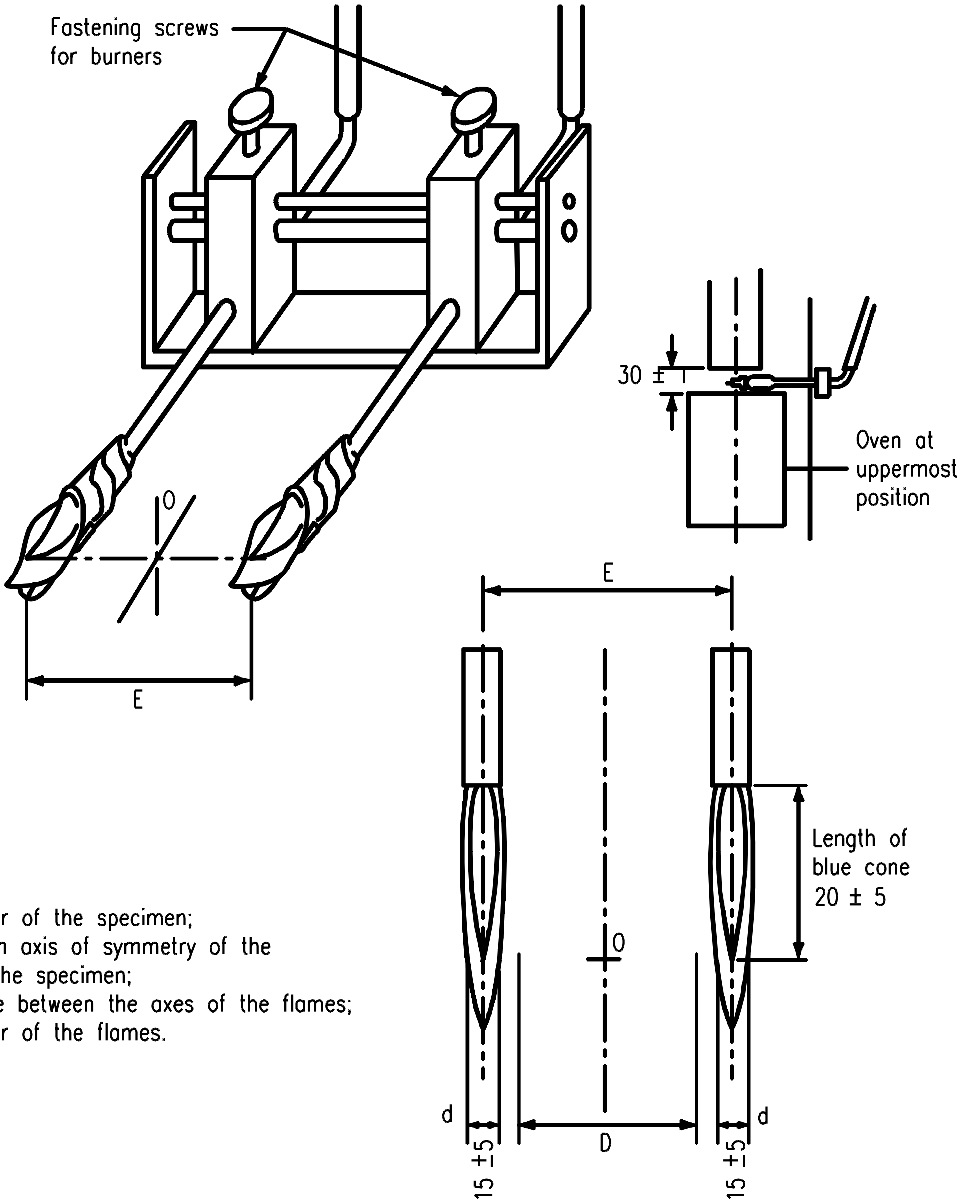
Notes:

1) Dimensions in millimeters.

2) No tolerances shown.

Figure 15 – Burners for Fire Propagation Test

(See Clause 8.14.8.2.1.1)



Legend:

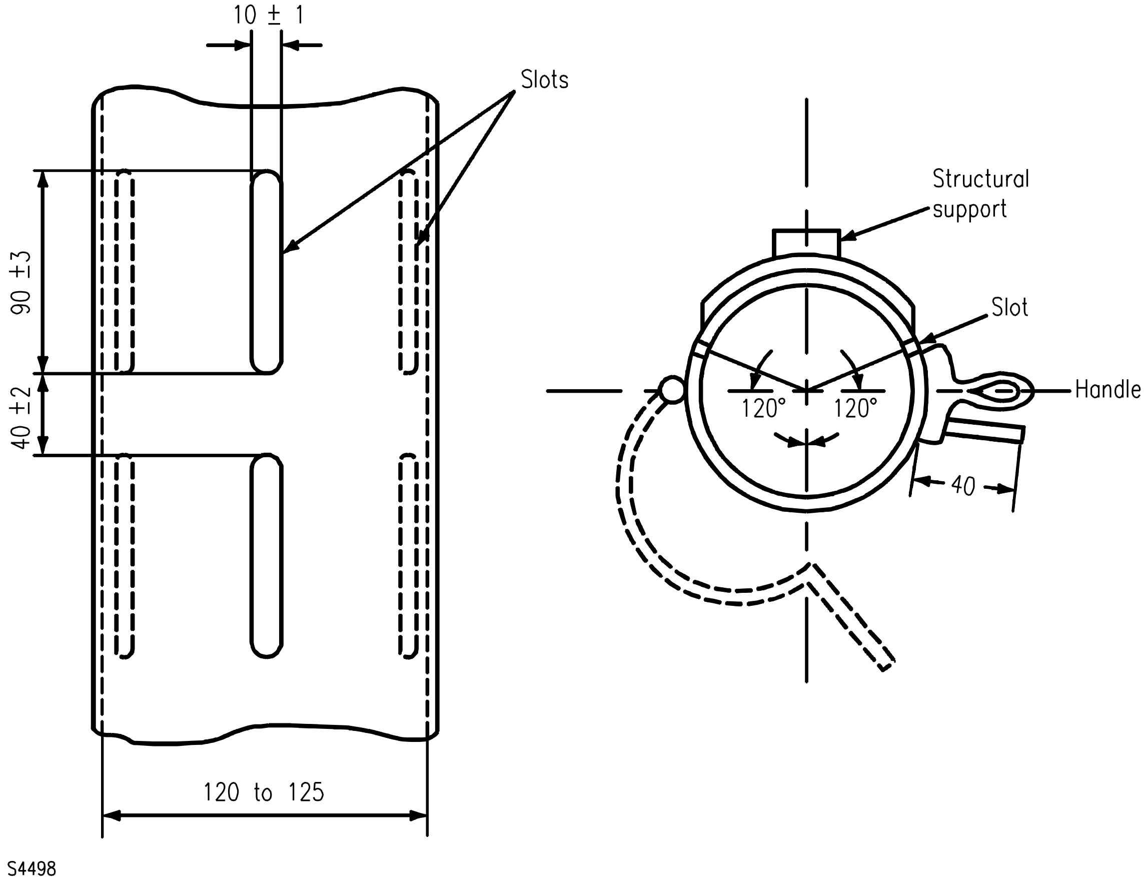
D is the diameter of the specimen;
0 is the common axis of symmetry of the chimney and the specimen;
E is the distance between the axes of the flames;
d is the diameter of the flames.

S4497

Note: *Dimensions in millimeters.*

Figure 16 – Metallic Chimney of Fire Propagation Test Chamber

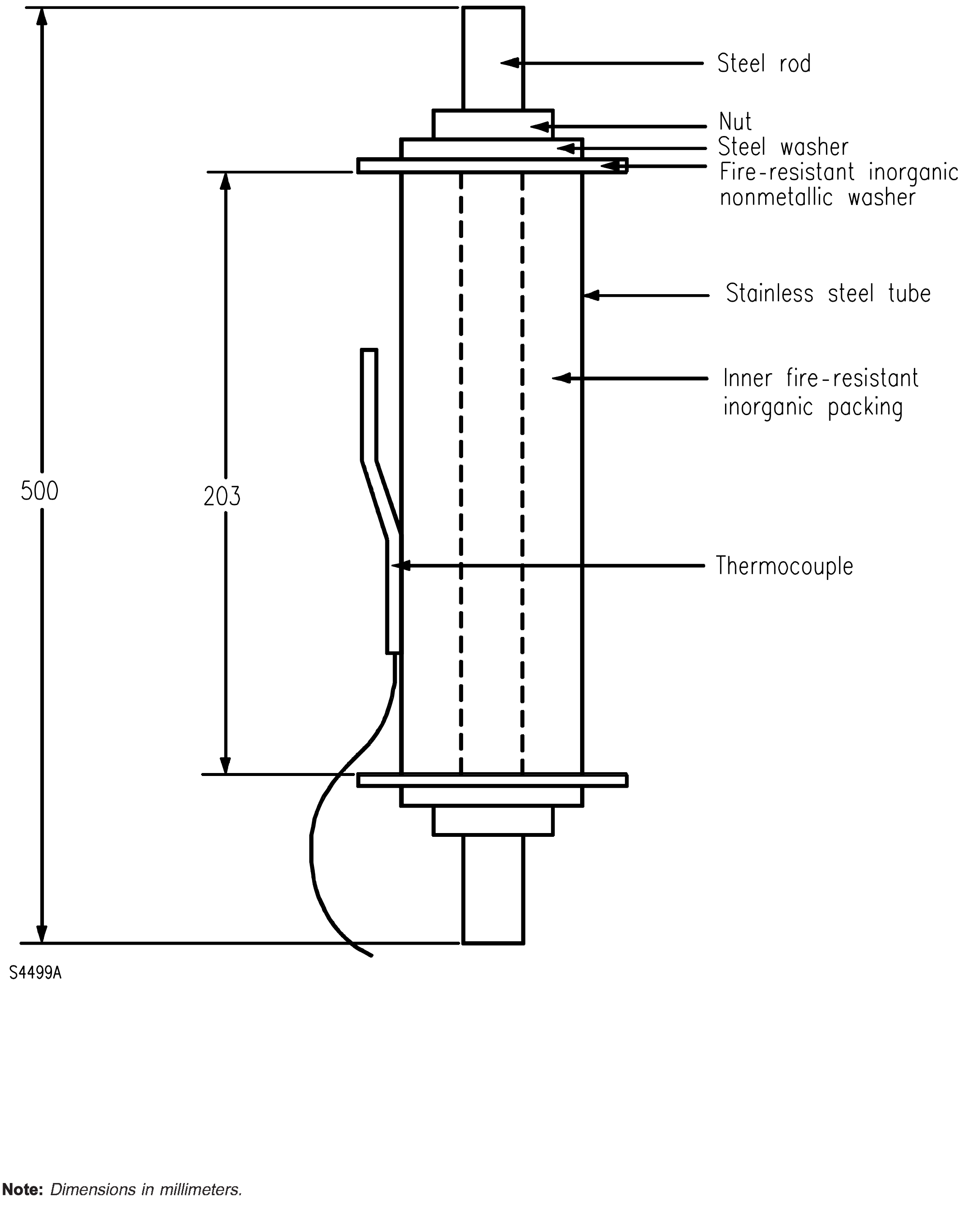
(See Clause 8.14.8.2.1.1)



Note: *Dimensions in millimeters.*

Figure 17 – Stainless-Steel Tube in Fire Propagation Test Chamber

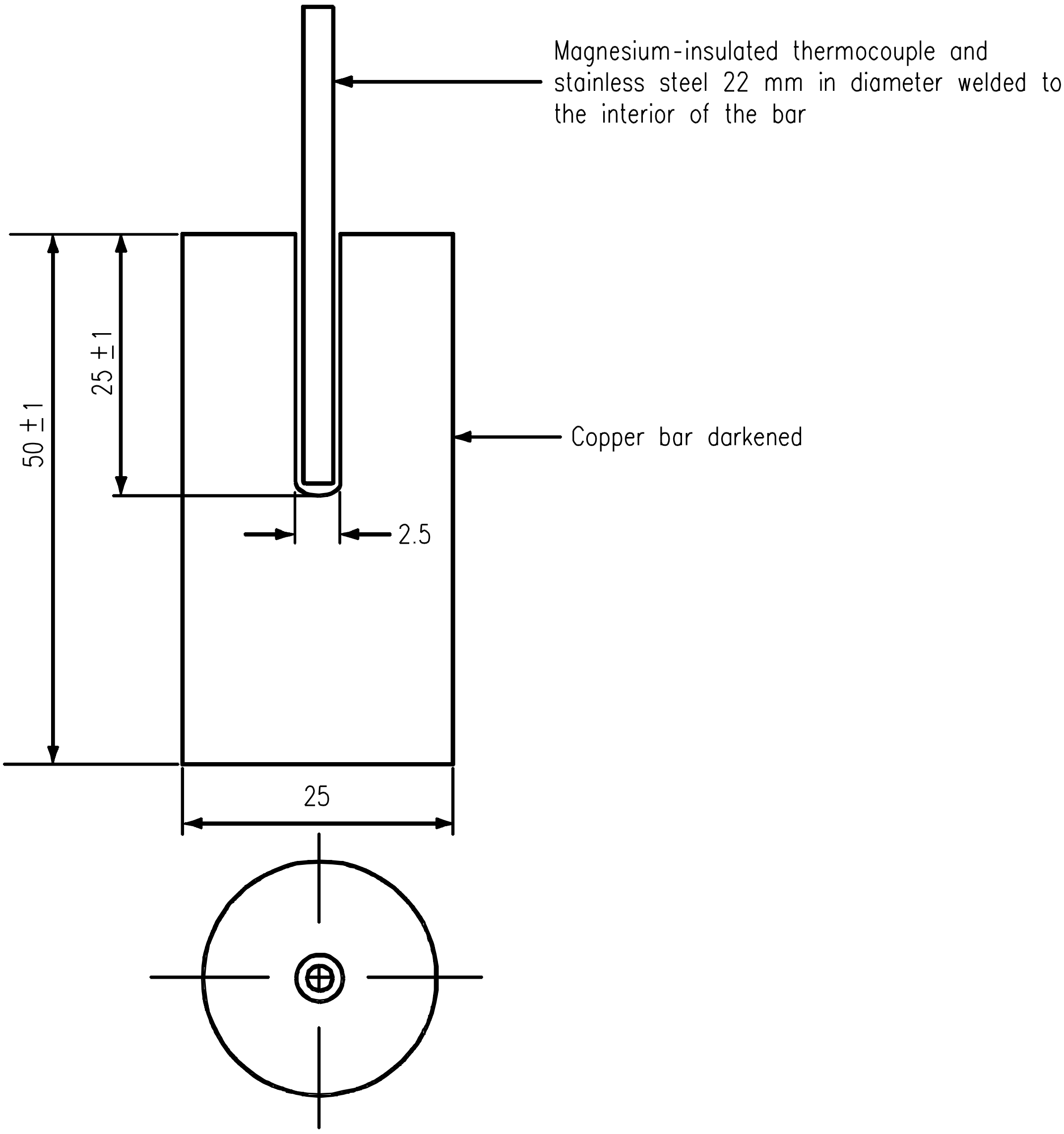
(See Clause 8.14.8.2.1.1)



Note: *Dimensions in millimeters.*

Figure 18 – Copper Bar for Flame Temperature Calibration in Fire Propagation Test

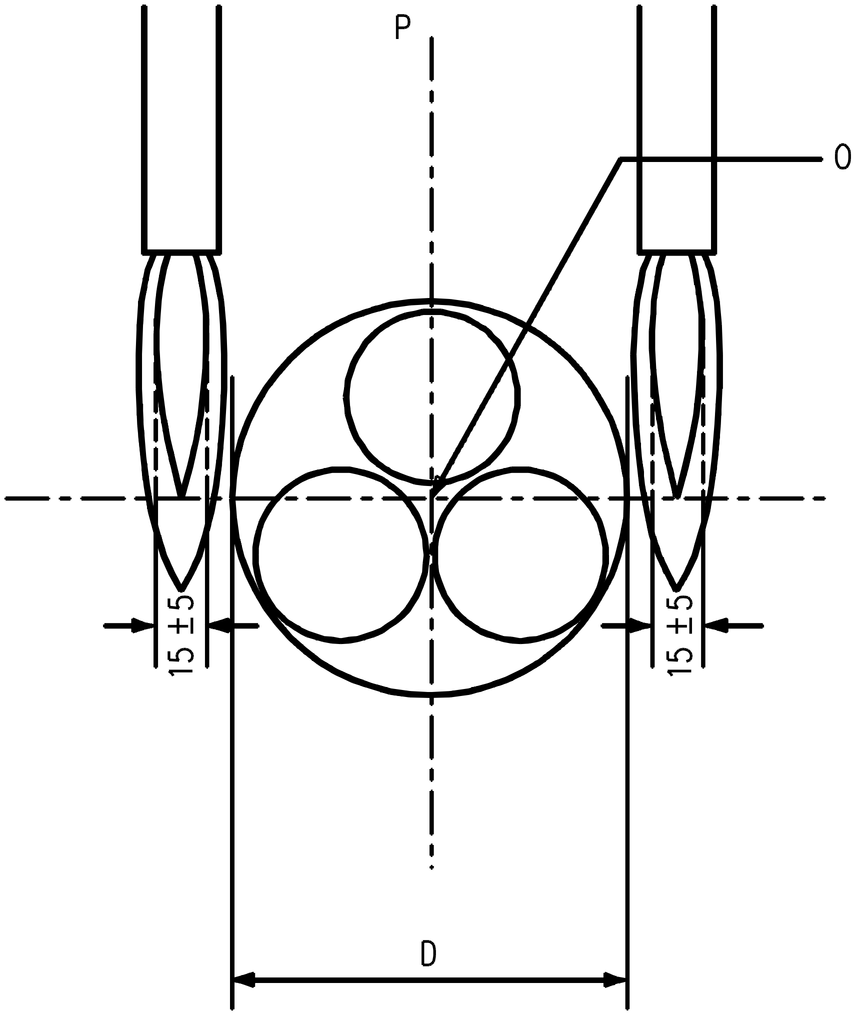
(See Clauses 8.14.8.2.1.1 and 8.14.8.2.2.2)



Note: *Dimensions in millimeters.*

Figure 19 – Arrangement of Specimen between Burners Used in Fire-Propagation Test Chamber

(See Clauses 8.14.8.2.3)



Legend:

O is the common axis of symmetry between chimney and oven;

P is the plane of symmetry of the valves;

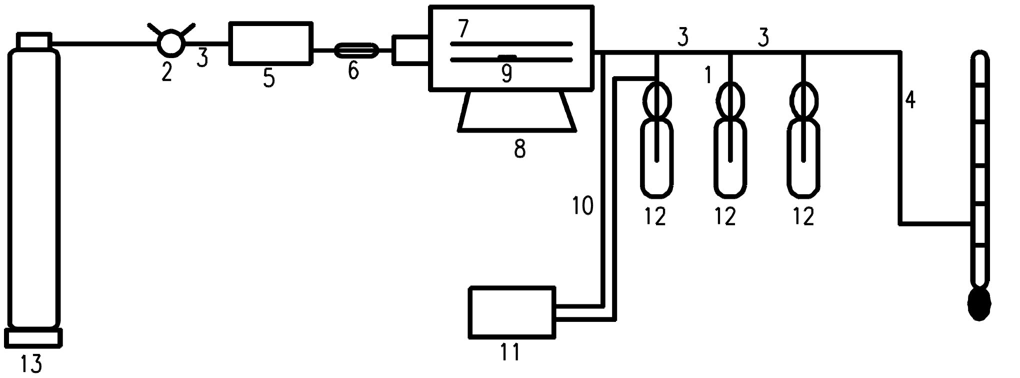
D is the diameter of the specimen.

S4501

Note: *Dimensions in millimeters.*

Figure 20 – Combustion System for Halogen Acid Gas Emission Test Procedure

(See Clauses 8.14.8.3.2.1 and 8.14.8.3.4)



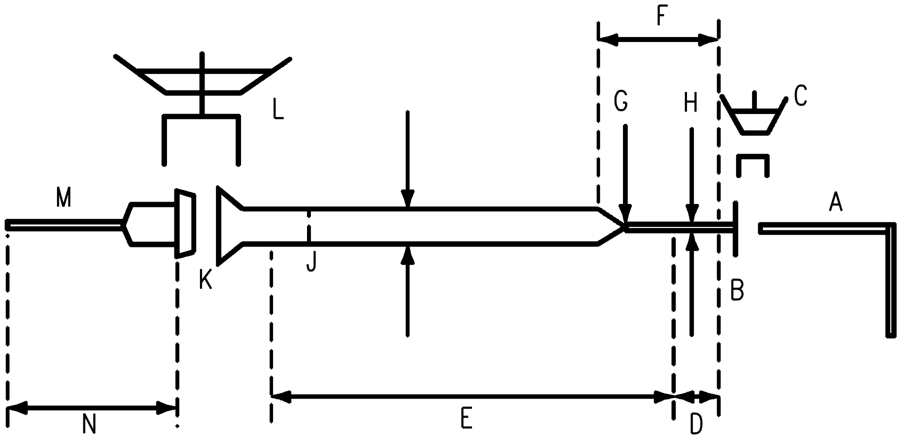
Legend:

[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

S4502

Figure 21 – Quartz Combustion Tube

(See Clause 8.14.8.3.2.1)



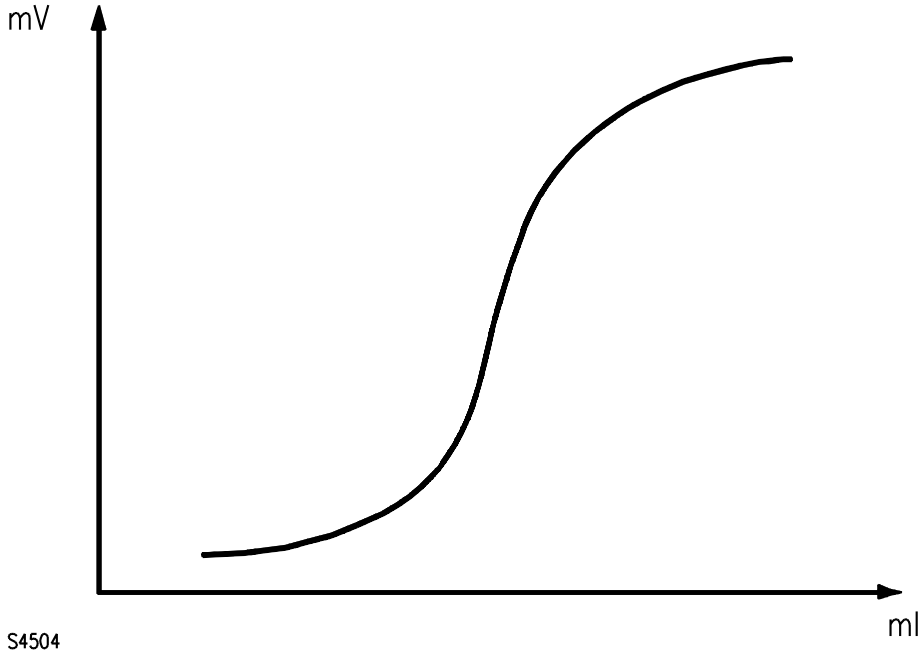
Legend:

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

S4503

Figure 22 – Typical Titration Graph for Halogen Acid Gas Emission

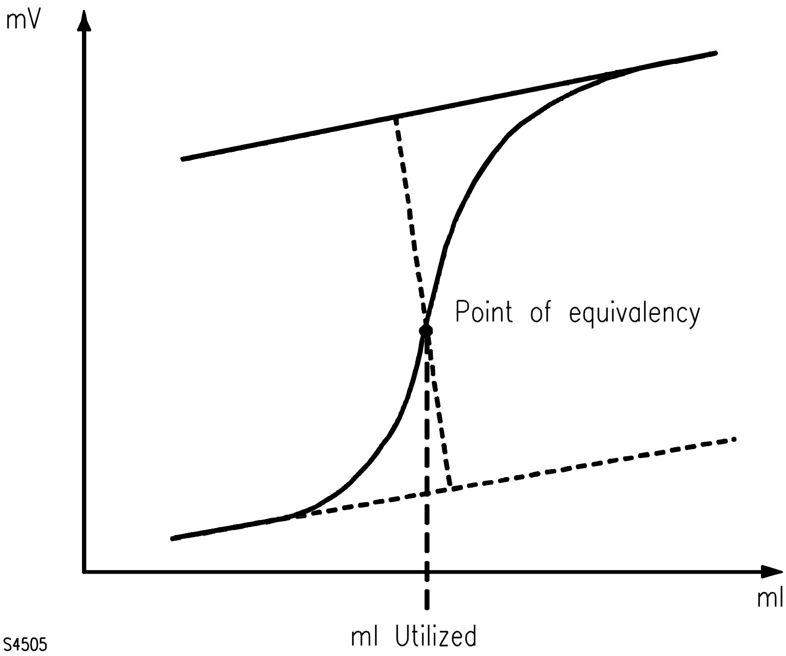
(See Clause 8.14.8.3.6)



S4504

Figure 23 – Geometric Determination of the Point of Equivalency of Halogen Acid Gas Emission

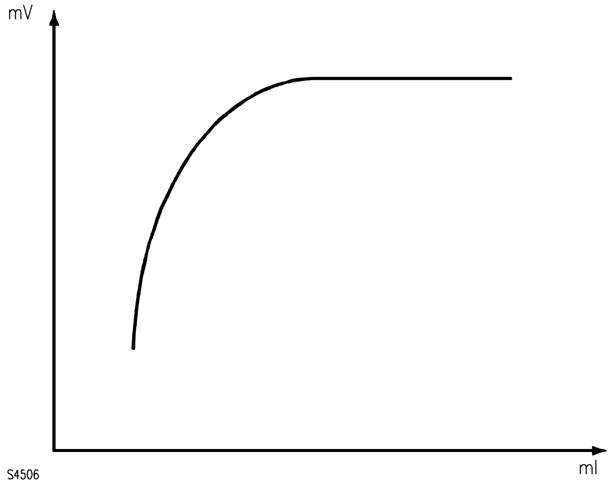
(See Clause 8.14.8.3.6 and Figure 24)



S4505

Figure 24 – Typical Null Titration Curve for Halogen Acid Gas Emission

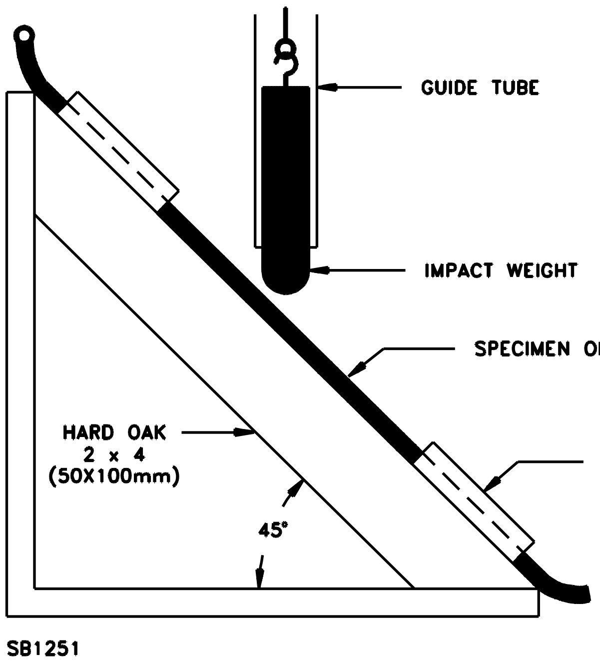
(See Clause 8.14.8.3.6)



Note: *As observed in this graph, a similar response to the upper end of the curve of Figure 23 is obtained, which is to say the curve records the behavior the reaction represented in Figure 23 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.*

Figure 25 – Glancing Impact Apparatus

(See Clause 8.19.2)



Annex A (normative) – Conductor types covered by this Standard
(See Clause 1.2)

Wire type designation	Voltage rating, V	Electrical code recognition		
		Canadian	Mexican	U.S.
XHHW-2	600	no	yes	yes
XHHW	600	no	yes	yes
XHH	600	no	no	yes
RHH	600 or 2000	no	yes	yes
RHW-2	600 or 2000	no	yes	yes
RHW	600 or 2000	no	yes	yes
SA	600	no	no	yes
SF	600	no	yes	no
SIS	600	yes	yes	yes
R90	600, 1000, 2000, or 5000	yes	no	no
RW75	600, 1000, 2000, or 5000	yes	no	no
RW90	600, 1000, 2000, or 5000	yes	no	no
RWU75	1000	yes	no	no
RWU90	1000	yes	no	no

Note: *See Annex B for a summary of construction and test requirements and the grouping of different wire types with identical requirements.*

Annex B (informative) – Summary of requirements

(See Clause 1.1)

Requirement	Wire type designation								
	XHH	**XHHW, XHHW2**	**RHW, RHW2**	**RHH**	**SA, SF**	**SIS**	**R90**	**RW75, RW90**	**RWU75, RWU90**
Voltage rating	600 V		600V and 2kV		600V		600v, 1kV, 2kV, and 5kV[a]		1kV
Temperature rating	1.2, Table 1								
Conductors	4.1.5.1, Table 2								
Number of conductors	Table 2								
Conductor stranding	4.1.5.2, Table 3								
Conductor diameter	4.1.6, Tables 5 – 10								
Conductor separator	4.1.8								
Insulation – General	4.2.1, Table 19								
Insulation – Physical properties	4.2.1, Table 11								
Insulation – Thickness	4.2.3, Tables 12 – 18								
Jackets and coverings	4.3, Tables 21 – 23								
Jacket physical properties	Table 20								
Shielding	4.4								
Multiple-conductor cables	4.5								
Color coding	4.6								
Fillers	4.7								
Jacket separators	4.8								
Overall jackets	4.9, Tables 19 and 26								
Evaluation of new materials	4.10								
Assemblies of conductors	4.11								
Conductor resistance	5.2, Tables 27 – 35								
Tests on aluminum conductors	5.3								
Long-term insulation resistance in water		5.4, Table 39						5.4, Table 37 – 38	
Long-term insulation resistance in air for 90°C rated conductors	5.5, Table 40			5.5, Table 40			5.5, Tables 40 – 41		
Capacitance and relative permittivity		5.6						5.5	
Conductor corrosion	5.7								
Insulation fall-In	5.8								
Heat shock of thermoplastic jacket	5.9								
Flexibility of separator under thermoplastic jacket	5.10								
Cold bend	5.11.1								
Cold impact (optional)	5.11.2								
Deformation	5.12								
Hot creep	5.13								
Horizontal- specimen flame test	5.14.1								
Burning particles test								5.14.2	
FT1 flame test (optional)	5.14.3								

Table Continued on Next Page

Table Continued

Requirement	Wire type designation								
	XHH	XHHW, XHHW2	RHW, RHW2	RHH	SA, SF	SIS	R90	RW75, RW90	RWU75, RWU90
VW-1 flame test (optional)	5.14.4								
Vertical tray flame (optional)	5.14.5								
FT4 vertical tray flame (optional)	5.14.6								
ST-1 limited smoke (optional)	5.14.7								
LS (low smoke), flame, smoke, and acid gas release (optional)	5.14.8								
Weather resistance (optional)	5.15								
Oil resistance (optional)	5.16								
Gasoline and oil resistance (optional)	5.17								
Crushing resistance	5.18								
Glancing impact	5.19								
Durability of ink printing	5.20								
Shrinkback	5.21						5.21		
Evaluation of new materials	5.22								
Spark test	5.23, Table 44								
Dielectric voltage-withstand test	5.24, Table 45								
Insulation resistance in water, 15°C	5.25, Tables 46 – 48								
Electrical continuity	5.26								
Markings on product	6.1								
Markings on package	6.2								
Deep-well submersible pump cable	7								

[a] For 5 kV, refer to Annex K.

Annex C (normative) – Chemical composition of recognized ACM, AA 8000 series aluminum alloy conductor materials

(See Clause 1.1)

Alloys		Composition, percent mass							Others	
ANSI	UNS	Aluminum	Silicon	Iron	Copper	Magnesium	Zinc	Boron	Each	Total
8017	A98017	Remainder	0.10	0.55 to 0.8	0.10 to 0.20	0.01 to 0.05	0.05	0.04	0.03[a]	0.10
8030	A98030	Remainder	0.10	0.30 to 0.8	0.15 to 0.30	0.05	0.05	0.001 to 0.04	0.03	0.10
8076	A98076	Remainder	0.10	0.6 to 0.9	0.04	0.08 to 0.22	0.05	0.04	0.03	0.10
8130	A98130	Remainder	0.15[a]	0.40 to 1.0[b]	0.05 to 0.15	–	0.10	–	0.03	0.10
8176	A98176	Remainder	0.03 – 0.15	0.40 to 1.0	–	–	0.10	–	0.05[c]	0.15
8177	A98177	Remainder	0.10	0.25 to 0.45	0.04	0.04 to 0.12	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 D (normative) – Copper-clad aluminum conductors

(See Clause 4.1.3)

D.1 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.

D.2 Sizes and stranding

Conductors shall be of the same size and assembly indicated for solid or concentric stranded aluminum wire in Table 2. The number of wires in the conductors shall be in accordance with Table 3.

D.3 Conductor resistance

The direct-current resistance of the copper-clad aluminum conductor shall not be greater than as specified for aluminum conductors in Tables 28 and 29, as appropriate.

D.4 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 MPa (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.

D.5 Marking requirements

D.5.1 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 the package marking.

D.5.2 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 E (informative) – Metric sizes
(See Clause 4.1.5)

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.*

E.1 Metric sizes for wire and cable products are not recognized in the *Canadian Electrical Code, Part I*, the *Standard for Electrical Installations*, and the *National Electrical Code*, but are employed in some jurisdictions requiring metric sized conductors. Tables E.1 and E.2 are based on IEC 60228 and 60228A.

E.2 The direct-current resistance values of conductors shall not be greater than given in Table E.3, except that a plus tolerance of 2 percent is permitted in the case of a conductor in a twisted multiple-conductor cable assembly.

E.3 Direct-current resistance shall be determined with the apparatus and according to the method described in CSA C22.2 No. 0.3, Clause 4.1.2, UL 1581, Section 220, or NMX-J-212-ANCE.

E.4 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 E.4.

Table E.1
Solid Class 1 Aluminum and Copper Conductors

Conductor area		Maximum diameter, mm
Square millimeters	Circular mils	
0.50	992	0.9
0.75	1 458	1
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
120	234 119	12.4
150	287 532	13.8

Table E.2
Concentric-Stranded Class 2 Aluminum and Copper Conductors

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 E.3
Maximum D-C Resistance in Ohms per Kilometer at 20°C

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	21.2	1.16	1.91	21.2	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 E.3 Continued on Next Page

Table E.3 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
1 000	–	–	–	0.0291	0.0176	0.0177

Note: *For compliance, see Clause 8.1.*

Table E.4
Closest AWG or kcmil Size(s) to Metric Conductor Size(s)

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

Annex F (normative) – Protective coverings other than jackets

(See Clauses 4.3.1 and 4.9.1.1)

F.1 General

F.1.1 A covering applied over the outer surface of the insulation of a single-conductor wire or cable, and each conductor of any 2-conductor flat parallel wire or cable, and of any cabled multiple-conductor cable shall be in accordance with Table 19. See Clause 4.3.2 for a list of materials known to comply with these requirements.

F.1.2 A fibrous covering when used shall be applied to the insulated conductor either before or after the process of vulcanizing, curing, or cross-linking the insulating compound. A separator, when used, shall be applied between the insulation and the fibrous covering.

F.1.3 If a wire or conductor assembly is intended, and tagged or otherwise marked for further processing, the second fibrous covering required for a single-conductor wire, and the overall fibrous covering required for a multiple-conductor assembly in Table 19 are not required or, if provided, need not comply with the requirements for braids or wraps in Clauses F.3 – F.9 inclusive.

F.2 Tapes

F.2.1 Tapes employed as fibrous coverings shall not be the final outer covering of a single- or multiple-conductor wire or cable.

F.2.2 Tapes over multiple-conductor assemblies shall be applied helically without any creases or folds and with an overlap of at least 3 mm (1/8 inch) on 0.8235 mm^2 (8 AWG) and smaller conductors and at least 6 mm or 1/4 inch on larger conductors. Tapes on single conductors shall be applied either helically or longitudinally, with the specified overlap, under a braid or wrap covering on an individual insulated conductor. (Such tape shall be required under the braid on 6 AWG – 2000 kcmil Type SA or SF cable.)

F.2.3 The thickness of a tape shall be determined by removing the tape from the insulation and measuring its thickness by means of a dead-weight dial micrometer having a presser foot 6.4 ±0.1 mm (0.250 ±0.010 inch) in diameter and exerting 85 ±3 gf (0.83 ±0.02 N or 3.0 ±0.1 ozf) on the tape, the load being applied by means of a weight.

F.3 Cotton braids

F.3.1 General

F.3.1.1 A cotton braid employed as a covering on an individual conductor or as an outer covering over two or more individual conductors shall be of a close weave, shall cover the insulated conductor or conductors over which it is applied, and shall be fabricated on a machine having the same number of ends per carrier throughout. Each end shall consist of the same kind (soft or glazed), size, and ply of yarn. The braid shall be applied to make the tangent of the lay angle (the angle of weave with reference to the axis of the wire or cable) not less than indicated in Table F.1. A cotton braid shall employ yarn in accordance with Table F.2.

F.3.1.2 Single-ply yarn shall be acceptable if the diameter under the braid is not larger than 20.32 mm (0.8 inch) Otherwise, at least 2-ply yarn shall be employed.

F.3.1.3 In determining the lay angle and yarn size for the overall braid of a twin wire (parallel conductors), a value equal to 1.64 times the diameter of the individual insulated conductor shall be taken as the diameter under the braid.

F.3.2 Coverage

F.3.2.1 The size, ply, and number of ends of yarn and the length of lay shall make the percent coverage Q, of a cotton braid in each direction at least 40 percent if the diameter under the braid is not larger than 12.7 mm (0.500 inch), and at least 50 percent if the diameter under the braid is larger than 12.7 mm (0.500 inch), when computed by means of whichever of the following formulas is applicable.

$$Q = \frac{NET_{mm}}{25.4 \sin A}$$

Where:

N = Number of picks per centimeter

E = Number of ends per pick

T = Diameter of one end of yarn in millimeters

A = Lay angle

$$Q = \frac{100\ NET_{in}}{\sin A}$$

Where:

N = Number of picks per inch

E = Number of ends per pick

T = Diameter of one end of yarn in inches

A = Lay angle

F.3.2.2 The number, N, of picks per centimeter or per inch shall be measured by means of a standard braid counter at three places that are at least 50 mm (2 inches) apart in any 300 mm (12 inch) section in the center 1 m (3 ft) of a 1500 mm (5 ft) specimen of the braid-covered wire or cable. The outer surface of the specimen shall be wiped with a cloth wet with an organic solvent. The average of the three determinations shall be taken as the number of picks per centimeter or the number of picks per inch for that specimen.

F.3.2.3 Values of yarn diameter used in determining picks per centimeter or picks per inch by the applicable formula F.3.2.1 were computed by means of whichever of the following formulas applies:

$$T_{mm} = \frac{0.7087\,K}{(S)^{0.5}}$$

or

$$T_{in} = \frac{0.0279\,K}{(S)^{0.5}}$$

Where:

T_{mm} *= Diameter of one end of yarn in millimeters, mm*

T_{in} *= Diameter of one end of yarn in inches, in*

K = Cabling factor (1.00 for single-ply yarn and 1.60 for 2-ply yarn)

S = Yarn size number

F.3.2.4 The lay angle A shall be determined by means of the formula

$$\cos A = \frac{100\,CET}{pi\,Q\,(2\,T + D)}$$

Where:

C = Number of carriers in each direction

E = Number of ends per pick

T = Diameter of one end of yarn in millimeters (T_{mm}) or in inches (T_{in})

Q = Minimum acceptable percent coverage in each direction

D = Diameter under the braid in inches or in millimeters

F.3.2.5 By transposition, the formula in F.3.2.4 becomes either

$$\text{Picks per centimeter} = N = \frac{25.4\,Q \sin A}{100\,ET_{mm}}$$

(See Table F.3)

or

$$\text{Picks per inch} = N = \frac{Q \sin A}{100\,ET_{in}}$$

(See Table F.4)

The transposed formula facilitates computation of the minimum acceptable number of picks per centimeter or the minimum acceptable number of picks per inch for any combination of factors when the lay angle, as determined by means of the formula in F.3.2.4, is not less than indicated in Table F.1.

F.3.2.6 If two braids are used to comply with the requirement for two fibrous coverings in F.3.2.1, the lay angle, yarn size, and coverage (including picks per centimeter or picks per inch or) of each braid shall be determined on the basis of the diameter under that braid and the number of carriers on the machine applying that braid. For the outer braid, the diameter under that braid shall be taken as the diameter over the inner braid. It is acceptable for the number of carriers for the inner braid to be less than the number of carriers employed for the outer braid, but the size and ply of the cotton yarn used shall comply with these requirements, and the number of ends per carrier in the inner braid shall not be less than the number of ends per carrier in the outer braid.

F.3.2.7 Tables F.4 and F.5 have been computed on the basis of Clauses F.3.1.1 – F.3.2.6 and give the minimum acceptable number of picks per centimeter (Table F.3) and the minimum acceptable number of picks per inch (Table F.4) for the braids most commonly used. The ranges of diameter given in the first column are for calculated diameter based on normal values of conductor diameter and insulation thickness. The nominal conductor diameter as measured shall be used. A braid complying with Table F.3 or F.5 has at least the minimum acceptable angle of lay and coverage. Braids are not limited to those covered in Tables F.4 or F.5 as long as they comply with the requirements in Clauses F.3.1.1 – F.3.2.6.

F.4 All-glass and glass/cotton braids

F.4.1 A glass braid and a combination glass-and-cotton braid on a Type SA and SF or other wire shall comply with the requirements in Clauses F.3.1.1 and F.3.2.6, shall employ a glass yarn that is not smaller than 150 – 1/0, and shall provide a coverage in each direction of at least 40 percent if the diameter under the braid is not larger than 12.70 mm (0.500 inch), and at least 50 percent if the diameter under the braid is larger than 12.70 mm (0.500 inch). The glass content of an all-glass braid shall comply with the requirement in Clause F.4.5.1.

F.4.2 To determine whether or not a braid employing glass complies with the requirement in Clause F.4.1 with respect to lay angle and coverage, the table indicating the minimum acceptable number of picks per centimeter or per inch (Table F.5) is to be used under the conditions indicated in Table F.1.

F.4.3 Table F.1 is based on the assumed use of 150 – 1/0 glass yarn. A larger size of yarn shall be acceptable if it has the required angle of lay and coverage.

F.4.4 In a combination braid, the ratio of glass to cotton is not specified, but the usual construction is half cotton and half glass with all-glass carriers in one direction and all-cotton carriers in the other direction.

F.4.5 Glass content

F.4.5.1 An all-glass braid on Type SA and SF wire, after removal of the saturant, shall contain glass in the amount of 70 percent or more by weight when tested as specified in Clauses F.4.5.1 – F.4.5.2.

F.4.5.2 In the case of an all-glass or glass-and-cotton or glass-and-rayon braid from Type SA and SF wire or an all-glass or glass-and-cotton or glass-and-rayon braid from other wire, the test shall be made on specimens prepared from the finished braid. The braid shall be removed from a 1 m (40 inch) sample length of the finished wire, and shall be cut into short sections approximately 3 mm (1/8 inch) in length. Reinforcing threads and binder threads of cotton or other organic material shall not be removed, even where such threads serve as an identifying marker. The short pieces shall then be well mixed and the saturant shall be removed from them by means of an organic solvent.

F.4.5.3 A specimen of the extracted braid containing glass and weighing 5 g shall be dried to a constant weight (W_1) in a weighed crucible at a temperature of 110 ±5°C (230 ±9°F), ignited in an electric furnace at a temperature of 800 ±20°C (1472 ±36°F) for 1 h, cooled to room temperature in a desiccator, then weighed again (W_2). The percentage of glass in the specimen shall then be calculated by means of the following formula:

$$70 \le X_{all-glass} = \frac{100W_2}{W_1}$$

Where:

X = percentage of glass

W_1 = Weight of the dried specimen before ignition

W_2 = Weight after ignition and drying

F.5 Cotton wraps and servings

F.5.1.1 A cotton serving or wrap covering an insulated conductor shall be closely laid, shall provide the coverage indicated in Clause F.5.2, and shall be composed of cotton yarn of a size and ply not less than indicated in Table F.6.

F.5.1.2 A cotton serving or wrap shall be constructed and applied to make the tangent of the lay angle (the angle between the yarn and the axis of the wire or cable) not less than indicated in Table F.7.

F.5.1.3 If a wrap consists of two or more servings, the lay of adjacent servings shall be in opposite directions, and the angle of lay and coverage of any outer serving shall be based on the diameter over the serving immediately under the outer serving.

F.5.2 Coverage

F.5.2.1 The size, ply, and number of ends of yarn and the length of lay shall result in a wrap that covers at least 80 percent of the surface to which it is applied, when computed by means of whichever of the following formulas applies:

$$Q = \frac{2540\,NW}{B_{mm}}$$

or

$$Q = \frac{100\,NW}{B_{in}}$$

Where:

Q = Percent coverage

N = Number of ends of yarn in the ribbon

W = Constant for the yarn size employed (see Table F.8)

B = C cos A = L sin A

C = Mean circumference of the serving = L tan A

L = Length of lay (measured)

A = Lay angle

F.5.2.2 With reference to F.5.2.1 and Table F.8, the value of C (the mean circumference of the wrap) need not be measured when determining the percent coverage provided by a cotton wrap or serving. For general uniformity, the value of C is to be computed from the expression

$$C = \pi (D + T)$$

Where:

D = Nominal diameter of the wire over the insulation (under the wrap)

T = Constant for the size of yarn employed as given in Table F.8.

The length of lay shall be measured using a sample of wire 500 – 600 mm (20 – 24 inches) long. When computed in this manner, the percent coverage shall be at least 80 without any minus tolerance.

F.5.2.3 Binder threads of an acceptable fibrous material shall be helically applied to the outermost serving or wrap and in the direction opposite that of the lay of the yarns in that serving. The binder threads shall be uniformly spaced and shall consist of material having a strength, elasticity, and a manner of application that enable the completed wire or cable to withstand the cold-bend test in Clause 5.9 without breaking any of the binder threads.

F.5.2.4 With reference to the moisture-absorption and cold-bend test described in Clause 5.9, the cold bend test shall be conducted first (with adjacent turns in contact with one another). The specimen shall then to be used for the moisture-absorption test with the helix elongated (after removal from the mandrel) to the point that adjacent turns are 3 – 6 mm (1/8 – 1/4 inch) apart.

F.6 Glass wraps

F.6.1 A glass serving or wrap on an insulated conductor shall be closely laid, shall employ a glass yarn that is not smaller than 150 – 1/0, shall have an angle of lay in accordance with Clause F.5.1.2 shall provide the coverage specified in Clauses F.5.2.1 and F.5.2.2, and shall have binder threads in accordance with Clauses F.5.2.3 and F.5.2.4. A glass wrap shall be acceptable as either an inner or outer covering on a conductor, but the outer covering shall be other than a glass wrap if the diameter under that covering is greater than 5.08 mm (0.200 inch).

F.6.2 The coverage requirement in Clause F.6.1 is based on the use of 150-1/0 glass yarn, which is the size most generally used, and for which the yarn constant W is 0.010 inch for computing coverage by means of the formula in Clause F.5.2.1. The yarn constant T shall be 0.1016 mm (0.0040 inch) for computing the mean circumference by means of the formula in Clause F.5.2.2.

F.7 Braids and wraps

Spun-rayon yarn shall be acceptable for either a braid or a wrap. A spun-rayon braid or wrap shall comply with the requirements for cotton coverings with No. 6 single-ply yarn being acceptable in place of No. 12 2-ply yarn if the diameter over the insulation (under the covering) is 20.35 – 38.10 mm (0.801 – 1.500 inches).

F.8 Saturation of fibrous coverings other than tapes

F.8.1.1 All fibrous coverings other than tapes shall be saturated and finished to render the completed construction acceptable as determined by means of the moisture test described in Clauses F.8.1.1 – F.8.1.6.

F.8.1.2 The apparatus for this test shall consist of a desiccator containing anhydrous calcium chloride, a set of mandrels having diameters as indicated in Table 39, a quick-damping balance accurate to 10 mg, and an agitated constant-temperature bath of tap water maintained at a temperature of 21.0 ±1.0°C (69.8 ±1.8°F). The bath shall either be fitted with a cover to keep out dust, or shall be placed within a tight enclosure during the test. Where at any time the water becomes dirty or shows the presence of a surface film of dust or wax, it shall be replaced with fresh water.

F.8.1.3 Before cutting a test specimen to size, the coil or other sample of the wire, cable, or assembly that is to be tested shall attain a room temperature of 21.0 ±1.0°C (69.8 ±1.8°F). Handling and flexing of samples to be tested shall be reduced to the absolute minimum required for conducting the test.

F.8.1.4 A specimen 610 ±6 mm (24 ±1/4 inches) in length shall be cut from the coil or other sample of wire, cable, or assembly and shall be bent around a mandrel of the diameter indicated in Table 39 (single conductor) or in Table F.9 (multiple-conductor cable or assembly). For a 33.6 mm^2 (2 AWG) or smaller wire and for a multiple-conductor cable or assembly for which the factor F in Table F.9 is 2 or 3, the maximum number of complete turns that fit on the mandrel shall be made around the mandrel with the wire tight on the mandrel, adjacent turns 3 – 6 mm (1/8 – 1/4 inch) apart, and with a 50 – 60-mm (2 – 2-1/2-inch) straight length at each end of the specimen extending away from the mandrel. For wire sizes larger than 33.6 mm^2 (2 AWG) and for a multiple-conductor cable or assembly for which the factor F in Table F.9 is 4.5, 6, 9, or 10, a half turn shall be made around the mandrel.

F.8.1.5 The specimen shall be removed from the mandrel without disturbing its form and shall be placed in the desiccator over anhydrous calcium chloride at a temperature of 21.0 ±1.0°C (69.8 ±1.8°F) for at least 18 h. It shall then be removed from the desiccator and weighed to the nearest 10 mg. The weight shall be recorded as W.

F.8.1.6 The specimen shall then be immersed in the tap-water bath, with 25 ±3 mm (1 ±1/8 inch) of each end of the coil or 180° bend projecting above the surface of the water. After 24 h of immersion, the specimen shall be removed from the bath, shaken vigorously for 5 s to remove adherent moisture and weighed again 2 min after removal from the bath. This weight is to be recorded as W_1. All fibrous coverings other than tape shall then be removed from the full length of the specimen. The conductor(s), insulation, and any tape shall then be weighed. In the case of an assembly for use in armored cable, any overall fibrous covering and any fibrous covering on the individual wires shall be taken together in one test and a second test is to be made on only the fibrous covering on the individual wires. This weight shall be recorded as W_2.

F.8.1.7 The moisture absorbed by the specimen shall not be adjusted for the portion of the specimen projecting above the water. The percentage of absorption shall be calculated (to 0.1 percent) by means of the expression:

$$\frac{100(W_1 - W)}{W - W_2}$$

F.8.2 The saturant and finish on a fibrous-covered multiple-conductor cable (cable that qualifies for the suffix letter “D” or “M”) shall make the completed cable acceptable when flame-tested.

F.9 Finish

F.9.1 The surface of a fibrous covering on a wire or cable shall be smooth and shall not be tacky. The finish shall not flake off of the wire or cable during or as a result of the cold-temperature bending described in Clause 5.11.1 without the surface of the wire actually being rubbed. In the absence of flaking, cracking of the finish during the bending is acceptable.

Table F.1
Cotton Braid Angles

(See Clauses F.3.1.1, F.3.2.5, F.4.2, and F.4.3)

Calculated diameter under braid		Value of tangent	Corresponding braid angle (degrees)
mm	inches		
0 – 25.4	0 – 1.000	0.700	36
25.5 – 38.1	1.001 – 1.500	0.839	40
Over 38.1	Over 1.500	1.000	45

Table F.2
Cotton Yarn Sizes

(See Clause F.3.1.1)

Calculated diameter under braid		Minimum size and ply of yarn
mm	inches	
5.08 or less	0.200 or less	14/1 or 30/2
5.09 – 8.89	0.201 – 0.350	12/1 or 26/2
8.90 – 20.32	0.251 – 0.800	10/1 or 20/2
20.33 – 38.10	0.801 – 1.500	12/2
38.11 – 76.20	1.501 – 3.000	8/2

Table F.3
Minimum Number of Picks per Centimeter for Particular Cotton Braids

(See Clauses F.3.2.5 and F.3.2.7 and Table F.5)

Calculated diameter under the braid, mm	Number of carriers	Size and ply of yarn and number of ends per pick													
		14/1 or 30/2		12/1 or 26/2		10/1 or 20/2			12/2			10/2		8/2	
		2	3	2	3	2	3	4	2	3	4	3	4	3	4
2.54 – 3.18	12	8.7		7.9		6.9									
	16	7.0		5.9											
	12	9.3	5.0	8.5	4.4	7.6	3.6								
3.20 – 3.81	16	8.2		7.3		6.3									
	20	6.5		5.4											
	12	9.6	5.6	8.8	5.0	8.0	4.3								
3.84 – 4.44	16	8.0	4.2	8.0	3.4	7.1									
	20	7.8		6.9		5.8									
	16	9.3	5.0	8.5	4.3	7.6	3.5								
4.47 – 5.08	20	8.5		7.6		6.6									
	24	7.4		6.5		5.2									
	16			8.7	4.8	7.9	4.1								
5.11 – 5.72	20			8.1		7.2									
	24			7.2		6.2									
	16			8.9	5.2	8.1	4.5								
5.74 – 6.35	20			8.5	4.3	7.6	3.5								
	24			7.8		6.8									
	16			9.1	5.6	8.4	4.9	2.9							
6.38 – 7.62	20			8.8	4.9	7.9	4.2								
	24			8.3	4.0	7.4									

Table F.3 Continued on Next Page

Table F.3 Continued

Calculated diameter under the braid, mm	Number of carriers	Size and ply of yarn and number of ends per pick													
		14/1 or 30/2		12/1 or 26/2		10/1 or 20/2			12/2			10/2		8/2	
		2	3	2	3	2	3	4	2	3	4	3	4	3	4
	16			9.4	5.8	8.5	5.3	35							
7.65 – 8.89	20			9.1	5.4	8.2	4.8	2.7							
	24			8.7	4.8	7.9	4.2								
	16					8.6	5.4	3.7	5.6	3.2					
8.92 – 10.16	20					8.4	5.1	3.2	5.3	2.6					
	24					8.2	4.7			4.9					
	16					8.7	5.6	3.9	5.7	3.4					
10.19 – 11.43	20					8.5	5.3	3.5	5.4	3.0					
	24					8.3	5.0	3.0	5.1						
	16					8.7	5.7	4.0	5.8	3.5					
11.46 – 12.70	20					8.6	5.4	3.7	5.6	3.2					
	24					8.5	5.2	3.2	5.3	2.8					
12.73 – 15.24	20					11.0	7.2	5.2	7.3	4.6	3.2				
	24					10.9	7.0	4,9	7.2	4.4	2.8				
15.27 – 20.32	20					11.1	7.2	5.3	7.4	4.8	3.4	4.3	3.0		
	24					11.0	7.2	5.2	7.4	4.5	3.2	4.2	2.8		
20.35 – 25.40	20								7.8	4.9	3.6	4.5	3.2	3.9	2.8
	24								7.7	4.8	3.5	4.4	3.1	3.8	2.6
	24								7.8	4.9	3.6	4.5	3.3	3.9	2.8
25.43 – 30.48	36								7.6	4.7	3.3	4.2	2.9	3.7	2.4
	48								7.4	4.3	2.8	3.8	2.2	3.2	
	24								7.8	5.0	3.7	4.5	3.3	4.0	2.9
30.51 – 38.10	36								7.7	4.8	3.5	4.4	3.0	3.8	2.6
	48								7.6	4.6	3.2	4.1	2.7	3.5	2.2.
38.13 – 50.80	36													3.9	2.8
	48													3.9	2.6

Table F.4
Minimum Number of Picks per Inch for Particular Cotton Braids

(See Clauses F.3.2.5, F.3.2.7 and F.4.2 and Table F.5)

Calculated diameter under the braid in inches	Number of carriers	Size and ply of yarn and number of ends per pick													
		14/1 or 30/2		12/1 or 26/2		10/1 or 20/2			12/2			10/2		8/2	
		2	3	2	3	2	3	4	2	3	4	3	4	3	4
.100 –.125	12	22.1		20.0		17.6									
	16	17.8		15.1											
	12	23.5	12.7	21.6	11.1	19.3	9.1								
.126 –.150	16	20.8		18.6		15.9									
	20	16.5		13.8											
	12	24.4	14.2	22.4	12.8	20.3	11.0								
.151 –.175	16	22.5	10.6	20.4	8.6	13.3									
	20	19.5		17.4		18.2									
	16	23.5	12.6	21.5	11.0	19.2	8.9								
.176 –.200	20	21.6		19.4		16.8									
	24	18.9		16.4		13.3									

Table F.4 Continued on Next Page

Table F.4 Continued

Calculated diameter under the braid in inches	Number of carriers	Size and ply of yarn and number of ends per pick													
		14/1 or 30/2		12/1 or 26/2		10/1 or 20/2			12/2			10/2		8/2	
		2	3	2	3	2	3	4	2	3	4	3	4	3	4
	16			22.0	12.3	20.0	10.5								
.201 –.225	20			20.5		18.2									
	24			18.4		15.7									
	16			22.7	13.3	20.6	11.5								
.226 –.250	20			21.5	10.9	19.2	8.8								
	24			19.8		17.2									
	16			23.2	14.1	21.2	12.5	7.4							
.251 –.300	20			22.3	12.5	20.1	10.7								
	24			21.1	10.8	18.8									
	16			23.7	14.8	21.6	13.4	8.8							
.301 –.350	20			23.6	13.7	20.9	12.2	6.9							
	24			22.1	12.2	20.0	10.6								
	16					21.9	13.8	9.4	14.2	8.2					
.351 –.400	20					21.4	12.9	8.1	13.4	6.7					
	24					20.7	11.9		12.4						
	16					22.1	14.2	9.9	14.5	8.7					
401 –.460	20					21.7	13.5	8.9	13.8	7.6					
	24					21.1	12.7	7.5	13.0						
	16					22.2	14.4	10.2	14.6	9.0					
.451 –.500	20					21.9	13.8	9.3	14.1	8.2					
	24					21.4	13.1	8.1	13.5	7.0					
.501 –.600	20					27.9	18.2	13.1	18.6	11.7	8.0				
	24					27.6	17.7	12.5	18.3	11.1	7.1				
.601 –.800	20					28.1	18.3	13.5	18.8	12.2	8.7	11.0	7.7		
	24					27.9	18.2	13.2	18.7	11.8	8.2	10.6	7.1		
.801 – 1.000	20								19.7	12.5	9.1	11.3	8.2	10.0	7.1
	24								19.5	12.3	18.8	11.1	7.8	9.7	6.7
	24								19.7	12.5	9.1	11.3	8.3	10.0	7.1
1.001 – 1.200	36								19.3	11.9	8.3	10.7	7.3	9.3	6.1
	48								18.7	11.0	7.0	9.7	5.7	8.1	
	24								19.8	12.7	11.5	8.4	8.4	10.2	7.4
1.201 – 1.500	36								19.5	12.3	11.1	7.7	7.7	9.7	6.7
	48								19.2	11.7	10.4	6.9	6.9	9.0	5.6
1.501 – 2.000	36													10.0	7.2
	48													9.8	6.6

Table F.5
Minimum Picks per Inch or Picks per Centimeter for All-Glass Braids

(See Clauses F.3.2.7 and F.4.2)

Cotton size with which glass is used	Number of ends per carrier for glass	Calculated diameter under braid		Picks per centimeter (inch)	(Table F.3) (Table F.4)
		mm	inches	More than 50 percent glass	50 percent or less glass
14/1	Same as that specified for 12/1 an all-cotton braid	5.08 or less	0.200 or less	As specified for 14.1 cotton	Same as that specified for all-cotton braid employing yarn of the same size as that with which the glass is used
		5.11 – 8.89	0.201 – 0.350	As specified for 12/1 cotton	
10/1		8.92 – 20.32	0.351 – 0.800	As specified for 10/1 cotton	
12/2	One more than that specified for an all-cotton braid	20.35 – 38.10	0.801 – 1.500	As specified for 12/2 cotton	
8/2	Double the number specified for an all-cotton braid	38.13 – 50.80	1.501 – 2.00	As specified for 8/2 cotton	

Table F.6
Yarn for Cotton Wrap or Serving

(See Clause F.5.1.1)

Diameter under serving		Minimum
mm	inches	
0 – 5.08	0 – 0.200	14/1
5.11 – 9.14	0.201 – 0.360	12/1
9.17 – 20.32	0.361 – 0.800	10/1
20.35 – 38.10	0.801 – 1.500	12/2

Table F.7
Cotton-wrap Angle

(See Clause F.5.1.2)

Diameter under wrap		Value of tangent	Corresponding lay angle in degrees
25.4 mm (1.000 inch) or less	14 – 9 AWG only	0.649	33
25.43 – 38.10 mm (1.001 – 1.500 inches)	All other wire sizes	0.700	35
		0.839	40

Table F.8
Constant for Size of Yarn

(See Clauses F.5.2.1 and F.5.2.2)

Size and ply of yarn (size/ply)		Values of constants T	
	W	mm	inch
14/1	0.0134	0.2438	0.0096
12/1	0.0144	0.2667	0.0105
10/1	0.0158	0.2896	0.0114
12/2	0.0204	0.3937	0.0155

Table F.9
Mandrel-Diameter Factor F for Moisture and Cold-Bend Tests of Multiple-Conductor Cables and Assemblies

(See Clause F.8.1.4)

Calculated diameter over the finished cable or assembly		Factor F by which the calculated diameter over the finished cable or assembly shall be multiplied to obtain the mandrel diameter
mm	inches	
0 – 9.52	0 – 0.375	2
9.53 – 12.70	0.376 – 0.500	3
12.71 – 19.05	0.501 – 0.750	4.5
19.06 – 28.58	0.751 – 1.125	6
28.59 – 38.10	1.126 – 1.500	9
Over 38.10	Over 1,500	10

Annex G (normative for Canada) – Color identification of circuit conductors

(See Clauses 4.6.2, 4.6.3 and 7.2.4)

Number of circuit conductors	Circuit conductors of multiple-conductor cables	Deep-well water-pump cable†
2	One black, and one white or gray*	Black, red
3	One black, one red and one blue‡	Black, red, yellow
4	One black, one red, one blue, and one white or gray	Black, red, yellow, blue

† The individual conductors in cables having more than four conductors shall be made distinguishable from each other in a manner suitable for the application.

* When specified by the purchaser (e.g., for 2-wire 208 or 240 V circuit), the white or gray conductor shall be replaced by a red conductor

‡ When specified by the purchaser (e.g., for single-phase, 3-wire circuit), the blue conductor shall be replaced by a white or gray conductor.

Annex H (normative) – Evaluation of materials having characteristics differing from those in Tables 11 or 20

(See Clauses 4.10 and 8.22.4)

H.1 The temperature rating of a new material shall be established. A short-term air oven aging test shall then be developed.

H.2 Six specimens, in addition to those described in Clause 8.22.1, shall be tested to determine unaged and aged tensile and ultimate elongation values. The applicable test duration and temperature shall be in accordance with Table 51 for the temperature rating of the material. 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.

H.3 Using six additional specimens from the same source (reel, carton, etc.) as those used to determine the temperature rating of the material, determine the retention of ultimate elongation and tensile strength under the conditions chosen in Table 51. Subtract 15 percent from the average of the retention values obtained and round to the nearest 5 percent.

H.4 If the average of the retained values is 35 percent or greater than those established for unaged, then these aged values shall become the requirements for this material. If either the average of the retained tensile or elongation value is less than 35 percent, the value shall be considered to be too low for reliable testing. In this case, the temperature and test duration for 90°C rated material shall be 10 d at 100°C, and for 75°C rated material shall be 7 d at 100°C, and the ultimate elongation and tensile strength requirements shall be determined as described in Clause H.3.

H.5 When sufficient data have been collected, the material shall be added to this Standard, including a common air oven aging test, and the evaluation of temperature rating is no longer necessary for that material.

Annex I (normative) – Formulas for calculating insulation resistance of types having parameters other than as specified in this Standard

(See Clause 5.4.1.2)

$$IR_T = K_{15} \times (TFC)^{-(T-15)} \times \log_{10}\frac{D}{d}$$

Where:

IR_T = Insulation resistance in GΩ·m at any temperature T°C

K_{15} = Constant for the insulation material at 15°C in GΩ·m

TCF = Temperature correction factor coefficient for 1°C for the material (see 8.25.2 and Table 54)

D = Diameter over the insulation (any units)

d = Diameter under the insulation (units identical to D)

or

IR_T = Insulation resistance in MΩ·1000 ft at any temperature T°C

K_{15} = Constant for the insulation material at 15°C in MΩ·1000 ft

TCF = Temperature correction factor coefficient for 1°C for the material (see 8.25.2 and Table 54)

D = Diameter over the insulation (any units)

d = Diameter under the insulation (units identical to D)

Annex J (normative) – Alternative national markings

(See Clauses 6.1.1 and 7.3.2)

Products intended for use in specific national applications shall be permitted to bear the following alternative markings to those specified in Clause 6 of the Standard.

Markings on Wire (Clause 6.1.1)

Multinational Alternative	English	Spanish	French
SR	WEATHER RESISTANT	RESISTENTE A LA INTEMPERIE	RÉSISTANT AUX INTEMPÉRIES
	SUNLIGHT RESISTANT		RÉSISTANT À LA LUMIÈRE SOLAIRE
GR I AND GR II	GASOLINE AND OIL RESISTANT	RESISTENTE A LA GASOLINA Y AL ACEITE	RÉSISTANT À L'ESSENCE ET À L'HUILE
CT	CABLE TRAY USE	CABLES PARA CHAROLAS	UTILISER POUR LE CHEMIN DES CÂBLES
GRD or ⏚	GROUNDING ONLY	SOLO PUESTA A TIERRA	MISE À LA TERRE SEULEMENT
(−40C)	MINUS 40, (−40)	MENOS 40	MOINS 40 (−40)
AL, ALUM	ALUMINUM	ALUMINIO	ALUMINIUM
	SUBMERSIBLE PUMP CABLE	CABLE BOMBA SUMERGIBLE	CÂBLE POUR POMPE SUBMERSIBLE
	SHIELDED	BLINDADO	BLINDAGE

Markings on Packaging (Clause 7.3.2)

English	Spanish	French
For Wiring Only Between Equipment Located at Water Well Heads and Motors of Installed Deep-Well Submersible Water Pumps	Solamente para alambrado entre los equipos localizados a las cabezas de pozos y los motores de bombas sumergibles instaladas.	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.

Annex K (normative) – Requirements for Types RW75, R90, and RW90 rated 5000 V
(See Table 1)

K.1 General

Types RW90, R90, and RW90 rated 5000 V shall meet the requirements for these same types rated at 600 V and 1000 V as detailed within this Standard, except as noted in this Annex.

K.2 Construction

K.2.1 Conductors

Conductors shall meet the requirements of Clauses 4.1.1 – 4.1.6. Size range includes 8 AWG – 2000 kcmil.

K.2.2 Conductor shielding

Circuit conductors shall be shielded. The shielding shall consist of a layer of semi-conducting, nonmetallic material at least 0.06 mm (0.0024 inch) thick applied over the entire surface of the conductor and firmly bonded to the inner surface of the insulation. An extruded non-conducting stress-controlling material in conjunction with EPR insulations shall be acceptable if the relative permittivity is in the range of 10 – 1000 and the a-c voltage withstand stress in V/mm is 60,000/permittivity (1500/permittivity in v/mil). The conductor shield and the other wire or cable components shall not have any deleterious effect on each other.

K.2.3 Insulation

Insulation material shall be XL, EP, and EPCV and shall meet the requirements of Clause 4.2. The insulation thickness shall be in accordance with Table K.1.

The insulation thickness shall be in accordance with Table K.1.

K.2.4 Jackets

Thermoplastic and thermoset jackets shall meet the requirements of Clause 4.3. Jackets are required for EP insulated constructions and optional for all others.

The jacket thickness shall be in accordance with Table K.2.

K.3 Tests

K.3.1 Long-term insulation resistance in water

The test in Clause 5.3.1 shall be applicable to Types RW75 and RW90 rated 5000 V and shall be performed following the tests specified in Clause 5.22 and 5.23. The insulation resistance shall be not less than the value specified in Table K.3.

K.3.2 Insulation resistance in air for Type R90, rated 5000 V

The test shall be performed in accordance with the method specified in Clause 5.4.1, except that the insulation resistance (IR) measurement shall be taken after 24 h. If the IR is less than the value shown in Table K.4, but more than 50 percent of that value, the test shall be continued an additional period of 144 h. At the conclusion of the test, values shall be not less than those specified in Table K.4.

K.3.3 Dielectric voltage-withstand in water

All finished wires and cables rated 5000 V shall withstand, without breakdown of the insulation an application of 13,000 V for a period of 5 min.

K.3.4 Insulation Resistance in Water at 15°C

Finished wires and cables rated 5000 V shall have an insulation resistance of not less than the values in Table K.5 when tested at the prevailing water temperature and corrected to 15°C.

K.3.5 Resistivity of extruded semiconducting shielding

K.3.5.1 The conductor shield shall have a maximum volume resistivity of 1000Ω·m at 90°C when tested in accordance with Clause K.3.5.2.

K.3.5.2 A specimen of finished cable shall be cut in half longitudinally and the conductor removed. Four silver-painted electrodes shall be applied to the conductor shielding. The two potential electrodes shall be at least 50.8 mm (2 inches) apart. A current electrode shall be placed at least 25.4 mm (1 inch) beyond each potential electrode. The power of the test circuit shall not exceed 100 mW. This test may be made using only two electrodes spaced at least 50.8 mm (2 inches) apart, but for referee test purposes, the four-electrode test method shall be used. The test shall be made at room temperature with either a-c or d-c voltage. The volume resistivity shall be calculated as follows:

$$P = R \times \frac{0.4(D^2 - d^2)}{1000L}$$

or

$$P = R \times \frac{(D^2 - d^2)}{100L}$$

Where:

P = volume resistivity, Ω·m

R = measured resistance, Ω

D = diameter over the conductor shielding, mm or inches

d = diameter over the conductor, mm or in

L = distance between potential electrodes, mm or inches

Table K.1
Insulation Thicknesses for 5000 V Cables
(See Clause K.2.3)

Conductor size		Insulation thicknesses mm (mils)	
mm^2	AWG or kcmil	Average	Minimum
8.37 – 107	8 – 4/0	2.79 (110)	2.51 (98)
127 – 253	250 – 500	3.04 (120)	2.74 (108)
304 – 507	600 – 1000	3.30 (130)	2.97 (117)
557 – 1010	1250 – 2000	3.55 (140)	3.20 (126)

Table K.2
Jacket Thicknesses for 5000 V Cables
(See Clause K.2.4)

Conductor size		Jacket thicknesses mm (mils)	
mm^2	AWG or kcmil	Average	Minimum
8.37 – 13.3	8 – 6	0.76 (30)	0.60 (24)
21.2 – 85.0	4 – 3/0	1.14 (45)	0.91 (36)
107 – 507	4/0 – 1000	1.65 (65)	1.32 (52)
557 – 1010	1250 – 2000	2.41 (95)	1.93 (76)

Table K.3
Long-Term Insulation Resistance in Water for 5000 V Cables

(See Clause K.3.1)

Conductor size		Type RW75 Minimum IR at 75°C, GΩ·m	Type RW90 Minimum IR at 90°C, GΩ·m
mm^2	AWG or kcmil		
8.37	8 AWG	20	15
13.3	6	17.5	13
21.2	4	15	11.5
26.7	3	14	10.5
33.6	2	13	9.9
42.4	1	12	9.0
53.5	1/0	11	8.3
67.4	2/0	10	7.6
85.0	3/0	9.3	7.0
107	4/0	8.2	6.2
127	250 kcmil	8.3	6.2
152	300	7.7	5.8
177	350	7.3	5.4
203	400	6.9	5.1
253	500	6.3	4.7
304	600	5.8	4.3
355	700	5.4	4.1
380	750	5.2	3.9
405	800	5.0	3.8
456	900	4.8	3.6
507	1000	4.6	3.4
557	1250	4.8	3.6
608	1500	4.4	3.3
887	1750	4.1	3.1
1010	2000	3.9	2.9

Note:
K = 60 at 75°C.
K = 45 at 90°C.

Table K.4
Insulation Resistance in Air for Type R90, 5000 V Rated

(See Clause K.3.2)

Conductor size		Minimum IR at 90°C
mm²	AWG or kcmil	(GΩ·m)
8.37	8 AWG	7.6
13.3	6	6.6
21.2	4	5.7
26.7	3	5.3
33.6	2	4.9
42.4	1	4.5
53.5	1/0	4.1
67.4	2/0	3.8
85.0	3/0	3.5
107	4/0	3.1
127	250 kcmil	3.1
152	300	2.9
177	350	2.7
203	400	2.5
253	500	2.3
304	600	2.1
355	700	2.0
380	750	1.95
405	800	1.90
456	900	1.80
507	1000	1.70
557	1250	1.80
608	1500	1.65
887	1750	1.55
1010	2000	1.45
Note: *K=22.5.*		

Table K.5
Insulation Resistance in Water at 15°C

(See Clause K.3.4)

Conductor size		Minimum IR at 15°C, GΩ·m
mm²	AWG or kcmil	
8.37	8 AWG	2000
13.3	6	1750
21.2	4	1500
26.7	3	1400
33.6	2	1300
42.4	1	1200
53.5	1/0	1100
67.4	2/0	1000
85.0	3/0	930
107	4/0	820
127	250 kcmil	830

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Table K.5 Continued

Conductor size		Minimum IR at 15°C, GΩ·m
mm^2	AWG or kcmil	
152	300	770
177	350	730
203	400	690
253	500	630
304	600	580
355	700	540
380	750	520
405	800	500
456	900	480
507	1000	460
557	1250	480
608	1500	440
887	1750	410
1010	2000	390

Notes:

1) K = 6000.

2) The insulation resistance of finished wires or cables having a thermoset or thermoplastic covering shall be not less than 60 percent of that specified above.