UL 444

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Communications Cables

Underwriters Laboratories Inc. (UL)
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UL Standard for Safety for Communications Cables, UL 444

Third Edition, Dated March 29, 2002

The new and/or revised requirements are substantially in accordance with UL's Bulletin(s) on this subject dated April 22, 1998. The bulletin(s) is now obsolete and may be discarded.

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that have been revised and that have a future effective date are located after the Standard, and are preceded by a ″SUPERSEDED REQUIREMENTS″ notice.

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:

Canadian Standards Association
CSA C22.2 No. 214-02
Sixth Edition

Underwriters Laboratories Inc.
UL 444
Third Edition

Communications Cables

March 29, 2002

Approved
by
Standards Council
of Canada

Commitment for Amendments

This Standard is issued jointly by Canadian Standards Association (CSA) and Underwriters Laboratories Incorporated (UL). Amendments to this Standard will be made only after processing according to the Standards writing procedures by CSA and UL.

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.

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Preface

This is the common UL and CSA Standard for Communications Cables. It is the sixth edition of CSA C22.2 No. 214 and the third edition of UL 444. This edition of CSA C22.2 No. 214 supersedes the previous editions, published in 1994, 1990, 1988, 1986, and 1984. This UL edition supersedes the previous editions published in 1994 and 1990.

This common standard was prepared by Canadian Standards Association and Underwriters Laboratories Inc. The effort of UL 444/CSA 214 Harmonization Committee is greatly appreciated.

The previous Tables 2A, 2B, 3A, 3B, 10 and 11 have been deleted, and Table 10 and a new Table 13 have been added. Tables have been renumbered.

This standard was reviewed by the CSA Subcommittee on C22.2 No. 214, under the jurisdiction of the Technical Committee on Wiring Products and the Strategic Resource Group, and has been formally approved by the Technical Committee.

This standard will be submitted to the American National Standards Institute (ANSI) for publication as an American National Standard.

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 an IEC format, but is not based on, nor shall it be considered equivalent to, an IEC standard. This standard is published as an identical standard. An identical standard is a standard that is the same in technical content except for conflicts in Codes and Governmental Regulations. Presentation shall be word for word except for editorial changes.

Interpretations

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

UL Effective Date

As of March 29, 2002 all products Listed or Recognized by UL must comply with the requirements in this standard.

CSA Effective Date

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

Foreword (CSA)

The Canadian Standards Association (CSA) develops standards under the name Canadian Standards Association, and provides certification and testing under the name CSA International. CSA International provides certification services for manufacturers who, under license from CSA, wish to use the appropriate registered CSA Marks on certain products of their manufacture to indicate conformity with CSA Standards.

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

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

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

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

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

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

No Text on This Page

Foreword (UL)

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

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

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

D. A product that contains features, characteristics, components, materials, or systems new or different from those covered by the requirements in this standard, and that involves a risk of fire or of electric shock or injury to persons shall be evaluated using appropriate additional component and end-product requirements to maintain the level of safety as originally anticipated by the intent of this standard. A product whose features, characteristics, components, materials, or systems conflict with specific requirements or provisions of this standard does not comply with this standard. Revision of requirements shall be proposed and adopted in conformance with the methods employed for development, revision, and implementation of this standard.

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

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

Communication Cables

1 Scope

1.1 This standard applies to 60 – 250°C single- or multiple-conductor jacketed or unjacketed, integral or nonintegral cables and single or multiple coaxial cables for telephone and other communication circuits such as voice, data, and audio for on-premise customer systems. These cables are not prohibited from containing one or more optical fibre members. For the purpose of this standard, a coaxial cable or coaxial member conductor is a single conductor with a shield. For the purpose of this standard, a single- or multiple-conductor unjacketed cable is a cross-connect wire.

1.2 This standard applies to communications cables that are intended primarily for installation in accordance with Section 60 of the *Canadian Electrical Code* (CEC), *Part I*, and Article 800 of the *National Electrical Code* (NEC). They are rated for 300 V applications but are not so marked.

1.3 This standard does not apply to communication cords.

2 Definitions

2.1 The following definitions apply in this standard:

2.2 **BONDED METAL SHIELD** – A covering over the cable core assembly consisting of a metal tape whose outer surface is adhesively bound to a polymeric jacket over it.

2.3 **CAPABILITY TEST** – A test that is conducted periodically on a cable component, or on a completed cable, intended to be proof of adequate construction and processing, and that is repeated for verification.

2.4 **COAXIAL CABLE** – A cable having one or more coaxial members, each consisting of a conductor centered inside one or more outer conductors consisting of metal tubes or shields, separated from the central conductor by a dielectric material.

2.5 **COVERING** – A jacket, sheath, or armour.

2.6 **CROSS-CONNECT WIRE (CABLE)** – A single- or multiple-conductor construction consisting of insulated conductors without an overall jacket.

2.7 **DIELECTRIC** – An insulating (nonconducting) medium.

2.8 **EQUIVALENT GAUGE** – A round conductor AWG number used to designate a flat conductor that has a cross-sectional area equal to that of the round conductor.

2.9 **GROUND PLANE** – A partially encompassing shield provided to reduce stray electrical fields.

2.10 **INTEGRAL** – A single extruded layer that serves as both insulation and jacket.

2.11 **JACKET** – A continuous nonmetallic outer covering.

2.12 **MANUFACTURING AND PRODUCTION TEST** – A test performed on a length of wire before further processing and/or on a completed cable before shipment.

Note: Where in-line packaging is used, and where conformity of the packaged product can be demonstrated, the tests may be performed on a master reel of the assembled cable prior to application of the final jacket.

2.13 **SEMICONDUCTING** – A material whose resistivity at room temperature is in the range of 10^{-2}–10^{9} Ω •cm.

2.14 **SHIELD** – A conducting layer consisting of tape, braid, wire, or sheath, or a semiconducting layer.

2.15 **THERMOPLASTIC** – An insulation or jacket material that is capable of being repeatedly softened by heating and hardened by cooling through a temperature range characteristic of the material, and which in its softened state is capable of being shaped through the application of force.

Note: Examples of thermoplastic materials are polyethylene (PE), poly (vinyl chloride) (PVC), nylon, and polyethylene terephthalate (PET).

2.16 **THERMOSET** – A cross-linked insulating or jacketing compound that does not soften and flow on subsequent heating.

3 General

3.1 Reference publications

Where reference is made to other publications, such reference shall be considered to refer to the latest edition and all amendments published to that edition up to the time when the referencing standard is approved.

CSA Standards

C22.1-1998,
Canadian Electrical Code, Part I;

CAN/CSA-C22.2 No. 0-M91 (R1997),
General Requirements – Canadian Electrical Code, Part II;

C22.2 No. 0.3-96,
Test Methods for Electrical Wires and Cables

UL Standards

UL 1581-2001,
Reference Standard for Electrical Wires, Cables, and Flexible Cords;

UL 1666-2000,
Test for Flame Propagation Height of Electrical and Optical-Fiber Cables Installed Vertically in Shafts;

UL 1685-1997,
Vertical-Tray Fire-Propagation and Smoke-Release Test for Electrical and Optical-Fiber Cables.

ANSI/NFPA[1] Standard

70-2002,
National Electric Code.

ASTM[2] Standards

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

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

B 286-95,
Specification for Copper Conductors for Use in Hookup Wire for Electronic Equipment;

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

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

B 452-98,
Specification for Copper-Clad Steel Wire for Electronic Application;

B 869-96,
Specification for Copper-clad Steel Electrical Conductor for CATV Drop Wire;

D 573-99,
Standard Test Method for Rubber-Deterioration in an Air Oven;

D 5374-99,
Test Methods for Forced-Convection Laboratory Ovens for Evaluation of Electrical Insulation;

D 5423-99,
Specification for Forced-Convection Laboratory Ovens for Evaluation of Electrical Insulation;

G 151-00,
Standard Practice for Exposing Nonmetallic Materials in Accelerated Test Devices that Use Laboratory Light Sources;

G 153-00,
Standard Practice for Operating Enclosed Carbon Arc Light Apparatus for Exposure of Nonmetallic Materials.

NFPA[3] Standard

NFPA 262-1999
Standard Method of Test for Fire and Smoke Characteristics of Wire and Cables.

[1] American National Standards Institute/National Fire Protection Association.

[2] American Society for Testing and Materials.

[3] National Fire Protection Association.

3.2 Units of measurement

If a value for measurement is followed by a value in other units in parenthesis, the second value may be only approximate. The first stated value is the requirement.

3.3 General requirements

The requirements of CAN/CSA-C22.2 No. 0, when appropriate, apply to this standard.

4 Construction

4.1 Conductors

4.1.1 The conductors shall be solid or stranded, annealed, bare or metal-coated copper. The centre conductor of MPP, MPR, MPG, and MP coaxial cables made of copper-clad steel shall have 30 percent or higher conductivity in accordance with ASTM Standard B 452, and the centre conductor of CMP, CMR, CMG, CM, CMH and CMX coaxial cables made of copper-clad steel shall have 21 percent or higher conductivity in accordance with ASTM Standard B 869. If the insulation adjacent to the copper conductor is of a material that corrodes unprotected copper in the test described in Clause 6.1, the conductor shall be covered with a coating of tin complying with ASTM Standard B 33, of lead or lead-alloy complying with ASTM Standard B 189, of nickel complying with ASTM Standard B 355, of silver complying with ASTM Standard B 298, or of another metal or alloy (evaluation shall be required). Metal-coating a conductor on which the coating is not required for corrosion protection shall be permitted. When this is done, the 100 per cent coverage requirement of the relevant ASTM Standard shall be waived.

The maximum temperature rating of cables relative to the diameter and coating of solid copper conductors or copper conductor strands shall not be higher than those shown in Table 1.

4.1.2 For stranded conductors, the length of lay of the strands shall not exceed 20 times the calculated diameter over the assembled conductor for No. 19 – 6 AWG conductor, or 25 times for No. 30 – 20 AWG conductor. The direction of lay of the strands may be right- or left-hand.

4.1.3 The conductors shall be continuous when tested in accordance with Clause 5.2.

4.1.4 The size of the copper conductor shall be determined either by means of the resistance shown in Tables 2 and 3, or by means of the dimensions shown in Table 4. In case of dispute, the resistance method shall be the referee method.

4.1.5 Resistance shall be determined in accordance with Clause 6.16.

4.1.6 Dimensions shall be determined in accordance with Clause 6.17.

4.1.7 A joint in a solid conductor or in one of the individual wires of a stranded conductor shall be made in a skillful manner, shall be essentially smooth, and shall not have any sharp projections.

A joint in a stranded conductor may be made by:

a) Separately joining each individual wire; or

b) Machine brazing or welding of the conductor as a whole.

In either case, the resulting solid section of the stranded conductor shall be not longer than 13 mm (1/2 in), there shall be no sharp points, and the distance between brazes or welds in a single conductor shall not average less than 915 m (3000 ft) in any reel length of insulated single conductor.

A joint made before insulation is applied to a conductor shall not increase the diameter of the solid conductor or individual wire (strand). A joint made after insulating shall not increase the diameter of the solid conductor or individual wire (strand) by more than 20 per cent.

The insulation applied to joints after insulating shall be equivalent to that removed (heat-shrinkable tubing, bonded patch, and molding have been accepted but taping has not) and shall comply with the requirements in this standard.

4.1.8 Any section of a conductor that includes a factory joint shall have a breaking strength that is not less than 85 per cent of the breaking strength of an adjacent section of the conductor without a joint.

4.2 Insulation

4.2.1 Each conductor shall be insulated with one or more continuous layers of solid and/or expanded material. The insulation shall be uniform and shall not have any defects (bubbles, open spots, rips, tears, cuts, or foreign material) that are visible without magnification to normal or corrected-to-normal vision . The average thickness of the insulation and the minimum thickness at any point of the insulation are not specified. The average thickness of insulation used, including the average thickness of the tube portion of an air-gap coaxial member, shall be determined by means of an optical device. The method for measuring the thickness of insulation and for rounding off the results shall be as described in Clause 6.15.

4.2.2 The insulation in an air-gap coaxial member shall consist of a solid tube over a solid spacer (thread) that has a nominally circular cross-section, applied to the conductor helically in a continuous length (length of lay is not specified).

4.2.3 Each conductor, including the centre conductor for a coaxial member, shall meet the dc or ac spark test as described in Clause 5.1 after being insulated and before any subsequent operation. One hundred per cent of product shall be tested by the manufacturer at the factory.

4.2.4 The thickness of insulation at any point in a cable with a separable jacket (non-integral construction) shall be sufficient to meet the applicable manufacturing and production tests of Clause 5 and the capability tests of Clause 6. The thicknesses of the integral insulation (solid) and jacket in 2-, 3-, or 4-conductor flat, parallel cable shall be not less than as indicated in Table 5.

4.2.5 The insulated conductors shall be distinctly identified.

4.2.6 The insulated conductors shall be suitable for indoor use where normal conditions are such that cables may be subjected to maximum operating conditions from 60 – 250°C, inclusive. See Clause 6.3 for temperature rating requirements.

4.3 Optical fibre members

4.3.1 One or more glass fibres that are individually coated and buffered, jacketed either singly in a tight jacket, or in a group in a loose tube, or enclosed in a nonmetallic tape, wrap, or braid that provides complete coverage may be included along with the copper conductors.

4.3.2 An optical fibre member, or group of members, may include one or more metallic or nonmetallic strength members.

4.3.3 The construction of the glass fibre, the coatings, and the fibre jacket is not specified. The construction of nonmetallic tape, wrap, or braid is not specified. The construction of nonmetallic or non-current-carrying metal strength members is not specified.

4.3.4 Non-current-carrying metallic members included in optical fibre member(s) shall be electrically continuous, and shall meet the requirements of Clause 5.2.

4.4 Core assembly

4.4.1 A communications cable shall be essentially round or flat.

4.4.2 Two or more insulated conductors with or without one or more coaxial or optical fibre members shall be assembled to form a cable core. A cable may also consist of one or more coaxial member with or without optical fibre members. A round cable core consisting of 12 or fewer pairs, or 2, 3, or 4 single insulated conductors, may have the pairs or insulated conductors laid straight, but otherwise all conductors, groups of conductors, members, and groups of members shall not be laid straight. In any case, the length of lay is not specified. The direction of lay may be right- or left-hand and may be changed at intervals throughout the length of the cable. The use of fillers is optional. Different conductors and coaxial members may be insulated with different materials and the conductors in the cable may be of any mixture of sizes and stranding complying with Clause 4.2 on conductor insulation.

4.4.3 When optical fibre member(s) are assembled with other electrical conductors in a common layer, they shall be cabled with the same direction and length of lay as the electrical conductors; otherwise the direction and the length of lay is not specified.

Optical fibre members may include one or more non-current-carrying, electrically conductive members such as a metal strength element or a metal vapour barrier. The construction of these parts is not specified.

4.4.4 Defective Parts

4.4.4.1 The cable is not acceptable if the applicable factory dielectric strength test described in Clause 5.3 shows any defective pair having a breakdown of the insulation of either conductor to a shield.

4.4.4.2 A defective pair shall be any pair in which the following discontinuity and/or dielectric faults are revealed in testing by the cable manufacturer at the cable factory:

a) Discontinuity in either conductor of the pair determined by means of the test described in Clause 5.2;

b) One or more of the following dielectric breakdowns of the insulation determined by means of the applicable dielectric strength test described in Clause 5.3:

i) Conductor to conductor within the pair;

ii) Either conductor of the pair to any conductor outside the pair.

4.4.4.3 Cables that contain 200 or more pairs may contain acceptable defective pairs in a quantity that shall not exceed 0.5 per cent of the number of pairs marked on the tag, reel, or carton for the cable. Both ends of a cable in which there are one or more acceptable defective pairs shall be marked to warn of the presence of the defective pair(s). A notice such as a defective-pair tag shall be attached to each end of a cable in which there are factory-located defects. The notices shall identify the factory counting system (establish a direction for counting multiunits) and shall also identify each of the factory-found acceptable defective pairs according to layer (if pertinent to the counting system), multiunit number, unit colors, and pair color.

4.5 Spare pairs

Cables that contain 400 or more pairs may also contain spare pairs to make certain that the number of usable pairs equals or exceeds the number of pairs marked on the tag, reel, or carton. The quantity and position of the spare pairs are not specified. The colors of each spare pair shall be derived from the standard colors and shall be in unique combinations, and it shall not be possible to confuse them with the colors of the regular cable pairs.

4.6 Core binders

The core, any group of conductors, or several groups within the core may be bound by a nonmetallic binder. No other details of the core binders are specified.

4.7 Core wrap

The core, any group of conductors, or several groups within the core may be enclosed in a nonmetallic core wrap consisting of a serving, wrap, tape, or other construction. A metal shield as described in Clause 4.8.1 may serve as a core wrap. No other details of the core wrap are specified.

4.8 Shields

4.8.1 An electromagnetic shield is optional other than as the outer conductor in a coaxial member. One or more shields may be used in a given cable.

4.8.2 Where used, the shield(s) shall be electrically continuous and shall comply with the test requirements of Clause 5.2. To facilitate electrical bonding to ground of the shield(s), a continuous uninsulated, uncoated or metal coated, solid or stranded, copper conductor (drain wire) may be placed in contact with the shield(s). Uncoated copper drain wires shall not be used when aluminum-faced tape is used as a shield.

4.9 Jackets

4.9.1 A jacket consisting of a continuous nonmetallic outer covering consisting of a material complying with the requirements of Clauses 4.9.2 – 4.9.8 shall be applied over the cable construction.

4.9.2 The jacket shall be uniform and shall not have any defects (bubbles, open spots, rips, tears, cuts, or foreign material) that are visible without magnification to normal or corrected-to-normal vision .

4.9.3 All cables except those with a core wrap or a bonded metal shield shall comply with the peel test requirements of Clause 6.11.

4.9.4 Minimum point and minimum average jacket thickness shall be in accordance with requirements specified in Table 6 for jacket materials other than fluoropolymers, and Table 7 for fluoropolymer jacket materials. Maximum average thickness requirements shall be determined from the submitted sample.

For reference purposes, measurements shall be made by means of an optical instrument that is calibrated to read to at least 0.001 mm (0.0001 in).

4.9.5 Cables on which a jacket thicker than as indicated in Table 6 or 7 is necessary to enable the cable to comply with any applicable flame or other test described in these requirements shall be made with whatever greater thickness of jacket may be needed for this purpose. In this case, the minimum thickness at any point of the thicker jacket shall be not less than 80 per cent of the average thickness of the heavier jacket.

4.9.6 Jackets shall be capable of meeting the unaged and heat-aged requirements in accordance with Clause 6.8.

4.9.7 Tensile strength values of jacket materials in Tables 8 and 9 shall be determined in accordance with UL 1581 or CSA Standard C22.2 No. 0.3.

4.9.8 A jacket that is damaged to the point that the underlying assembly is exposed or that is opened for the purpose of repairing a conductor shall either be stripped and replaced in its entirety or have a second jacket applied over the first.

4.10 Metallic sheaths

An electrically continuous metal covering may be applied over the jacketed cable (see Note to Table 10).

4.11 Conductors for cable types MPP, MPR, MPG, and MP

Cables marked MPP, MPR, MPG, or MP shall meet the following additional requirements:

a) **conductor size** – the size of conductors in a multiple-conductor cable (coaxial cable excluded) shall not be smaller than No. 26 AWG; and

b) **coaxial cables** – coaxial cables may have copper-covered steel centre conductors with a minimum of 30 per cent conductivity.

5 Manufacturing and production tests

5.1 Spark test after insulating

5.1.1 No insulated conductor shall show more than an average of one fault per 915 m (3000 ft) in any reel length of single insulated conductor when spark tested as described in Clauses 5.1.2 – 5.1.16.

5.1.2 A dc or ac spark tester shall include a voltage source, an electrode, a voltmeter, a system for detecting, counting, and signalling faults, and the necessary electrical connections. The ability of the equipment to comply with the requirements in Clause 5.1.3 shall be certified at least annually by an accredited independent calibration service or its investigated equivalent such as by checking the test potential with an applicable voltmeter whose calibration is traceable to a nationally recognized standard.

5.1.3 The voltage source of a dc or ac spark tester shall maintain the following test voltage under all normal conditions of leakage current:

a) An essentially sinusoidal rms potential of 1750 V for an ac test;

b) 2500 V for a dc test. The current output of which the dc power supply is capable shall not exceed 5 mA. Any ripple shall not exceed 1 per cent. After a fault, the dc test voltage shall recover to the full test voltage in 5 ms or less, unless 610 mm (2 ft) or less of the product travels through the electrode in the time that it takes for the full voltage recovery;

c) For conductor gauge sizes 22 – 30 AWG which are to be used in cables without coaxial members but with foam or foam skin insulation and protected by bonded metal shields, the following spark test voltage may be used:

Conductor size	Test Voltage
22, 23 AWG	1500 V dc or 1050 V ac
24, 25 AWG	1200 V dc or 850 V ac
26 – 30 AWG	1000 V dc or 750 V ac

d) For cables without bonded metal shields, and with foam insulation that is not more than 0.20 mm (0.008 in) in average thickness and does not have a skin, the spark test voltage may be reduced to 1250 V ac or 1750 V dc, provided that the dielectric strength test voltage required by Clause 5.3.5 is met.

5.1.4 One terminal of a dc power supply and the core of a transformer and one end of its secondary winding in an ac supply shall be solidly connected to earth (ground). A voltage source shall not be connected to more than one electrode.

5.1.5 The electrode of a dc or ac spark tester shall be of the link- or bead-chain type, or shall be of another type that shall be evaluated. A link- or bead-chain electrode shall make intimate contact throughout its entire length with the surface of the insulated conductor being tested.

5.1.6 The bottom of a metal link- or bead-chain 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 in) greater than the diameter of the largest product being tested.

5.1.7 For a bead-chain electrode, the longitudinal and transverse spacings of the chains and the diameter of each bead shall comply with Table 11. The vertical spacing between beads in each chain shall not exceed the diameter of a bead and shall not be less than one quarter of the diameter of a bead.

5.1.8 The electrode shall be provided with an earthed (grounded) metal screen or an equivalent guard that protects operating personnel against electric shock from the electrode and associated live parts.

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

5.1.10 The equipment shall include a fault detector, fault counter, and a means of signalling each fault that occurs. When a fault is detected, the signal shall be maintained until the indicator is reset manually or automatically.

5.1.11 The fault detector shall detect a voltage breakdown of the insulation. A breakdown is characterized by arcing between the electrode and the earthed (grounded) conductor under test. A breakdown is defined as a decrease of 25 per cent or more from the test voltage applied between the electrode and the earthed (grounded) conductor.

5.1.12 The fault detector shall consist essentially of a trigger circuit that converts an input pulse of short duration to an output pulse of a magnitude and duration that reliably operates the fault-indicating circuit.

5.1.13 The fault counter shall accumulate the faults as a numerically increasing sequence and shall display the accumulated total. The response time of the fault counter shall result in the counter registering faults spaced no farther than 610 mm (24.0 in) apart for any combination of product speed and counter response time. The distance shall be calculated as follows:

Distance between faults =

Product speed expressed as 0.656 metres per minute x counter response times in seconds (inches per second or 0.2 x feet per minute)

5.1.14 For a dc test using a link- or bead-chain electrode, the surface of the insulated conductor shall be in intimate contact with the link- or bead-chains for a distance of 125 ±25 mm (5.0 ±1.0 in).

5.1.15 The length of a link- or bead-chain electrode is not specified for an ac test but the rate of speed at which the insulated conductor travels through the electrode shall keep any point on the product in contact with the electrode for not less than a total of 18 positive and negative crests of the ac supply voltage (the equivalent of a full 9 cycles of the ac supply voltage). The maximum acceptable speed of the product shall be determined for an ac test by means of whichever of the following formulae is applicable:

Metres per minute = 1/150 x frequency in hertz x electrode length in millimetres

Feet per minute = 5/9 x frequency in hertz x electrode length in inches

5.1.16 The conductor being tested shall be earthed (grounded) during the spark test. If the conductor coming from the pay-off reel is bare, the conductor shall be earthed (grounded) at the pay-off reel or at another point at which continuous contacts with the bare conductor, prior to the insulating process, is maintained, but that need not be tested for continuity or earthed (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 both the pay-off and take-up reels, unless each conductor is tested for continuity before the spark test is made and is 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.

5.2 Continuity

The metallic component under test shall be connected in series with an ac or dc source of voltage, less than 30 V, and a means of indicating an unbroken circuit (eg, an incandescent lamp, a bell, or a buzzer). Operation of the indicator shall be evidence of continuity of the component under test.

This test is required only on completed cable before shipment, or on master reels before packaging (put-up).

5.3 Dielectric strength

5.3.1 The dielectric strength requirement shall be chosen based on the construction (see Clauses 5.3.2 – 5.3.5; see Clause 6.21 for cross-connect wire) and shall be tested in one of the following ways by the cable manufacturer at the cable factory:

a) The jacketed cable shall be tested on each master reel before the final rewind operation, or as individual shipping lengths, or after the final rewind operation. A master reel is any reel containing a single length of finished cable that is intended to be cut into shorter lengths for shipping.

b) The assembled cable shall be tested before the overall jacket is applied. In this case, one shipping length from each master reel of the finished cable shall also be tested. If there is a dielectric breakdown of the insulation on any conductor in the finished cable in that length, 100 per cent of the finished cable on the master reel from which the length was taken shall be tested.

Note: *Where an ac voltage is used, the frequency shall be 48 – 62 Hz.*

5.3.2 For all cables except those described in Clauses 5.3.3 – 5.3.5, the insulation shall withstand, without breakdown, a voltage of 2.5 kV dc or 1.5 kV ac for a minimum of 2 s, applied between conductors and between conductors and shields (if present).

5.3.3 For cables with bonded metal shields with foam or foam-skin insulation and conductor gauge sizes 22 – 30 AWG, the foam or foam-skin insulation shall withstand for a minimum of 2 s, without breakdown, the following voltages applied between conductors:

Conductor size	Test voltage
22, 23 AWG	1500 V dc or 1050 V ac
24, 25 AWG	1200 V dc or 850 V ac
26 – 30 AWG	1000 V dc or 750 V ac

In addition, the insulation between the conductors and the bonded shield shall withstand, without breakdown, 5.0 kV dc or 3.0 kV ac for a minimum of 2 s.

5.3.4 For coaxial members, the insulation shall withstand, without breakdown, 2.5 kV dc or 1.5 kV ac for 2 s when the test potential is applied between the conductor and the shield, with the shield connected to earth (ground).

5.3.5 For cables without bonded metal shields, and having foam insulation that is not more than 0.20 mm (0.008 in) in average thickness and does not have a skin, the dielectric strength test voltage shall be 2000 V ac or 2850 V dc applied for at least 2 s.

6 Capability tests

6.1 Corrosion resistance of uncoated copper conductors

Uncoated copper conductors shall be removed from specimens of the finished cable and from specimens of insulated conductors aged at the elevated temperature for the length of time indicated in Clause 6.3 that applies to the insulating material on the conductor. A minimum of three unaged specimens and three aged specimens shall be tested. None of the specimens of the uncoated copper shall show any evidence of pitting or of corrosion compounds in a close visual examination without magnification with normal or corrected-to-normal vision. Normal oxidation darkening or other discoloration that leaves the texture of the surface of the copper unchanged shall be disregarded.

6.2 Crush resistance of insulation

6.2.1 An average force of at least the level indicated in Table 10 shall be necessary to crush the insulation on a conductor taken from the finished cable to the point that the conductor contacts the earthed (grounded) metal of the testing machine. The test shall be made on an insulated solid conductor as described below, with the results qualifying both solid and stranded conductors having the same form of insulation (solid or foamed) of the same material in the same thicknesses.

6.2.2 The following solid insulations shall be considered to have acceptable crushing strength without this test: solid insulations that are at least 0.15 mm (0.006 in) in average thickness and that are shown by test to have a tensile strength (unaged specimens) of at least 13.8 MPa (2000 lbf/in^2). All foamed insulation shall be tested.

6.2.3 The insulated conductors shall be removed from a sample length of the finished cable having solid conductors and individually straightened with the fingers. Specimens 180 mm (7 in) long shall be cut from the straight insulated conductors. Each of the five specimens shall be tested separately by being crushed twice between two 50 mm (2 in) wide, flat, horizontal steel plates in a compression machine whose jaws close at the rate of 5.0 ±0.5 mm/min (0.20 ±0.02 in/min). The edges of the plate shall not be sharp. The length of a specimen shall be parallel to the 50 mm (2 in) dimension of the plates, 25 mm (1 in) of the specimen shall extend outside of the plates at one end of the specimen, and 100 mm (4 in) of the specimen shall extend outside the plates at the other end of the specimen.

6.2.4 The plates shall be electrically connected together, to the metal of the testing machine, and to earth (ground). The specimens, the apparatus, and the surrounding air shall be in thermal equilibrium with one another at a temperature of 24 ±8°C throughout the test. The machine shall be started and the specimen subjected to the increasing force of the plates moving toward one another until a short circuit occurs (as indicated by a low-voltage indicator such as a buzzer, lamp, or LED) between the conductor in the specimen and one or both of the earthed (grounded) plates. The maximum force exerted on the specimen before the short circuit occurs shall be recorded as the crushing force for that end of the specimen.

6.2.5 After the short circuit occurs, the machine shall be reversed and the plates separated. The specimen shall be turned end for end, rotated 90°, reinserted (from the end opposite the one originally inserted) between the plates, and crushed. The two crushing forces shall be averaged for each specimen. The average of all ten of the crushing forces obtained for the five specimens shall be used as the value to compare with the requirement in Table 10.

6.3 Insulation unaged and heat-aged requirements

6.3.1 For cables to be rated 60°C

Specimens of solid single-layered unaged insulation removed from finished insulated conductors shall have a minimum tensile strength of 8.3 MPa (1200 lbf/in^2) and a minimum elongation of 100 per cent when tested in accordance with the relevant test procedures in CSA Standard C22.2 No. 0.3 and UL 1581. Specimens of foam and multiple-layered insulation shall be required to comply only with the flexibility test described below. For the crush resistance test of insulation to be waived (see Clause 6.2.2), the minimum tensile strength shall be 13.8 MPa (2000 lbf/in^2).

For all insulated conductor types, specimens 305 mm (13 in) long shall be placed in a circulating-air oven conforming to ASTM Standard D 5423 (Type II ovens) and D 5374 and maintained at a temperature of 100 ±2°C for 7 d or 121±2°C for 48 h. A minimum of six specimens shall be tested. Insulations with band-marking inks may have the ink removed before specimens are aged. After removal from the oven, the specimens shall rest for 16 – 96 h in still air at room temperature and then wound tightly, for six close turns, around a mandrel having a diameter no greater than that of the insulated conductor under test. The insulation shall be examined for cracks using a lens having magnification of 5X. The insulated conductor shall then be straightened, one side of the tube of insulation sliced off with a knife or razor-blade, and the conductor removed for examination of the inner surface of the insulation. There shall be no cracks on either the inside or the outside surface of the insulation. In the event of test results that do not comply, an additional minimum of six specimens shall be tested, all of which shall comply with the requirement. For the crush resistance test of insulation to be waived (see Clause 6.2.2), the minimum tensile strength shall be 13.8 MPa (2000 lbf/in^2).

6.3.2 For cables to be rated 75 - 250°C

6.3.2.1 Specimens of solid single-layered insulations removed from finished insulated conductors shall meet the appropriate values of unaged elongation and tensile strength shown in Table 8 when tested in accordance with the relevant test procedures in CSA Standard C22.2 No. 0.3 and UL 1581, except that for insulations with band-marking inks the ink may be removed before specimens are aged.

6.3.2.2 Specimens of solid single-layered insulations except PVDF rated 125°C shall meet the appropriate values of aged retention of elongation and tensile strength shown in Table 9 when tested in accordance with the relevant test procedures in CSA Standard C22.2 No. 0.3 and UL 1581.

6.3.2.3 PVDF rated 125°C, foamed, and multi-layered insulations shall meet the requirements of Clause 6.3.2.4.

6.3.2.4 Specimens of PVDF rated 125°C, foamed, or multi-layered insulations 305 mm (13 in) long shall be placed in a circulating-air oven conforming to ASTM Standards D 5423 (Type II ovens) and D 5374 and aged for the appropriate time and temperature shown in Table 9 for the insulation adjacent to the conductor. When the insulation is foamed, the aging shall be as specified for the solid insulation. A minimum of six specimens shall be tested. Insulations with band-marking inks may have the ink removed before specimens are aged. After removal from the oven, the specimens shall rest for 16 – 96 h in still air at room temperature and then be wound tightly, for six close turns, around a mandrel having a diameter no greater than that of the insulated conductor under test. The insulation shall be examined for cracks using a lens having magnification of 5X. The insulated conductor shall then be straightened, one side of the tube of insulation sliced off with a knife or razor-blade, and the conductor removed for examination of the inner surface of the insulation. There shall be no cracks on either the inside or the outside surface of the insulation.

6.4 Insulation shrinkback

6.4.1 Immediately before testing, 200 mm (8 in) specimens shall be cut from the centre of a 1.5 m (60 in) length of insulated conductor and then reduced to 150 mm (6 in) by trimming each end of the specimen. For a coaxial cable with a skin over the insulation, the skin shall not be removed. The 150 mm (6 in) specimen shall be placed on a felt bed or on a layer of preheated talc in a circulating-air oven conforming to ASTM Standards D 5423 (Type II ovens) and D 5374 and held for 1 h at a temperature specified in Clauses 6.4.2 and 6.4.3. At the end of the conditioning period, the specimen shall cool to room temperature. The total shrinkback of the insulation, which is the sum of the shrinkback measured at both ends of the conductor, shall not exceed 9.5 mm (3/8 in). A minimum of three specimens shall be so tested. In the event of test results that do not comply, an additional three specimens shall be tested, all of which shall comply with the requirement.

6.4.2 For cables to be rated 60 – 105°C, the air oven temperature shall be 121 ±2°C. For materials that melt or deform at this temperature, the test shall be conducted at 115 ±2°C.

6.4.3 For cables to be rated 125 – 250°C, the air oven temperature shall be 150 ±2°C.

6.5 Insulation cold bend

Specimens of the insulated conductor and a cylindrical mandrel matched to the diameter of the insulated conductor (see Table 12) shall be conditioned at a temperature of −20 +3, −2°C for not less than 4 h. While still at this temperature, the conductor shall be wound five close turns around the mandrel at a rate of 4 – 6 s per turn. The insulation shall show no visible cracks under normal or corrected-to-normal vision without magnification. A minimum of three specimens shall be so tested. In the event of test results that do not comply, an additional minimum of three specimens shall be tested, all of which shall comply with the requirement.

6.6 AC leakage current through overall jacket

6.6.1 The rms current flow through the overall jacket on one specimen of the finished cable shall not exceed 10 mA when a 48 – 62 Hz essentially sinusoidal rms potential of 1500 V is applied as described in Clauses 6.6.2 and 6.6.3. The test potential shall be applied between all of the conductors and any shield(s) connected together and an earthed (grounded) metal foil that is in intimate contact with the centre 150 mm (6 in) of the outside surface of a specimen of any convenient length.

6.6.2 The apparatus shall consist of a circuit breaker, current meter, or other means of indicating an rms current of 10 mA flowing in the test circuit. The test potential shall be supplied by a transformer.

6.6.3 The applied rms potential shall be increased from near zero at an essentially uniform rate that results in 1500 V being applied in 30 s. The potential shall be held constant at 1500 V for 60 s and shall then be reduced to near zero at the rate mentioned above. The cable shall not be acceptable if the rms current through the jacket on the single specimen exceeds 10 mA at any time while the test potential is being increased, held, or decreased.

6.7 Durability of printing

6.7.1 All cable types with surface-applied markings of ink shall meet the requirements of Clauses 6.7.2 – 6.7.7.

6.7.2 The test apparatus shall consist of the following:

a) A forced-air oven complying with ASTM Standard D 573; and

b) A 450 ±5 gram (1 lb ±1%) weight having a layer of craft felt approximately 1.2 mm (0.05 in) thick securely attached to a machined flat surface with dimensions of 25 x 50 mm (1 x 2 in).

Note: *For the purpose of this test, any commerically available type of felt consistency may be used.*

6.7.3 Two 300 mm (12 in) specimens of the finished wire bearing the surface-applied markings shall be required.

6.7.4 One specimen shall be heated in a forced-air oven at the temperature and for the period specified for the rated product in Clause 6.8. Upon removal from the oven, the specimen shall be allowed to rest at room temperature for a period of 1 h.

6.7.5 The specimen shall then be laid on a solid flat surface with the printing up. The weight having the 50 mm (2 in) dimension with the attached felt shall be slid back and forth over the length of the specimen. This operation shall be repeated two more times. The time to perform the three back and forth cycles shall be 5 – 10 s.

6.7.6 The procedure described in Clause 6.7.5 shall be performed on the as-receved specimen conditioned at 23 ±5°C.

6.7.7 The printing on both samples shall remain legible.

6.8 Unaged and heat-aged requirements of jacket

6.8.1 Specimens of jacket removed from completed cable shall meet the appropriate values shown in Table 8.

6.8.2 For cables to be rated 60°C, jacket material removed from a length of finished cable shall meet the aging test as follows: 7 d, 100 ±2°C, and at least 50 per cent retention of the unaged elongation and 75 per cent retention of unaged tensile strength when six specimens are tested in accordance with the relevant test procedures in CSA Standard C22.2 No. 0.3 and UL 1581, with the following modifications:

a) Jackets thinner than 0.46 mm (0.018 in) average, 0.36 mm (0.014 in) minimum at any point shall be buffed only to remove imperfections, not natural indentations.

b) Cables with an overall diameter not greater than 5.1 mm (0.200 in) may have their jackets tested as tubular specimens rather than as die-cut specimens. Tubular specimens shall not be used for larger cables.

6.8.3 For jackets to be rated 75 – 250°C, a minimum of six specimens shall be aged for the length of time at the temperature shown in Table 9 and tested in accordance with the relevant procedures in CSA Standard C22.2 No. 0.3 and UL 1581, with the following modifications:

a) Jackets thinner than 0.46 mm (0.018 in) average, 0.36 mm (0.014 in) minimum at any point shall be buffed only to remove imperfections, not natural indentations.

b) Cables with an overall diameter not greater than 5.1 mm (0.200 in) may have their jackets tested as tubular specimens rather than as die-cut specimens. Tubular specimens shall not be used for larger cables.

Minimum retention of elongation and tensile strength requirements in Table 9 shall be used as pass criteria. This shall apply to all jacket materials except PVDF rated 125°C. For these materials, the flexibility test described in Clause 6.9 shall be used.

6.8.4 For cables to be rated 75 – 105°C, the maximum cable rating shall be that of the insulation, provided that the jacket rating is not greater than 15°C below the cable rating.

6.8.5 For cables to be rated 125 – 250°C, the lowest of the insulation or jacket ratings shall determine the cable rating.

6.9 Flexibility (PVDF jackets rated 125°C only)

6.9.1 Aged specimens of PVDF jackets rated 125°C in place on the cable shall not show any cracks on either the inside or outside surface after specimens are wound onto a cylindrical mandrel of the diameter indicated in Clause 6.9.2. A minimum of three specimens shall be tested. In the event of test results that do not comply, an additional minimum of three specimens shall be tested, all of which shall comply with the requirement.

6.9.2 The specimens that are to be aged shall be conditioned in accordance with CSA Standard C22.2 No. 0.3 or UL 1581 for the length of time and at the temperature indicated for the jacket material in Table 9. The conditioning shall be followed by 16 – 96 h of rest in still air at room temperature before the specimens are wound onto a mandrel. The aged specimens shall be wound at room temperature for six complete turns (adjacent turns touching) onto a circular mandrel having a diameter twice that of the diameter over the overall jacket. Each specimen shall be unwound before being examined.

6.10 Cable cold bend

6.10.1 Specimens of finished cable shall be conditioned to a temperature of −20 +3, −2°C for a period of 4 h and, while still at this temperature, wound three close turns around a cylindrical mandrel having a diameter as shown in Clause 6.10.2. (If the mandrel is metal, it shall be conditioned at the same temperature.) The jacket and shields (if present) shall show no visible cracks when examined under normal or corrected-to-normal vision. After removal of the test sample from the cold chamber, the rate of bending shall be such that the entire cycle of three bends for small cables up to 3.3 cm (1.3 in) diameter is completed in 30 s and for larger cables in 60 s after removal from the cold chamber. As an alternative the test may be performed in the cold chamber. A minimum of three specimens shall be so tested. In the event of test results that do not comply, an additional minimum of three specimens shall be tested, all of which shall comply with the requirement.

6.10.2 The mandrel diameter shall be a multiple (x) of the diameter over the outside of the cable and shall be based on cable construction as follows:

Cable Construction	Mandrel
No shield(s)	8x
Shield(s) other than those over the completed cable core	12x
Any shield (bonded or unbonded) over the completed cable core	15x

6.11 Jacket peel test

6.11.1 The overall jacket on a cable not having an overall metal shield or a nonmetallic core wrap shall be capable of being removed (stripped) without any tearing or other damage to the insulation. The jacket shall be peeled from the cable in 30 s or less time by a weight exerting 13.3 N (3 lbf) when specimens of the finished cable are tested as described in Clauses 6.11.2 – 6.11.4. A minimum of three specimens shall be so tested. In the event of test results that do not comply, an additional minimum of three specimens shall be tested, all of which shall comply with the requirement.

6.11.2 Specimens of 1.2 m (4 ft) length shall be cut from a straight sample length of finished cable that is constructed without a core wrap or shield. Both ends of each specimen shall be cut clean and square. The specimens, the apparatus, and the surroundings shall be in thermal equilibrium with one another at a temperature of 24 ±8°C throughout the test.

6.11.3 The jacket on each specimen shall be slit longitudinally. Cables whose outside diameter is at least 12.7 mm (0.5 in) shall have two slits 180° apart, and smaller cables shall have a single slit. Each cut shall be straight and parallel to the longitudinal axis of the cable and shall extend from one end of the cable to the other. At one end of each specimen, the entire jacket (cable that is slit once) or one half of the jacket (cable with two slits) shall be rolled or folded down over itself a distance of about 50 mm (2 in). The cable assembly thus bared shall be secured in a clamp or other support fixture that does not disturb the circular cross section of the assembly. The cable shall hang down below the support with the longitudinal axis of the cable vertical. A rod, pointer, or other indicator that does not touch the cable shall be adjusted to mark the top of the rolled-down or folded-down portion of the jacket.

6.11.4 A weight that exerts 13.3 N (3 lbf) shall be clamped or otherwise attached to the midpoint of the cut end of the rolled-down or folded-down portion of the jacket. After being attached, the weight shall be released to exert its downward pull on the jacket tending to strip more of the jacket from the cable. The time that it takes for the weight to strip 915 mm (36 in) of jacket from the cable, as measured belowthe indicator, shall be recorded. The cable is not acceptable if more time than 30 s is required for 915 mm (36 in) of jacket to be stripped from the cable.

6.12 Sunlight resistance of jacket of outdoor Type CMX cable

6.12.1 The overall jacket on Type CMX cable that is smaller in diameter than 6.35 mm (0.25 in) and is surface or tape marked "outdoor" shall be acceptable for exposure to sunlight if the ratio of the average tensile strength and ultimate elongation of five conditioned (300 h) specimens of the overall jacket to the average tensile strength and ultimate elongation of five unaged specimens of the overall jacket is 0.85 or more when the jacket is tested as outlined in Clauses 6.12.2 – 6.12.7.

6.12.2 Five samples of complete cable that is not larger in overall diameter than 13 mm (0.5 in) or five longitudinally halved, thirded, or quartered samples of the overall jacket that have been removed from larger finished cable and retain their original shape (they shall not be flattened) shall be mounted vertically in the specimen drum of carbon-arc-radiation and water-spray exposure equipment that is similar to the Type D apparatus described in ASTM G 151 and G 153. The outer surface of the jacket shall face the arcs. The samples shall be centred between the top and bottom of the drum. The drum of the apparatus used shall be 787 mm (31 in) in diameter (the diameter from the face of a sample on one side of the drum to the face of a sample on the opposite side of the drum shall be about 762 mm (30 in)). The drum shall also be 450 mm (17-3/4 in) high and shall revolve at the rate of 1 r/min. The apparatus shall have arcs between two sets of vertical carbon electrodes that are 13 mm (1/2 in) 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 2750 angstrom units or 275 nm and whose transmission improves to 91 per cent at 3700 angstrom units or 370 nm. The same horizontal plane shall bisect both arcs and intersect each sample at its midpoint. The globes shall be replaced after whichever of the following occurs first: either 2000 h of use or 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.

6.12.3 Radiation from the arcs shall be kept by positive, nonmakeshift means from reaching persons within sight of the apparatus. Ventilation shall be provided to keep the products of combustion in the 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.

6.12.4 Means shall be provided to enable each sample to pass through a fine spray of water once during each revolution of the drum in the cycle of 3 and 17 min, repeated as noted in Clause 6.12.5. The water shall be clean, its pH shall be 6.0 – 8.0, its temperature shall be 16 ±5°C, and the water shall not be recirculated unless these conditions are maintained. While the arcs are in operation but the spray is off, the equilibrium black-panel temperature of the drum shall be 63 ±5°C.

6.12.5 With the drum revolving continuously at 1 r/min, with the arcs operating continuously and each carrying a current of 15 – 17 A at a drop in rms potential of 120 – 145 V, and with prudent attention to the risk to eyesight and to the other health risks presented by the arcs and the products of the 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 operation with each sample 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 2-h sequence shall be repeated resulting, in turn, in a total elapsed operating time of 300 h. The apparatus shall be turned off after the total operating time of 300 h. The samples shall be permitted to cool to room temperature before being removed from the drum for testing.

6.12.6 Die-cut specimens shall be prepared from the overall jacket conditioned in the apparatus. The surface facing the arcs shall not be buffed, split, skived, or planed away. Die-cut specimens shall also be prepared from unaged samples of the overall jacket taken from the finished cable.

6.12.7 The five conditioned specimens of the overall jacket and the five unaged specimens of the overall jacket 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 unaged specimens. The jacket shall not be acceptable if either the tensile strength or ultimate elongation ratio is less than 0.85.

6.12.8 As an alternate to the sunlight resistance test procedure described above, the xenon arc method described in CSA Standard C22.2 No. 0.3 or UL 1581 may be used.

6.13 Cold impact of outdoor Type CMX cable

6.13.1 After being conditioned for 4 h in circulating air that is precooled to and maintained at a temperature of −10 ±2°C, the jacket and insulation of finished Type CMX cable that is smaller in diameter than 6.35 mm (0.25 in) and is surface-marked or designated by a marker tape as “outdoor” shall not crack when specimens of the complete cable are subjected to the energy of a free-falling flat-faced circular weight that impacts the cable at the point at which the cable is laid on a flat, horizontal oak or equivalent anvil. The test shall be conducted and the results evaluated as described in Clauses 6.13.2 – 6.13.10.

6.13.2 The impact anvil shall consist of a 200 mm (8 in) section of 2 x 4 lumber [actual cross section measures 38 mm by 89 mm (1-1/2 in by 3-1/2 in)] consisting of the following or its investigated equivalent, with the grain running lengthwise: Clear-grade red or white oak having a specific gravity of 0.57 (green) to 0.67 (dry). The anvil shall be secured to a concrete floor, the framework of the building, or another solid support.

6.13.3 The impact energy shall be provided by a weight in the form of a circular steel cylinder having a diameter of 25 mm (1.0 in) and a flat impact face that is perpendicular to the longitudinal axis of the weight and has rounded edges. The weight of 0.3 kg (2/3 lb) shall be 76.2 mm (3.0 in) long to enable the weight, when dropped from the height indicated in Clause 6.13.8, to supply an energy of 2.7 J (24 in lbf) to the cable.

6.13.4 The impact specimens shall consist of ten separate 380 mm (15 in) sections cut from a straight sample length of the complete finished cable.

6.13.5 The specimens shall be cooled for 4 h in circulating air that is precooled to and maintained at a temperature of −10 ±2°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 ±8°C through the test.

6.13.6 At the conclusion of the 4 h of cooling, the impact weight shall be supported with its lower face horizontal. A vertical line through the centres of gravity of the impact weight and the stationary anvil shall be coincident with a vertical line through the dimensional centre of the lower face of the impact weight and the dimensional centre 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 cable. The rails or other guide(s) shall not interfere with the free fall of the impact weight. A mechanism shall be provided at the top of the guide(s) for releasing the impact weight to fall freely through a height of 915 mm (36 in) and strike the cable. A means shall also be provided to keep the weight from striking the cable more than once during each drop.

6.13.7 The ten test specimens of the cable shall be individually removed from the cold chamber and tested in succession, each within 15 s of its removal from the chamber. For the first specimen, the impact weight shall be secured several cable diameters above the anvil, and the specimen shall be placed and secured on the anvil with the longitudinal axis of the specimen horizontal, parallel to thelongitudinal axis of the oak anvil (with the grain), and in the vertical plane containing the coincident vertical lines mentioned in Clause 6.13.6.

6.13.8 The position of the impact weight shall be adjusted to place the lower face of the weight 915 mm (36 in) above the upper surface of the first specimen of the cable. The impact weight shall be released from this height, shall fall freely in the guide(s), shall strike the specimen once, and shall then immediately be raised to and secured at the 915 mm (36 in) height. Each of the remaining nine specimens shall be tested likewise from this height.

6.13.9 After each specimen has been impacted, and with a minimum of handling, the specimens shall each be unsecured from the anvil and placed on a horizontal surface away from the apparatus, where they are to rest undisturbed for at least 4 h in still air to warm to a room temperature of 24 ±8°C before being examined for inside and outside surface cracks. The specimens shall then be disassembled and examined further for inside and outside surface cracks in the jacket and in any of the insulation. Cracking on the inside surface of the jacket or insulation can be detected as circumferential depressions in the outer surface of a specimen of material other than a fluoropolymer. Circumferential depressions in a fluoropolymer surface are likely to be yield marks (locally stronger points) rather than indicators of cracking. The examinations shall be made without magnification with normal or corrected-to-normal vision.

6.13.10 The cable shall not be acceptable if any of the cracking described in Clause 6.13.9 is visible in the jacket or insulation of more than two of the ten specimens.

6.14 Flame and smoke requirements

Note: *Appendix A gives guidelines for sample selection. Appendix B gives permitted cable substitutions.*

6.14.1 Types MPP and CMP shall comply with the test described in NFPA Standard 262.

6.14.2 Types MPR and CMR shall comply with the test described in UL 1666.

6.14.3 Types MPG and CMG shall comply with the FT4 test described in Clause 4.11.4 of CSA Standard C22.2 No. 0.3 or with the FT4/IEEE 1202 type of flame exposure (smoke measurements are not applicable) described in UL 1685. The length of char shall not exceed 1.5 m.

6.14.4 Types MP and CM, and cross-connect wire, shall comply with the UL flame exposure (smoke measurements are not applicable) described in UL 1685. The cable shall not exhibit damage that reaches the upper end of any sample (a maximum of 244 cm or 8 ft, 0 in).

6.14.5 Types CMX and CMUC shall comply with the VW-1 flame test described in Section 1080 of UL 1581.

6.14.6 Type CMH shall comply with the FT1 test described in Clause 4.11.1 and Appendix B of CSA Standard C22.2 No. 0.3, or with the vertical flame/FT1 test described in Section 1060 of UL 1581.

6.15 Measuring thickness of insulation and rounding off the results

6.15.1 Thickness measurements of insulation having an average thickness or minimum thickness at any point of not more than 0.152 mm (0.006 in), including any skin, shall be made by means of a micrometer microscope or other optical instrument that is calibrated to read directly to at least 0.001 mm (0.0001 in). Otherwise, a simply manipulated optical device that is accurate to 0.01 mm (0.001 in) may be used, with each measurement recorded to the nearest 0.01 mm (0.001 in).

6.15.2 The conductor and any covering over the insulation or skin shall be removed from the finished insulated conductor. A thin slice of the insulation plus any skin shall then be cut perpendicular to the longitudinal axis of the resulting hollow tube. Measurements shall be taken of the maximum and minimum wall thicknesses of the slice. The recorded maximum and minimum thicknesses shall be added together and divided by 2 without any rounding off of the sum, but with the resulting average rounded off (see Clauses 6.15.3 – 6.15.5) to the same degree as specified in Clause 6.15.1 for the recorded measurements. The average thickness so determined and the recorded minimum thickness shall be taken as the average and minimum-at-any-point thicknesses that are to be compared with the thicknesses established for the construction.

6.15.3 Rounding off to the nearest 0.0001:

a) A figure in the fourth decimal place shall remain unchanged if

i) the figure in the fifth decimal place is 0 – 4 and the figure in the fourth decimal place is odd or even; or

ii) if the figure in the fifth decimal place is 5 and the figure in the fourth decimal place is even (0, 2, 4, and so forth).

b) A figure in the fourth decimal place shall be increased by 1 if

i) the figure in the fifth decimal place is 6 – 9 and the figure in the fourth decimal place is odd or even; or

ii) the figure in the fifth decimal place is 5 and the figure in the fourth decimal place is odd (1, 3, 5, and so forth).

6.15.4 Rounding off to the nearest 0.001:

a) A figure in the third decimal place shall remain unchanged if

i) the figure in the fourth decimal place is 0 – 4 and the figure in the third decimal place is odd or even; or

ii) if the figure in the fourth decimal place is 5 and the figure in the third decimal place is even (0, 2, 4, and so forth).

b) A figure in the third decimal place shall be increased by 1 if

i) the figure in the fourth decimal place is 6 – 9 and the figure in the third decimal place is odd or even; or

ii) the figure in the fourth decimal place is 5 and the figure in the third decimal place is odd (1, 3, 5, and so forth).

6.15.5 Rounding off to the nearest 0.01:

a) A figure in the second decimal place shall remain unchanged if

i) the figure in the third decimal place is 0 – 4 and the figure in the second decimal place is odd or even; or

ii) if the figure in the third decimal place is 5 and the figure in the second decimal place is even (0, 2, 4, and so forth).

b) A figure in the second decimal place shall be increased by 1 if

i) the figure in the third decimal place is 6 – 9 and the figure in the second decimal place is odd or even; or

ii) the figure in the third decimal place is 5 and the figure in the second decimal place is odd (1, 3, 5, and so forth).

6.16 Conductor resistance

6.16.1 Resistance measurements shall be made by testing in accordance with the relevant test procedure of CSA Standard C22.2 No. 0.3 or UL 1581.

6.16.2 For temperatures other than 20 and 25°C, temperature factors for adjusting the dc resistance of conductors shall be made according to Table 1 of CSA Standard C22.2 No. 0.3 or Table 220.1 of UL 1581.

6.16.3 The dc resistance of each cabled conductor in a finished cable shall not exceed the value in Table 2 or 3 when multiplied by the appropriate factor Table 13.

6.17 Conductor diameter

Measurements of the diameter of a solid conductor or of a wire (strand) from a stranded conductor shall be made over the metal-coated or uncoated copper by optical means or by means of a machinist's micrometer caliper having flat surfaces on both the anvil and the end of the spindle. In either case, the equipment shall be calibrated to read directly to at least 0.01 mm (0.001 in) with each division of a width that facilitates estimation of each measurement to 0.001 mm (0.0001 in). The maximum and minimum diameters at a given point on the solid conductor or on the strand shall each be recorded to the nearest 0.001 mm (0.0001 in), added together, and divided by 2 without any rounding off of the sum or resulting average.

6.18 Compressive loading test for Type CMUC

6.18.1 A minimum of three specimens, each tested separately, shall be placed between parallel steel plates of a compression machine whose jaws close at a rate of 5.0 ±0.5 mm/min (0.02 ±0.02 in/min). The dimensions of the lower plate shall be such that the test specimen is completely supported during the test, but are otherwise not specified. The dimensions of the upper plate shall be such that it completely covers the steel disk it will be brought to bear down on, but are otherwise not specified. Both plates shall be free of sharp edges and burrs. A 0.5 m (1.6 ft) specimen of finished Type CMUC cable that has been hand-folded back on itself to simulate a right-angle turn shall be placed on the lower plate. A 150 mm (6.0 in) square of commercial carpet, consisting of 300 g/m^2 of nylon with 950 g/m^2 of foam backing, shall be placed over the specimen. A steel disk 13 mm (0.5 in) in diameter, 13 mm (0.5 in) thick, shall be placed over the carpet square and centred over the cable fold. The plates of the compression machine shall be brought together such that they bear down on the steel disk with a force of 1.3 kN (290 lbf) for a period of 3s, and then released. The cycle of applying and releasing the compressive force shall then be repeated four more times. After the five compressive load cycles, the specimen cable shall comply with the dielectric strength test described in Clause 6.18.2 as applicable. The test specimens shall not be straightened between the compressive load cycles or before the dielectric strength test. For cable not designed to be folded, this test shall be performed without folding the specimens.

6.18.2 Specimens of nonshielded Type CMUC cable that have been subjected to the compressive loading test described in Clause 6.18.1 shall be immersed in water for 1 h, with between 153 mm (6 in) and 203 mm (8 in) length submerged to either side of the compressed area. The ends of the specimens shall be kept dry, and shall extend a minimum of 33 mm (1.3 in) above the water. The cable shall withstand, without breakdown, the application of a 48 – 62 Hz sinusoidal or nearly sinusoidal rms potential of 1.0 kV between conductors, and between all conductors and the water for 60 s. The applied potential shall be increased from near zero at a uniform or nearly uniform rate that is not less than 100 per cent of the potential rating of the wire or cable in 60 s, and is not more than 100 per cent in 10 s (the rate of increase is not to exceed 500 V/s in any case.

6.19 Heat shock test for cross-connect wire

The test method shall be as described in the applicable clauses in CSA Standard C22.2 No. 0.3 and in UL 1581. The insulation shall be aged in a circulating-air over conforming to ASTM Standards D 5423 (Type II ovens) and D 5374 for 1 h at the temperature of 100 ±1.0°C (212.0 ±1.8°F) for cables rated 60°C. For cables rated above 60°C, the conditioning temperature shall be as specified in Table 9. The mandrel diameter shall be 1.59 mm (0.062 in). A minimum of three specimens for each insulation type shall be tested. The insulation shall not show any cracks on the inside or outside surface after being wound onto mandrels in the manner described in 540.1 and 540.2 of UL 1581. In the event of test results that do not comply, an additional minimum of six specimens shall be tested, all of which shall comply with the requirement.

6.20 Deformation test for cross-connect wire

The test method shall be as described in the applicable clause in CSA Standard C22.2 No. 0.3 and in Section 560 of UL 1581. The insulation shall be aged in an air oven at 100.0 ±1.0°C (212.0 ±1.8°F). Conductor sizes 12 – 20 AWG shall be subjected to a load of 0.40 kgf or 3.92 N (0.88 lbf). Conductor sizes 21 – 30 AWG shall be subjected to a load of 0.25 kgf or 2.45 N (0.55 lbf). The maximum decrease in insulation thickness shall be 50 per cent. A minimum of three specimens for each insulation type shall be tested. In the event of test results that do not comply, an additional minimum of six specimens shall be tested, all of which shall comply with the requirement.

6.21 Dielectric tests for cross-connect wire

6.21.1 Dielectric test before and after aging on a mandrel tested in water

A minimum of three specimens each shall be tested both before and after the specified conditioning. The overall length of the specimen shall be 457 mm (18 in). Samples of finished wire both before and after aging in an air over for 1 h at a temperature of 100°C for cable rated 60°C, and for cables rated above 60°C at the temperature and for the time indicated in Table 9, shall be placed in a cold chamber for a period of 1 h at a temperature of −10°C (14°F). At the end of the conditioning, the specimens shall be wound around a 1.59 mm (0.062 in) mandrel for six complete and close turns with the ends taped in place. The specimens shall then immediately be placed in a water bath at room temperature for a period of not less than 1 h. The specimens shall be subjected to an applied ac potential that is increased from near zero at a uniform or nearly uniform rate that is not less than 100 per cent of the potential rating of the wire or cable in 60 s and is not more than 100 per cent in 10 s (the rate of increase is not to exceed 500 V/s in any case). This ac potential shall be applied between the conductor and an electrode placed in water until 1500 V (1060 V dc) is attained. The test potential shall be held for a period of 1 min without breakdown. All specimens shall withstand the 1500 V potential for 1 min without breakdown. In the event of test results that do not comply, an additional six specimens shall be tested, all of which shall comply with the requirement.

6.21.2 Dielectric test on unaged specimens in water at room temperature

Six metres (20 ft) of 7.6 m (25 ft) coils shall be immersed in a tank of water at room temperature for not less than 12 h. At the end of this period, an ac potential that is increased from near zero at a uniform or nearly uniform rate that is not less than 100 per cent of the potential rating of the wire or cable in 60 s, and is not more than 100 per cent in 10 s (the rate of increase is not to exceed 500 V/s in any case) shall be applied between the conductor and an electrode placed in water until 1500 V (1060 V dc) is attained. This test potential shall be held for a period of 1 min. Three specimens each shall be tested. All specimens shall withstand the 1500 V potential for 1 min without breakdown. In the event of test results that do not comply, an additional minimum of six specimens shall be tested, all of which shall comply with the requirement.

7 Marking of Cables

7.1 General

Markings shall be readily legible and repeated at intervals in accordance with Clause 7.5 throughout the entire cable length. The voltage rating for the cable shall not be marked on or in the cable. Surface marking of cross-connect wire is not required.

7.2 Type of marking

7.2.1 General

The type of marking shall be one of the following, as applicable.

7.2.2 Surface marking

Surface marking shall consist of ink, indented, or embossed, printed on the outside surface of the overall jacket.

7.2.3 Printed marker tapes

Printed marker tapes shall be allowed only as follows:

a) directly under a transparent or translucent jacket, provided that it is readily legible through the jacket;

b) anywhere in the cable, outside an insulated conductor, and outside a unit assembly, and only for cable whose outermost covering is wire armour, a metal braid, or interlocked armour; or

c) where impracticality of a surface marking is demonstrated.

7.3 Required marking

7.3.1 General

The sequence of items is not specified.

7.3.2 **AWG size**

For cables with all conductors of the same size, only the size (but not the quantity) shall be required. If a coaxial member(s) is present, the size shall be marked.

For cables containing a mixture of AWG sizes, the quantity and size of each shall be required.

Conductors that exceed the maximum resistance requirement in Tables 2 and 3 for a specific AWG size shall be identified as the AWG of the next smaller AWG conductor (next higher AWG number).

The use of marking “AWG” shall be optional.

7.3.3 **Flame test classification**

7.3.3.1 Cables shall be marked as follows:

a) MPP or CMP – cables meeting CSA FT6;

b) MPR or CMR – cables meeting UL 1666;

c) MPG or CMG – cables meeting CSA FT4 or FT4/IEEE 1202 type of flame exposure (without smoke measurements) in UL 1685;

d) MP or CM or cross-connect – cables meeting UL flame exposure (without smoke measurements) in UL 1685;

e) CMX or CMUC – cables meeting UL 1581 Sec. 1080 (VW-1); and

f) CMH – cables meeting CSA FT1 or vertical flame/FT1 Sec. 1060 UL 1581.

7.3.3.2 Cables containing optical fibre member(s) shall be marked with the suffix “-OF” after the type designations in Clause 7.3.3.1.

7.3.4 **Responsible organization**

Markings shall specify name, trade name, or applicable mark, or file number, as well as manufacturing location identification if the cable is manufactured in more than one location. The manufacturing location identification is the name of the cable manufacturer, that manufacturer’s trade name for the cable, or both, or any other distinctive marking by means of which the manufacturing location for the cable can readily be identified.

7.3.5 **Temperature rating**

For cable rated over 60°C, the temperature rating shall be stated as °C or C.

7.3.6 **Type CMX "Outdoor"**

A cable marked "CMX Outdoor" shall be smaller in diameter than 6.35 mm (0.25 in), pass the VW-1 flame test in Section 1080 of UL 1581, and meet the sunlight resistance test and the cold impact test described in Clauses 6.12 and 6.13, respectively, of this standard.

Cables marked "CMX Outdoor - MPR" or "CMX Outdoor - CMR" shall also comply with the requirements for MPR or CMR cables. Cables marked "CMX Outdoor - MPG" or "CMX Outdoor - CMG" shall also comply with the requirements for MPG or CMG cables. Cables marked "CMX Outdoor - MP" or "CMX Outdoor - CM" shall also comply with the requirements for MP or CM cables. These cables may have an overall diameter greater than 6.35 mm (0.25 in).

7.3.7 **"AUDIO ONLY" cable**

Cables, other than coaxial cable, that employs Nos. 11 – 6 AWG copper conductors shall be marked with the words "AUDIO ONLY" in addition to other required markings.

Note: *Coaxial cable is not required to be marked with the words "AUDIO ONLY".*

7.4 Optional marking

7.4.1 "Shielded" may be marked on cable containing one or more shields.

7.4.2 The temperature rating of 60°C rated cable may be included if marked in accordance with Clause 7.3.5.

7.4.3 A private labeller may be identified.

7.4.4 Sequential length marking may be specified.

7.4.5 Other information, except a voltage rating, may be added if it does not confuse or mislead. However, cables with multiple qualifications, such as additional NEC type(s) or AWM, may bear additional markings, including the voltage rating. The additional multiple markings as a group shall be clearly separated from other markings.

7.5 Intervals

7.5.1 Required marking shall appear at intervals throughout the entire cable length as specified in Clauses 7.5.2 and 7.5.3.

7.5.2 All required markings on the outside surface of the overall jacket or on a marker tape visible through the overall jacket shall be repeated at intervals that are not greater than 1 m (40 in).

7.5.3 Where permitted by Clause 7.2.3 (b) or (c), markings on a marker tape not visible through the overall jacket shall be repeated at intervals not greater than 635 mm (25 in).

8 Marking on tag, reel, or carton

8.1 General requirements

8.1.1 The information specified in Clauses 8.1.2 – 8.1.7 shall be on a tag affixed to each shipping length of cable, its reel or carton, or directly printed on the reel or carton.

8.1.2 All of the information required in Clause 7.2 shall be provided.

8.1.3 The number of conductors or pairs shall be provided.

8.1.4 The date of manufacture by month and year shall be provided.

8.1.5 If the cable is also marked AWM (Appliance Wiring Materials) style, the voltage marking shall be acceptable.

For a cable that contains one or more optical fibres, the following statement, or another statement to the same effect, shall be provided:

“Optical fibre portion(s) of cable are for installation (optical and electrical functions associated) as described in applicable parts of the *Canadian Electrical Code, Part I,* and the *National Electrical Code* (NFPA 70) with levels of energy transmitted not exceeding those of Class I laser radiation (21 CFR Part 1040).”

8.1.6 For a cable that contains one or more optical fibre members, with any individual optical fibre member or group of such members having a metal or other electrically conductive part, the following wording, or other wording to the same effect, shall be provided:

“Optical fibre portion(s) of cable contain non-current-carrying metal or other electrically conductive parts.”

8.1.7 For a cable, other than a coaxial cable, employing Nos. 11 – 6 AWG copper conductors, the following wording shall be provided: “For use in audio applications only.”

8.2 Other marking

Other information may be added if it does not confuse or mislead.

TABLES

Table 1
Maximum temperature rating of cables relative to diameter and coating of the solid copper conductor or of each copper conductor strand

(See Clause 4.1.1.)

Metal coating	Diameter	
	Smaller than 0.38 mm (0.015 in)	At least 0.38 mm (0.015 in)
Uncoated, tin or tin/lead alloy coating	150°C	200°C
Silver coating	200°C	200°C
Nickel coating	over 200°C	over 200°C

Table 2
Maximum direct current resistance of copper conductors in ohms per km

(See Clauses 4.1.4 and 6.16.3, and 7.3.2.)

Conductor size (AWG)	Stranded conductor				Solid conductor			
	Uncoated		Coated		Uncoated		Coated	
	20°C	25°C	20°C	25°C	20°C	25°C	20°C	25°C
30	354	361	371	377	374	384	390	397
29	277	282	288	294	293	299	305	311
28	223	227	232	236	236	240	245	250
27	175	179	182	186	185	189	193	197
26	140	143	145	148	148	151	154	157
25	111	113	115	117	117	119	121	124
24	87.6	89.2	90.9	93.2	93.8	95.8	103	105
23	69.2	70.5	71.9	73.2	73.2	74.5	76.1	77.8
22	55.4	56.4	57.4	58.7	59.1	60.4	65.0	66.3
21	43.6	44.6	45.6	46.3	46.3	47.2	48.2	49.2
20	34.4	35.1	35.8	36.4	36.4	37.1	38.1	38.7
19	27.5	28.4	28.6	29.1	29.1	29.7	30.2	30.8
18	21.9	22.3	22.7	23.1	21.4	21.8	22.2	22.7
17	17.4	17.7	17.9	18.3	16.9	17.2	17.6	17.9
16	13.7	14.0	14.3	14.6	13.5	13.7	14.0	14.3
15	10.8	11.1	11.3	11.5	10.6	10.8	11.1	11.3

Table 2 Continued on Next Page

Table 2 Continued

Conductor size (AWG)	Stranded conductor				Solid conductor			
	Uncoated		Coated		Uncoated		Coated	
	20°C	25°C	20°C	25°C	20°C	25°C	20°C	25°C
14	8.60	8.76	8.96	9.09	8.45	8.61	8.78	8.96
13	6.82	6.96	7.09	7.22	6.69	6.82	6.96	7.09
12	5.41	5.51	5.61	5.71	5.31	5.42	5.53	5.64
11	4.33	4.43	4.49	4.59	4.22	4.30	4.39	4.48
10	3.41	3.48	3.54	3.61	3.34	3.41	3.48	3.55
9	2.705	2.758	2.813	2.868	2.652	2.704	2.730	2.784
8	2.144	2.186	2.230	2.274	2.102	2.143	2.163	2.206
7	1.700	1.734	1.768	1.802	1.667	1.699	1.716	1.749
6	1.348	1.375	1.403	1.430	1.323	1.348	1.361	1.388

Notes:
(1) *Use of sizes 11 – 6 AWG copper conductors is appropriate only in multiple-conductor jacketed cables (integral or nonintegral) employing the surface marking "AUDIO ONLY" or as the central conductor in a coaxial member. No. 6 AWG and smaller copper-clad steel conductors are appropriate only as the central conductor in a coaxial member.*
(2) *Use of sizes 15 – 10 AWG is limited to centre conductors of coaxial cables.*

Table 3
Maximum direct current resistance of copper conductors in ohms per 1000 ft

(See Clauses 4.1.4, 6.16.3, and 7.3.2.)

Conductor size (AWG)	Stranded conductor				Solid conductor			
	Uncoated		Coated		Uncoated		Coated	
	20°C	25°C	20°C	25°C	20°C	25°C	20°C	25°C
30	108	110	113	115	114	117	119	121
29	84.5	86.1	87.9	89.6	89.3	91.1	92.9	94.7
28	67.9	69.3	70.7	72.0	71.8	73.3	74.7	76.2
27	53.4	54.5	55.6	56.6	56.5	57.6	58.8	59.9
26	42.7	43.6	44.4	45.2	45.1	46.0	46.9	47.8
25	33.7	34.4	35.0	35.7	35.6	36.3	37.0	37.7
24	26.7	27.2	27.7	28.4	28.6	29.2	31.5	32.1
23	21.1	21.5	21.9	22.3	22.3	22.7	23.2	23.7
22	16.9	17.2	17.5	17.9	18.0	18.4	19.8	20.2
21	13.3	13.6	13.9	14.1	14.1	14.4	14.7	15.0
20	10.5	10.7	10.9	11.1	11.1	11.3	11.6	11.8
19	8.39	8.66	8.71	8.87	8.86	9.04	9.21	9.39
18	6.66	6.79	6.92	7.04	6.52	6.65	6.78	6.91
17	5.29	5.40	5.47	5.59	5.15	5.25	5.36	5.47
16	4.19	4.27	4.35	4.44	4.10	4.18	4.26	4.35
15	3.30	3.37	3.44	3.50	3.24	3.30	3.37	3.43

Table 3 Continued on Next Page

Table 3 Continued

Conductor size (AWG)	Stranded conductor				Solid conductor			
	Uncoated		Coated		Uncoated		Coated	
	20°C	25°C	20°C	25°C	20°C	25°C	20°C	25°C
14	2.62	2.67	2.73	2.77	2.57	2.62	2.68	2.72
13	2.08	2.12	2.16	2.20	2.04	2.08	2.12	2.16
12	1.65	1.68	1.71	1.74	1.62	1.65	1.68	1.71
11	1.32	1.35	1.37	1.40	1.29	1.32	1.34	1.37
10	1.04	1.06	1.08	1.10	1.02	1.04	1.06	1.08
9	0.8245	0.8407	0.8574	0.8742	0.8084	0.8242	0.8319	0.8483
8	0.6535	0.6663	0.6795	0.6929	0.6407	0.6532	0.6594	0.6724
7	0.5182	0.5284	0.5389	0.5495	0.5081	0.5181	0.5229	0.5332
6	0.4112	0.4192	0.4276	0.4359	0.4031	0.4110	0.4148	0.4230

Notes:

(1) *Use of sizes 11 – 6 AWG copper conductors is appropriate only in multiple-conductor jacketed cables (integral or nonintegral) employing the surface marking "AUDIO ONLY" or as the central conductor in a coaxial member. No. 6 AWG and small copper-clad steel conductors are appropriate only as the central conductor in a coaxial member.*

(2) *Use of sizes 15 – 10 AWG is limited to centre conductors of coaxial cables.*

Table 4
Minimum diameter for solid conductors and cross-sectional area for stranded conductors

(See Clause 4.1.4.)

Conductor size (AWG)	Diameter of solid conductor		Cross-sectional area of stranded conductor	
	mm	in	mm^2	cmil
30	0.251	0.0099	0.0497	98
29	0.284	0.0112	0.0633	125
28	0.318	0.0125	0.0790	156
27	0.358	0.0141	0.100	198
26	0.384[a]	0.0151[a]	0.126	248
25	0.432[a]	0.0170[a]	0.159	314
24	0.485[a]	0.0191[a]	0.201	396
23	0.546[a]	0.0215[a]	0.254	501
22	0.610[a]	0.0240[a]	0.318	627
21	0.688[a]	0.0271[a]	0.404	796
20	0.772[a]	0.0304[a]	0.509	1000
19	0.866[a]	0.0341[a]	0.641	1264
18	1.013	0.0399	0.807	1588
17	1.138	0.0448	1.02	2009
16	1.278	0.0503	1.28	2528
15	1.435	0.0565	1.62	3195

Table 4 Continued on Next Page

Table 4 Continued

Conductor size (AWG)	Diameter of solid conductor		Cross-sectional area of stranded conductor	
	mm	in	mm^2	cmil
14	1.613	0.0635	2.04	4028
13	1.81	0.0713	2.58	5076
12	2.03	0.0800	3.24	6399
11	2.28	0.0898	4.09	8065
10	2.56	0.1010	5.16	10172
9	2.87	0.113	6.50	12828
8	3.22	0.127	8.20	16180
7	3.63	0.143	10.34	20404
6	4.06	0.160	13.03	25715

[a] *Minimum acceptable diameter (0.95 x nominal) of a solid conductor of this size.*

Table 5
Thickness of integral insulation (solid) and jacket on 2-, 3-. or 4-conductor flat, parallel cable and distance between conductors

(See Clause 4.2.4.)

Cable types and sizes	Nominal thickness away from tear area(s) (vertical dashed line through web or webs in Figure 1) and outside point P or X (defined in Figure 2 A[a] (Information only – not a requirement)		Minimum thickness at any point before separation measured outside point P or X (defined in Figure 2) B[a]		Minimum thickness at any point after separation C[a]		Minimum distance between copper conductors D[a]	
	in	mm	in	mm	in	mm	in	mm
Nos. 24 – 8 AWG	0.030	0.76	0.027	0.69	0.013	0.33	0.047	1.19
Nos. 7 – 6 AWG	0.045	1.14	0.040	1.02	0.027	0.69	0.080	2.03

[a] *Dimensions A – D are illustrated in Figure 1.*

Table 6
Thickness[a] of overall jacket (except for fluoropolymers)

(See Clauses 4.9.4, 4.9.5, and Table 7.)

Cable core diameter mm (in)		Tensile strength less than 17.24 MPa (2500 psi) mm (in)		Tensile strength at least 17.24 MPa (2500 psi) mm (in)	
		Minimum average thickness	Minimum thickness at any point	Minimum average thickness	Minimum thickness at any point
	0.0 – 3.3	0.33	0.25	0.33	0.25
	(0.00 – 0.13)	(0.013)	(0.010)	(0.013)	(0.010)
Over	3.3 – 8.89	0.58	0.46	0.33	0.25
	(0.13 – 0.35)	(0.023)	(0.018)	(0.013)	(0.010)
Over	8.89 – 10.16	0.69	0.56	0.46	0.36
	(0.35 – 0.40)	(0.027)	(0.022)	(0.018)	(0.014)
Over	10.16 – 17.78	0.81	0.66	0.46	0.36
	(0.40 – 0.70)	(0.032)	(0.026)	(0.018)	(0.014)
Over	17.78 – 38.10	1.14	0.91	0.76	0.61
	(0.70 – 1.50)	(0.045)	(0.036)	(0.030)	(0.024)
Over	38.10 – 63.50	1.52	1.22	1.14	0.91
	(1.50 – 2.50)	(0.060)	(0.048)	(0.045)	(0.036)
Over	63.50 – 88.90	1.91	1.52	1.52	1.22
	(2.50 – 3.50)	(0.075)	(0.060)	(0.060)	(0.048)

[a] *A thicker jacket may be required to enable the cable to comply with one or more tests.*

Note: *For cables that are not round, the equivalent diameter shall be calculated as* $1.1284(TW)^{1/2}$

where

T = the thickness of the cable

W = the width of the cable.

Table 7
Thickness[a] of overall fluoropolymer jacket

(See Clauses 4.9.4 and 4.9.5.)

Cable core diameter mm (in)		Minimum average thickness mm (in)	Minimum thickness at any point mm (in)
	0.00 – 6.35	0.20	0.15
	(0.00 – 0.25)	(0.008)	(0.006)
Over	6.35 – 8.89	0.25	0.20
	(0.25 – 0.35)	(0.010)	(0.008)
Over	8.89 – 12.70	0.33	0.25
	(0.35 – 0.50)	(0.013)	(0.010)
Over	12.70 – 17.78	0.38	0.30
	(0.50 – 0.70)	(0.015)	(0.012)
Over	17.78 – 38.10	0.51	0.41
	(0.70 – 1.50)	(0.020)	(0.016)

[a] A thicker jacket may be required to enable the cable to comply with one or more tests.

Notes:

1) *A jacket that is applied directly over wire serving, wrap, or braid (no intervening wrap or other protective covering) shall not be thinner in average thickness than 0.33 mm (0.013 in) and shall not be thinner at any point than 0.25 mm (0.010 in).*

2) *For cables that are not round, the equivalent diameter shall be calculated as* $1.1284(TW)^{1/2}$

where

T = the thickness of the cable

W = the width of the cable.

Table 8
Minimum unaged properties of insulations and jackets

(See Clauses 4.9.7, 6.3.2.1, and 6.8.1.)

Material	Ultimate elongation %	Tensile strength	
		MPa	lbf/in^2
ECTFE ETFE	100	34.5	5000
FEP	200	17.2	2500
FRPE	100	8.3	1200
HDPE	300	16.5	2400
LDPE	350	9.7	1400
PFA	200	17.2	2500
PP	150	20.7	3000
PTFE	175	27.6	4000
PVC	100	13.8	2000
PVDF	100	24.1	3500
SRPVC	100	20.7	3000
XL	150	10.3	1500
XLPO	150	13.8	2000

Table 8 Continued on Next Page

Table 8 Continued

Material	Ultimate elongation %	Tensile strength	
		MPa	lbf/in^2

Notes:

1) *All materials shall be tested at 500 ±25 mm/min (20 ±1 in/min) except ECTFE, ETFE, FRPE with a density of 930 kg/m^3 or higher, HDPE, PP, PVDF, and SRPVC. These materials shall be tested at 50 ±5 mm/min (2.0 ±0.2 in/min).*

2) *An insulation or a jacket of a material other than one of those mentioned in the first column of this table may be used, provided that it has been evaluated to verify acceptability for use in the intended application.*

Table 9
Heat-aged properties of insulation and jackets for ratings 75 – 250°C

(See Clauses 4.9.7, 6.3.2.2, 6.3.2.4, 6.8.3, and 6.9.2, 6.19, and 6.21.1.)

Rating (°C)	Jacket or insulation	Time (days)	Temperature (°C)	Min. retention (%) of unaged	
				Elongation	Tensile strength
75	FRPE	2	100	75	75
	HDPE	2	100	75	75
	LDPE	2	100	75	75
	PP	10	100	70	70
	PVC	10	100	50	85
	SRPVC	7	113	70	70
	XL	7	113	70	70
90	PVC	7	121	50	85
	SRPVC	7	121	70	70
	XL	7	121	70	70
105	XLPO	7	136	70	85
	PVC	7	136	50	85
	SRPVC	7	136	70	70
125	PVDF	7	158	Flex test on mandrel	
		or 30	136		
150	ECTFE ETFE	7	180	75	85[a]
	PVDF	60	158	50	50
200	FEP	7	232	75	75
	PFA	4	260	85	85
250	PTFE	60	260	85	85

[a] Or 34.5 MPa (5000 lb/in^2) minimum.

Note: *An insulation or a jacket of a material other than one of those mentioned in the first column of this table may be used, provided that it has been evaluated to verify acceptability for use in the intended application.*

Table 10
Crushing force for insulations

(See Clauses 4.10, 6.2.5, and 6.2.5.)

Source of conductors	Minimum acceptable average force to crush insulated conductor	
	N	lbf
From cables with a bonded metal shield or its evaluated equivalent:		
Conductors from a cable having a bonded metal shield	890	200
From all other cables:		
Conductors from a cable without a metallic sheath or with any unbonded metal shield	1334	300

Note: *Cables with metallic sheaths that are evaluated and shown to protect the conductors to at least the same degree as an 175 µm (8 mil) aluminum bonded metal shield are acceptable over conductors having the lower crushing level. Interlocked steel or aluminum armour or corrugated or smooth continuous aluminum armour on a cable is acceptable protection for the conductors without test. Otherwise, the evaluation shall consist of a comparison of the performance of the other sheath with a bonded metal shield in the cable crushing and cable impact tests.*

Table 11
Maximum acceptable centre-to-centre spacing of bead-chains

(See Clause 5.1.7.)

Diameter of a bead[a]		Longitudinal spacing within each row[a]		Transverse spacing between rows[a]			
mm	in	mm	in	Chains staggered		Chains not staggered	
				mm	in	mm	in
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.					

[a] A 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 insulated conductor.

Table 12
Cold blend mandrel diameter

(See clause 6.5.)

Diameter over insulated conductor mm (in)	Diameter of mandrel	
	mm	(in)
0-2.11 (0.083)	6.35	(0.250)
Over 2.11 (0.083) but not over 2.64 (0.104)	7.95	(0.313)
Over 2.64 (0.104) but not over 3.18 (0.125)	9.53	(0.375)
Over 3.18 (0.125) but not over 3.71 (0.146)	11.1	(0.438)
Over 3.71 (0.146) but not over 4.24 (0.167)	12.7	(0.500)
Over 4.24 (0.167) but not over 4.78 (0.188)	14.3	(0.563)
Over 4.78 (0.188) but not over 5.28 (0.208)	15.9	(0.625)
Over 5.28 (0.208) but not over 5.82 (0.229)	17.5	(0.688)
Over 5.82 (0.229) but not over 6.35 (0.250)	19.1	(0.750)
Over 6.35 (0.250) but not over 6.88 (0.271)	20.7	(0.813)
Over 6.88 (0.271) but not over 7.42 (0.292)	22.2	(0.875)
Over 7.42 (0.292) but not over 8.46 (0.333)	25.4	(1.000)

Table 13
Cabling factor for calculating dc resistance

(See Clause 6.16.3.)

Construction	Multiplier
Cabled in one layer	1.02
Cabled in more than one layer	1.03
Cabled as one pair	1.04
Cabled as an assembly of pairs or other precabled units	1.04
Note: *Multipliers larger than the above shall be used when the manufacturer demonstrates that they are required.*	

Figure 1
Integral flat cable

See Table 5 for dimensions A – D

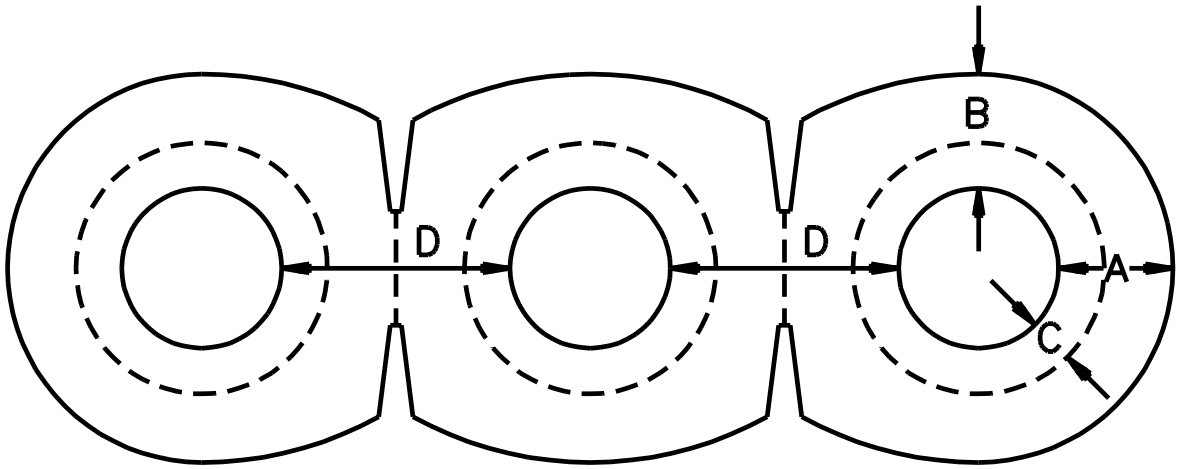

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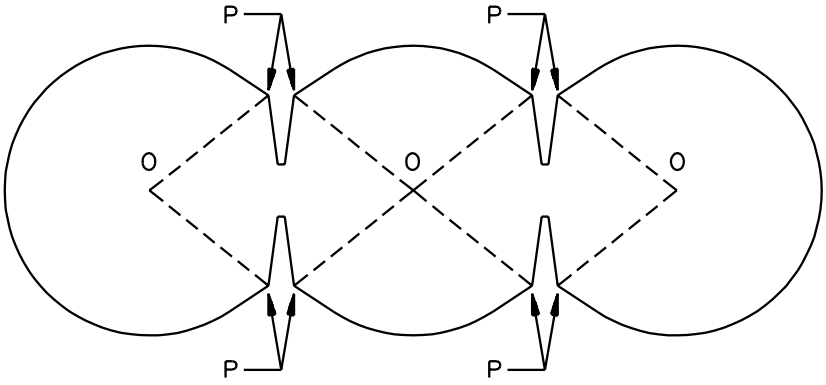
Figure 2
Definition of regions of valley slopes on which thickness measurements are not to be made in integral flat cables

(See Table 5)



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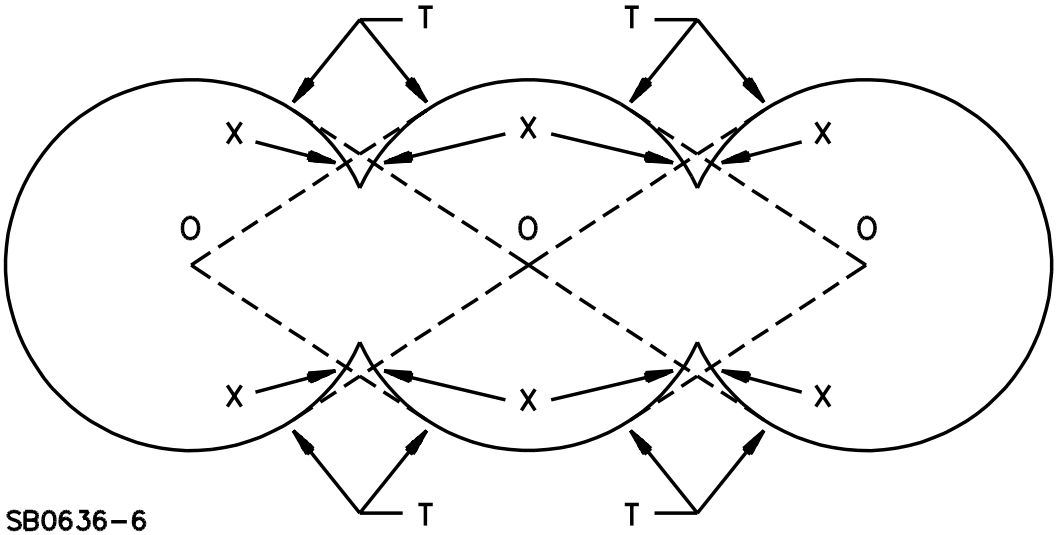
a) Constructions with a Cross-Section Having a Definite Point P at the Outer End of Each Valley

Slope OP in each case is a straight line from the centre O of a conductor to P on the same segment of the cross-section. Thickness measurements are not to be made on any valley slope.



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b) Constructions with a Cross-Section not Having a Definite Point to Mark the Outer End of Each Valley

Slope OT in each case is a straight line from the centre O of a conductor to T, the point of tangency, on the adjacent segment of the cross-section. Thickness measurements are not to be made deeper on a valley slope than point X, which is the intersection of the line OT with the valley slope. Thickness measurements are to be made on each slope segment TX.

Appendix A

Guidelines for sample selection for flame and smoke test requirements

Note: *This Appendix is not a mandatory part of this standard.*

Table A1
Guidelines for sample selection for flame and smoke test requirements

Flame and smoke test	Sample selection
FT1 or VW1	No guidelines needed
FT4 or UL flame exposure or FT4/IEEE 1202 Type of flame exposure in UL 1685 (without smoke measurements)	One set each of the smallest, largest, and intermediate diameters in the product range
UL 1666	Typically the test samples for these cables are the smallest diameter in the product range
FT6	Typically the test samples for these cables are the smallest and largest diameters in the product range

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Appendix B

Cable substitutions

Note: *This Appendix is not a mandatory part of this standard.*

B1 The following cable substitutions are appropriate:

(a) Communications cables marked MPP, CMP, MPR, CMR, MPG, CMG, MP, CM, CMX, CMH, FT6, FT4, or FT4/1202 have been found to meet the standard criteria for FT1.

(b) Communications cables marked MPP, CMP, MPR, CMR, MPG, CMG, or FT6 have been found to meet the standard criteria for FT4 and FT4/1202.

(c) Communication cables marked MPP and CMP have been found to meet the standard criteria for FT6.

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